Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Introduction

Unit Arrangement

Units are arranged by objective. Each objective or grouping of objectives contains:

- Information
- References
- Student activities and/or student labs
- Internet resources
- Transparencies
- Tests

This design is intended to facilitate the teacher in planning lessons and to provide students with guided notes. References include texts, guides on professional techniques, activity guides, and previous series within the Agricultural Science and Technology curricula. Internet resources include titles and site addresses.

INTRODUCTION

The Agricultural Science and Technology Curriculum Guides are the product of extensive planning and development. In 1987 an Agricultural Education Technical Committee was assembled to determine the competencies necessary to prepare students for careers in agriculture. In 1989 a committee of secondary agriculture instructors, state supervisory staff and University of Idaho Agricultural and Extension Education faculty arranged the competencies into an outline of courses appropriate for secondary agriculture programs in Idaho. These curriculum guides provide the secondary agriculture instructor with up-to-date instructional materials in developing lessons for the student interested in pursuing a career in agriculture.

The arrangement of the 1996-1997 guides follows the modular method for organizing curriculum as outlined in *Improving Vocational Curriculum* (Duenk, 1993). This format was adapted to improve the ease of interpreting and implementing the curriculum, as well as updating the organization of the guides to fit current instructional needs. This includes augmenting the guides by providing sites for additional information via the internet, and formatting the curricula for computer access.

A list of references, activities, internet sites, transparencies and/or hand-outs are provided with each module.

Teacher information is provided as needed, with any additional explanation.

Format

- Curriculum Introduction
- Additional Resources
- Unit Introduction
- Unit Objectives
- Information
    - ⇒ Information by Objectives
    - ⇒ List of References
    - ⇒ Activities / Labs
    - ⇒ Internet Resources
    - ⇒ Transparencies / Hand-outs
- Unit Test

Ag 514 Botany / Horticulture Plant Science

A. Potting Soil and Media

B. Soil Fertility

C. Organic Matter and Fertilizers

D. Basic Plant Processes

E. Plant Growth and Development

F. Plant Growth Regulators

G. Introduction to Sexual Plant Propagation

H. Care and Transplanting of Seedlings

I. Environmental Factors of Plant Production

J. Introduction to Asexual Plant Propagation

K. Propagation by Cuttings

L. Propagation by Layering and Division

M. Propagation by Bulbs, Corms, and Tubers

N. Propagation by Tissue Culture

O. Propagation by Budding

P. Propagation by Grafting

Q. Plant Identification

R. Plant Pests and Their Control

S. Weeds and Their Control

T. Beneficial and Non-Beneficial Insects

U. Plant Disease Identification and Control

V. Scientific Method Term Project

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 A - Potting Soil and Media

Unit Objectives

1. List the reasons for variation in types of soils.
2. Discuss how the root zone affects the availability of plant nutrients.
3. Select plants tolerant to various pH ranges.
4. Test soils for pH levels.
5. Develop a chart of planting media with the characteristics of each media.
6. List several soil mixes identifying media data for each soil mix.
7. Identify the correct fertilizers to add for various soil mixes.
8. Describe the importance of sterilizing a potting soil mix.
9. Sterilize a potting soil mix.
10. Properly mix potting soil.

Information

1. List the Reasons for Variation in Types of Soils

Soil

Material covering the face of the earth.
Supports growth of plants.
Includes artificially modified or moved soils.

Food Chain

Progression of food energy from one species to the next.
Soil begins the food chain of land animals.

Four Components of Soil

Minerals chemical / physical (rock)
Water
Air
Organic humus = carbon (non-living) & living

Air and water

Fill in gaps left in soil.
Gaps are left by the grouping of mineral particles.

Soil Origins

Organic

Decayed and accumulated vegetation grown and died for thousands of years.
Black, productive, scarce; e.g. peat.

Inorganic

Decomposition by weathering: wind, rain, sleet, snow, wetting and drying, freezing and thawing, wearing away, cracking.
Glacial deposition. Types:
- **Till** - boulders, rocks, sand, silt, clay
- **Moraine** - receding front of glacier

Alluvial water deposition.
Flood plain out-of-bank deposited soil.
Deltas water-borne slow deposition at mouths of streams and rivers.
Lacustrine deposition lake backfill from entering streams until lake is filled and disappears.
Marine sediments ocean-entering deposition creating shorelines and landmasses.
Aeolian soils rock-worn wind-deposited soils.
Loess soils wind-borne glacial silt and clay deposits.
Volcanic soils lava flows and wind-borne ash.

Parent material mass of rock material or peat from which soil profile originates.
Soil horizons characteristics of soil formed in layers over time from mineral and organic depositions on bedrock.
Soil profile vertical section of soil at a given location showing layered pattern of materials from surface to bedrock.

Soil Ecosystem plant, animal and microbial life that live in a soil area.
Carbon cyle
- Living plant ooze of plant protein and other nutrient materials through root systems.
- Microorganisms feed on ooze.
- Decomposition of dead plants which return nutrients to the soil.

Soils combination of silt, sand and clay.
Texture size of individual soil particles; aka soil "separates."
Sand
- Highly permeable
- Separates between 2 mm and .05 mm

Silt
- Less permeable
- Separates between .05 mm and .002 mm

Clay
- Practically impermeable
- Separates smallest-sized less than .002 mm.

Cations positively charged nutrients.
Cation exchange
- **Soil solution** water surrounds soil particles, suspending nutrients.
- **Osmosis** cations from soil pulled into solution; plants take in nutrients through root systems.

Cation exchange capacity soil capacity to exchange amounts of cations.
Clay conductivity
- Role in soil fertility
- Particles with net negative charge
- Attracts nutrients / adhere to surface area
- Highest cation exchange capacity

Silt conductivity
- Higher cation exchange capacity
- Slow water movement for

Sand conductivity
- Lowest cation exchange capacity

Leaching loss of soil nutrients by water movement through larger soil particles.

References

1. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
2. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
3. Curriculum Guide for Agricultural Science and Techology 510 - Botany / Plant and Soil Science. Idaho State Division of Vocational Education.

Student Activities

- **List the Reasons for Variation in Types of Soil**
- **"Splash" - *The Growing Classroom: Garden-Based Science***. Addison-Wesley

Student Lab

- **Exploring Soil**

Internet Resources

Key search words: <soil - education>
Sites:
- VIRCON (Virtual Conservation Connection) http://webcom.com/vircon/
- Agriculture Network Information Center http://www.aguic.nal.usda.gov/agdb/erdcalfr.html

Transparencies

- **Soil Particle Size Determines Texture**
- **Determing Soil Texture by Feel**

From Agricultural Science and Technology 510A:
- **Soil-Plant-Animal-Cycle**
- **Composition of Average Soil**
- **Soil Origins**
- **Physical Breakdown of Rocks**
- **Soil Profile**

1. Student Activity: List the Reasons for Variation in Types of Soils

List the elemental components of soil formation.

1. ______________________________ 3. ______________________________

2. ______________________________ 4. ______________________________

Give four examples of natural occurrences which lead to further development of soil.

1. ____

2. ____

3. ____

4. ____

Describe five environmental interactions which can change the course of soil development.

1. ____

2. ____

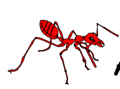
3. ____

4. ____

5. ____

Think and Answer:

How do these objects contribute to the development of soil?

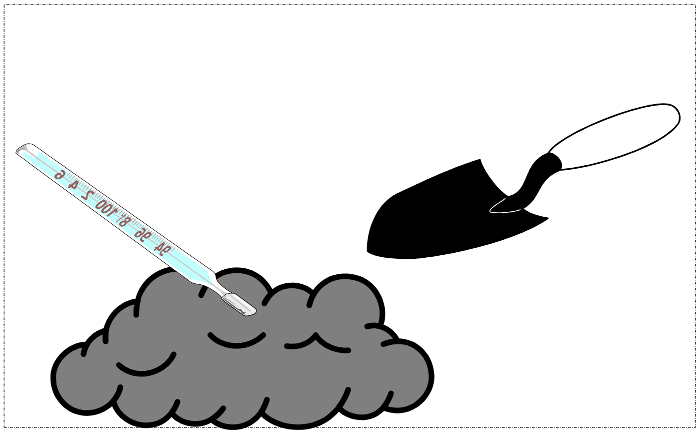


Ant

Dead Tree

1. Student Lab: Exploring Soil

Purpose: to determine the physical characteristics and origins of a soil sample.



Materials:

- Spade or trowel
- Plastic bags with zip lock feature
- Small notebook
- White tray or pan to examine contents of samplings
- Forceps
- Magnifying lens
- Microscope
- Soil thermometer

Procedure:

Soil samples must be representative of an area. Therefore, choose a site with several examples in mind; i.e. an area with a stream running through it would have a floodplain, slope and upland. Take samples from each. A meadow would have an edge effect. Pick open sunny areas and shady areas to test, as well as areas that exhibit a change in vegetation. An upland would have tree fall that might be in a state of decay. Sample soils at the area of decomposition and two yards away from the area.

1. Sketch or get a map of the area where you will collect samples.
2. Divide the area into test sites.
3. Make notations in the notebook regarding each site. Record:
    - Location of area sampled and its significance as a sample site
    - Location of each sample site within the area
    - Macro-climate at time of sampling
4. Take soil temperature at each site where sample was taken (measuring micro-climate).
5. Label each sample according to the location where the sample was taken.
6. Bring your samples, examining equipment and notebook to class the next day.
7. Examine the contents of each plastic bag by emptying them into the white tray or pan and record the findings in your notebook. Use forceps to separate and examine items. Use magnifying lens to assist in identification of items. If available, use a microscope to identify microbial elements.
8. Identify soil types in the sample by using the textural triangle and feel method.
9. What was the parent material for this soil? What contributed to the humus?
10. Write a short paper detailing your project, what you expected to find at each site, and what was found. Turn in with your notebook.

Q&A: Why is measuring soil temperature important to understanding soil formation?

Teacher Answer Sheet
1. "List the Reasons for Variation in Types of Soils"

Elemental components of soil formation:
Minerals, water, air, organic (humus)

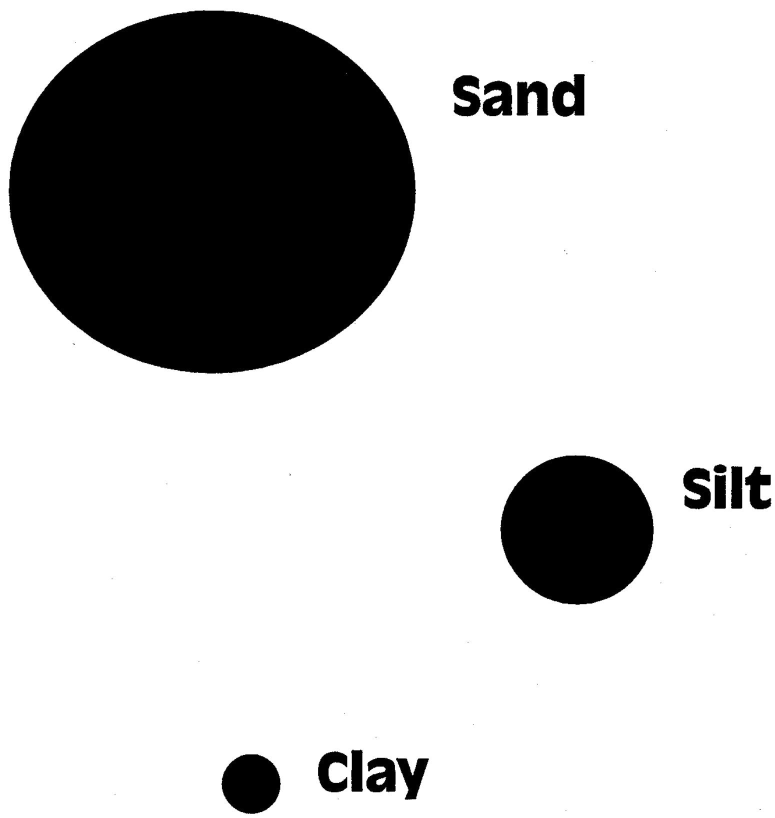
Natural occurrence:
Multiple answers possible. See "Soil Origins" on information sheet.

Environmental interactions:
Multiple answers possible; e.g. composting, development, building dams, fire, mining, et al.

Under "Think and Answer":
Ant - channeling allows air and water movement through soil
Dead tree - adds organic matter - carbon cycle
Fire - aids the process of decomposition, particularly in dry areas. Drawback: fire destroys bacteria which aid in decomposition. Ash is the main contributor to soil, lacking moisture and nutrients.

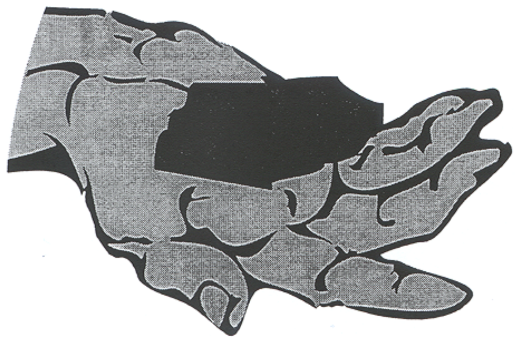
Q&A:
Measuring temperature reveals which bacteria are at work in the decomposition process. Psycrophiles operate at cool temperatures no lower than 28 degrees F and digest carbon as they generate heat. Mesophiles operate at 60 to 70 degrees F up to 100 degrees F and are responsible for most of the decomposition process. Above 100 degrees F thermophiles are active, doing their best work between 131 to 140 degrees F. This temperature kills pathogens and weed seeds and is good for composting, but temperatures too high can destroy soil bacteria (as in fires). The more optimum the humus temperature, the better the rate of decomposition and therefore, nutrient recycling.
Source: Ortho Books. (1992). *Easy Composting*. San Ramon, CA: Author.

Soil Particle Size Determines Texture



- ✓ **Water-holding capacity (e.g. clay)**
- ✓ **Permeability (e.g. sand)**
- ✓ **Plant growth (e.g. humus)**
- ✓ **Land classification (e.g. glacial till)**

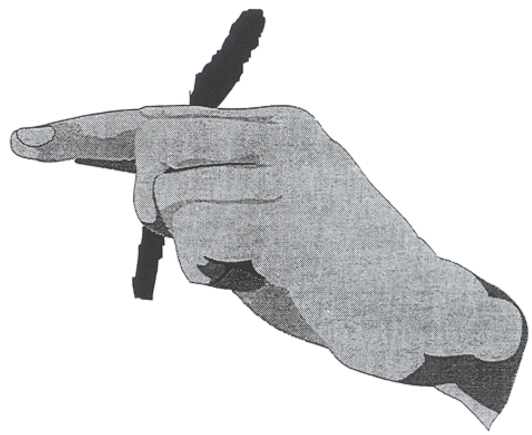
Determining Soil Texture by Feel



In the palm of your hand, work soil into a ball.

then,

Work the soil into a ribbon.



Results:

If the soil crumbles, it has a COARSE TEXTURE.
If the soil makes a ribbon but feels slightly gritty, it has a MEDIUM TEXTURE.
If the soil makes a smooth ribbon, it has a FINE TEXTURE.

Information

2. Discuss How the Root Zone Affects the Availability of Plant Nutrients

Roots

- **Anchor** the plant*
- **Absorb** water and minerals from the soil and conduct to plant stem*
- **Store** large quantities of a plant's food*
- **Propagate** or reproduce (in some plants)
- *essential functions

Root Structure

- **Internally much like stems**
  - **Phloem** food conduction
  - **Cambium** new cells
  - **Xylem** water and mineral conduction
- **Externally not like stems**
  - **Root cap** as root pushes through soil produces new cells which lubricate and protect root cap
  - **Root hairs** single-celled / absorb moisture & minerals / conduct to larger roots & stem
  - **Side roots** form as roots grow older

Root Systems

- **Fibrous**
  - Monocots (primarily)
  - Hold soil in place / prevent erosion
  - Easier to transplant
  - Shorter, smaller, more compact
- **Tap root**
  - Dicots (primarily)
  - Longer and fewer roots
- **Specialized**
  - **Adventitious roots** sprout from stems or leaves (e.g. vines)
  - **Aerial roots** suspended in air (e.g. orchids)
  - **Aquatic roots** take nutrients from water & soil beneath water (e.g. water lilies)

Nutrient Absorption

Root hairs

Semipermeable membrane tiny pores on root hairs that allow the passage of water molecules by osmosis

Osmosis vacuum that causes water to move into the vascular cylinder of the root

Vascular cylinder contains the phloem which transports sugar & dissolved nutrients to the plant

Diffusion movement of nutrients throughout the plant which results in higher to lower nutrient solute concentration available to plant

Root nodules swellings on roots containing rhizobium bacteria which take nitrogen from the atmosphere, combine with oxygen, and produce NO_3 or NH_3, forms of nitrogen which can be used by the plant

Root Zone

Active feeder roots for a tree, normally in the top 12 to 18 inches of soil, starting one third of the distance from the trunk to the drip line and extending as far as three or four times the spread of the branches.

Rhizoplane plant root surface

Rhizosphere area of soil immediately surrounding plant roots altered by growth, respiration, and exchange of nutrients

Edaphic environment soil and the area where roots are located

Healthy Root Zone fosters the availability of air, water and nutrients to the plant

Root Pruning forces the growth of additional feeder roots / controls the growth of the plant / assists the plant in more efficiently accessing its nutrient supply

Girdling from roots / restricts the flow of water and nutrients to the plant (woody) / must be severed from the healthy root system.

Cutting roots loss of root hairs necessary for absorption / occurs when inappropriately pruning for transplanting.

References

1. Allaby, M. (Ed.) (1992). *The Concise Oxford Dictionary of Botany*. Oxford, UK: Oxford University Press.
2. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
3. Ortho Books (1995). *Easy Gardening: Tips from Garden Professionals.* San Ramon, CA: Author.
4. Reiley, H.E. & Shry, C. L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.

Student Activity

- Discuss How the Root Zone Affects the Availability of Plant Nutrients: **“Root It Out”**

Student Labs

From Agricultural Science and Technology 512E:
- **Examining Roots and Stems**
- **Root Growth**

Internet Resource

- Horticulture Teaching Resources http://www-2.ag.ohio-state.edu/hvp/htr/htr.html

Transparencies

From Agricultural Science and Technology 510A:
- **Hard Pans Effect on Soil Depth**

From Agricultural Science and Technology 512E:
- **Types of Root Systems**
- **Below Ground Stem Modifications**

2. Student Activity: Discuss How the Root Zone Affects the Availability of Plant Nutrients

"Root It Out"

Purpose: to illustrate root types, growth and function.

Information: root zones affect the availability of plant nutrients to the plant by their permeability, nutrient content and moisture-holding capacity. The nutrient solution that plants take in through their root hairs comes from a thin coating of water around each grain of soil. Root hairs absorb this soil-generated nutrient solution into the plant. As the root hairs grow they find new sources of water and soil nutrients, continuously transferring the solution through the semipermeable membrane on the root hairs by osmosis, into the vascular cylinder, and throughout the plant.

Materials: see "Making and Using Root View Boxes" from *The Growing Classroom: Garden-Based Science*, Addison-Wesley, p.448.

- One root view box per student
- Seeds with fibrous and tap root systems (recommendations: carrots, lettuce, radishes & marigolds)
- Potting soils, compost-produced soil, topsoils from various sites illustrating various textures and therefore nutrient-providing capacities.
- Labels & grease pencils
- Notebook

Procedure:

1. Construct one root view type box of your choice.
2. Discuss and decide which plant you will grow in which soil type in order that all plant and soil types as above will be represented throughout the class.
    - Plants - demonstrating various root types
    - Soil - demonstrating various root zone
    - nutrient-providing capacities
3. Fill the root view boxes with the assigned soil.

4. Plant the seed in the soil according to package directions for the size of planting area available.
5. Label the boxes according to ownership, plant type and soil.
6. Tip the root view boxes forward and secure them in order to view the plant roots as they mature against the viewing area (aided by geotropism, the directional movement of plants in response to the pull of gravity).
7. Water the plants as needed.
8. Observe the plant growth daily. Record the plant watering record in the notebook.
9. Answer the following questions in the notebook:
    - What type of medium are the plants grown in?
    - Name the visible parts of the root and discuss the appearance of each in your potting or soil medium.
    - Choose three other potting or soil mediums and make an hypothesis on how the roots would appear and fare if grown in them.
    - What do nonsoil growing substances lack?
    - How would roots look if grown without gravity?

Discussion:

1. What type of root zone would encompass an adventitious root? . . . an aerial root? . . . an aquatic root?
2. What type of nutrients would a plant receive from air or water?

Notes

References

1. Allaby, M. (Ed.) (1992). *The Concise Oxford Dictionary of Botany*. Oxford, UK: Oxford University Press.
2. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
3. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park: Addison-Wesley.

Information

3. Select Plants Tolerant to Various pH Ranges

Soil pH

Scale from 0 to 14 measuring acidity to alkalinity. Units increase 10 times between each.
Based on hydrogen ion concentration in soil.
7.0 is neutral.
Below 7.0 is acidic.
Above 7.0 is alkaline, or basic.
Greater the distance from 7.0 (neutral), the greather the acid < 7.0 > or the alkalinity.
Acid or low pH occurs when the concentration of H^+ ions increases.
Alkalinity or high pH occurs when the concentration of OH^- ions increases.
Soil samples are tested to determine pH in order to determine the nutrients available to plants.
Governs nutrient availability.
Balance between plant nutrient elements (K, Mg, and Ca) and non-nutrient elements (H and Al).

Acid Soils

Parent material was acidic.
Amount of rainfall exceeds evaporation of moisture from the soil; i.e. leaching, causing depletion of bases: Ca, Mg, K, Na.
Absorption of bases by plant growth.
Low amounts of cation exchange capacity (CEC).

Akali Soils

Water evaporation is equal to or greater than the amount of rainfall.
Calcium and sodium salts build up.

Lowering pH in Alkali soils

Sulfur, iron sulfate or aluminum sulfate.
Flushing soils with low-salt irrigation water.

Liming soils

Soils too acidic.
Treatment for low pH (5.5-6.5).
Releases phosphorus.
Binds aluminum and iron.
Activates soil organisms.
Encourages release of nutrients to plants.

Improves soil structure.

Modifying pH

Colors of flowers are related to soil pH:

Blue - alkaline soils

Pink - acidic soils.

Nitrogen fertilizer can either raise or lower soil pH:

Ammonium fertilizer - acidifying

Nitrate / nitrogen fertilizer - alkaline forming.

References

1. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
2. Reiley, H.E., & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.

Student Activity

- **Select Plants Tolerant to Various pH Ranges**

Internet Resource

- **"Plant Tracker"** http://www.axis-net.com/pfaf/

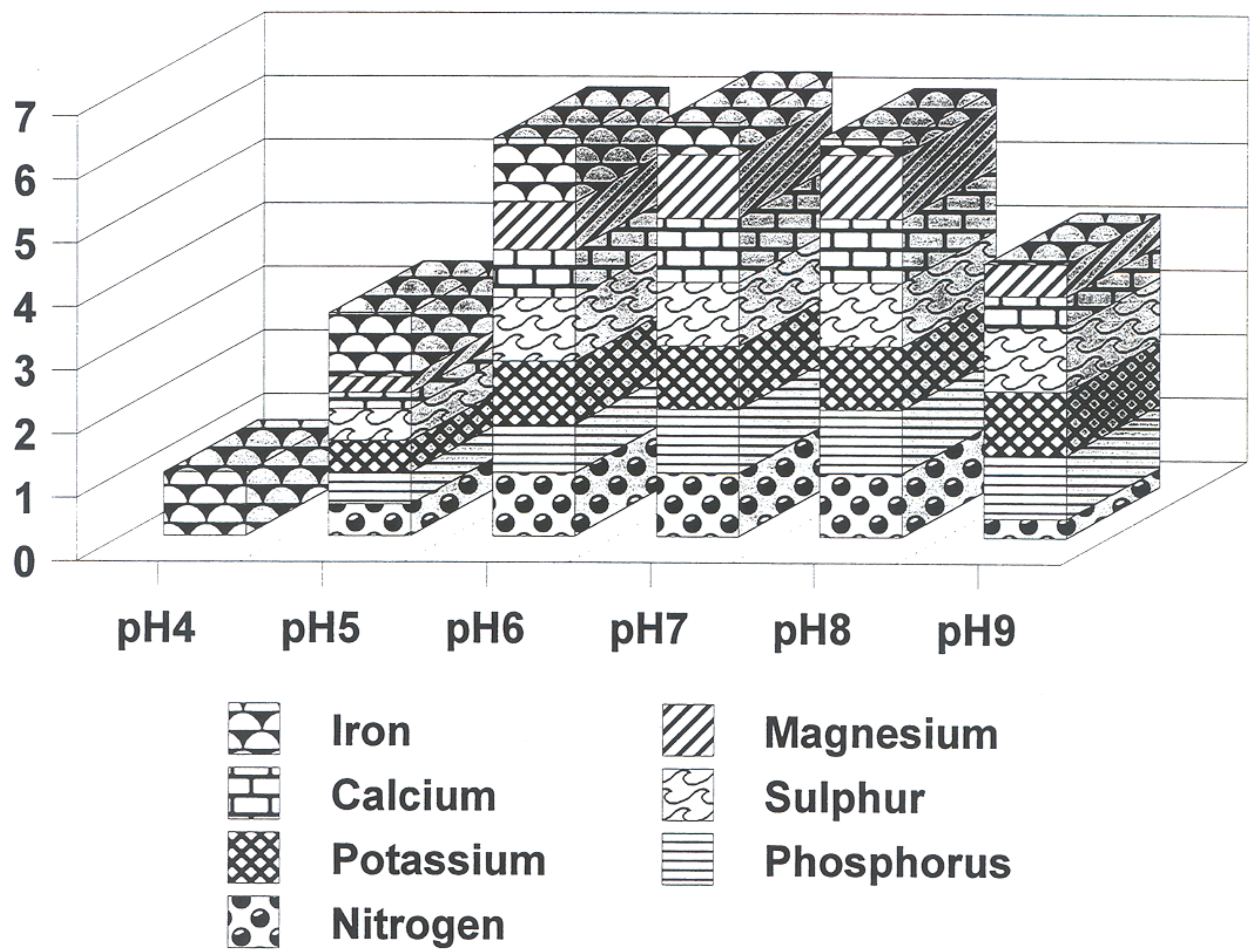
Transparencies

- **Plant Nutrients Available per Soil pH**

From Agricultural Science and Technology 510A:

- **pH Scale**
- **pH Scale (relative strength)**
- **pH Scale (familiar products)**
- **pH Scale (for soil reaction)**
- **Low pH Limits Root Growth**
- **Ion Exchange of Soil Particles**

Plant Nutrients Available per Soil pH

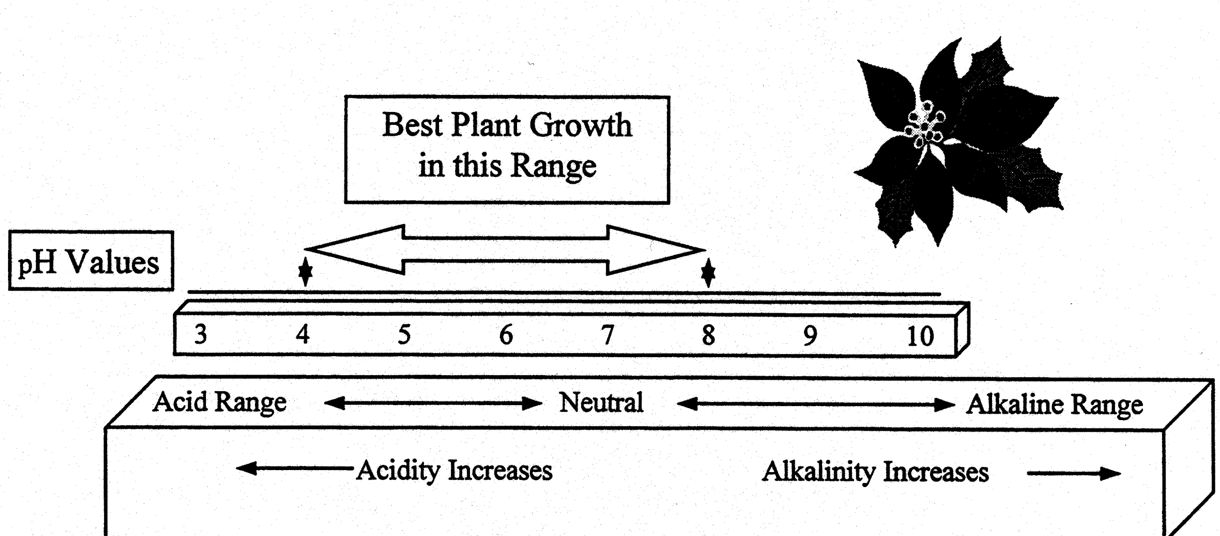


- ❑ **Plants grow best in soil with a range of 5.5 to 8.0.**
- ❑ **Soils should be modified to plant needs based on the results of a soil test.**

3. Student Activity: Select Plants Tolerant to Various pH Ranges

On the basis of the information in this section, research and list the pH ranges of six flowers, vegetables and small fruits. Reference your sources.

Flowers	pH Range	Vegetables	pH Range	Small Fruits	pH Range
Sources:		Sources:		Sources:	



The lower the pH, the more acidic the soil.
The higher the pH, the more alkaline the soil.

Information

4. Test Soils for pH Levels

Soil Samples

About 6 inches of soil core is taken for testing pH.
Core sampling: soil probe
Site sampling: small shovel
Seven to 9 samples throughout a site.
Samples should be representative of the area.
Clean container for each sample.
Plastic bag into a soil sampling box for shipping to a lab.
Label the sample.
Indicate plants to be grown in soil.
Request fertilizer report with soil test results.

Soil Tests

Determine nutrients present in soil.
Analysis done by lab or grower.
Commercially available soil testing kit for grower use.

Test for:

pH
Phosphorus
Potassium
Calcium
Magnesium
Sulfur

Why test for soil pH?

Determines the availability of nutrients to plants.
Better plant growth in soil that meets needs of plants.

References

1. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
2. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

3. Shry, C.L., Jr., & Reiley, H.E. (1997). *Introductory Horticulture* (5th ed.). Albany, NY: Delmar.
4. Shry, C.L., Jr., & Reiley, H.E. (1997). *Lab Manual to Accompany Introductory Horticulture* (5th ed.). Albany, NY: Delmar.
5. University of Wisconsin-Madison. (1993). *Bottle Biology*. Dubuque, IA: Kendall / Hunt.
6. University of Wisconsin-Madison. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activity

From *Bottle Biology*, Kendall / Hunt (p. 26):
- **Acids and Bases: Make Your Own pH Indicator**

Student Lab

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt (p. 217):
- **Fermentation: Making Kimchee in Soda Bottles**

Internet Resources

- Natural Resources Conservation Service Ecological Sciences Division
  http://www.nhq.ncrs.usda.gov/BCS/soil/survey.html
- National Soil Survey Center
  http://www.statlab.iastate.edu:80/soils/nssc/

Transparencies

From Agricultural Science and Technology 510B:
- **Soil Sampling A, B**
- **Soil Sampling C, D**
- **Soil Sampling E, F**
- **Soil Sampling G, H**
- **Soil Sampling (TM 12)**
- **Soil Sample Bag**
- **Soil Test Request and Report Form**

Information

5. Develop a Chart of Planting Media with the Characteristics of Each Media

Plant Media soilless rooting material in which plants grow.
Rooting Function provide a plant with nutrients and a place to anchor itself.

Nutrients substances roots absorb from the soil in water uptake.
Anchor keeps plants from falling over by allowing roots to anchor the plant.

Media Types
- **Soil**
- **Soilless or artificial**
- **Liquid**

Soilless Media Content

Contain no topsoil.
Vermiculite heat-treated mica mixed with other materials to hold moisture.
Perlite volcanic origins / large particles. Used to provide drainage and aeration.
Sphagnum moss dehydrated remains of acid bog plants / shredded / sterile / lightweight / controls disease / holds moisture well / used to cover seeds.
Peat moss partially decomposed vegetation collected from marshes, bogs or swamps / holds moisture well / contains about 1% nitrogen / low in phosphorus & potassium.
Limestone calcium carbonate ($CaCO_3$).
Tree bark pine or oak bark broken into small pieces used in container growing or mulching.
Slow-release fertilizer plant food made available to plants over a gradual length of time.

Soilless Mixes

Contain two or more soilless media.
Excellent drainage use high percentage of coarse materials.
Organic material use for moisture retention.
Perlite or bark use for drainage and aeration.
Commercial mix (e.g.) 50% shredded sphagnum moss, 50% vermiculite, & slow-release plant food.

Soil / Soilless Mixes

Soil conditioning add to soil for moisture-holding capacity and improved drainage.
Soil sterilized or pasteurized.
Planting mix 1/3 soil, 1/3 peat, bark shavings or leaf mold, 1/3 sand.

Hydroponics or Liquid

Nutrients needed by plants supplied by solution.
Nutrient solution contains water with dissolved nutrient salts.
Plants require support.

Advantages

Nutrition controlled through solution.
Yield per compact unit area is greater.
Space roots do not spread due to direct contact with nutrients.
Pest containment reduced weed, disease, and insect control.

Substrates - growing plants in . . .

Sand sterilized rooting material / individual drip irrigation.
Gravel irrigation flow-through.
Plastic bags filled with rockwool, peatlite and sawdust / fed by drip irrigation.

Bare root systems

Aeroponic plants suspended in air / mist with oxygen-rich nutrient solution at regular intervals.
Continuous flow plants float on surface of shallow pools in individual panels.
Nutrient film technique plants in channels / roots covered with plastic sheets / plants fed by recirculating shallow stream of nutrient solution.

Advantages of Soilless Media

Uniform mix
Sterile no diseases, insects or weed seeds
Lightweight
Moisture retention and drainage

Disadvantages of Soilless Media

Container instability due to lightweight material.
Low mineral content nutrient supplementation may be needed.
Rooting problems with transplanting.

Soilless media on roots fail to blend with soil.
Moisture / nutrients unable to pass from soil to roots.
Clay in soil may cause root bind; roots won't pass from ball to soil.

Prevents moisture / nutrient uptake.

Solution

Soil / soilless mix
Transplant with root-to-soil exposure.
Mix sphagnum moss into transplanted soil site.

References

1. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
2. Shry, C.L., Jr. & Reiley, H.E. (1997). *Introductory Horticulture* (5th ed.). Albany, NY: Delmar.

Student Activities

- **Charting Your Course**

From *Bottle Biology*, Kendall / Hunt (p. 42):
- **Cooking with Soils: Experiment with Plant Nutrition**

Transparency

- **Ideal Growing Medium**

5. Student Activity: Charting Your Course

Purpose

Demonstrate an understanding of the various types of soilless planting media and their “best-use” applications.
Demonstrate ability to create an informative reference chart.

Procedure

⇒ Based on the Information section, “Develop a Chart of Planting Media with the Characteristics of Each Media,” design a chart cross-referencing the following elements of soilless planting media:

- Soilless planting media content
- Characteristics
- Best use application
- Advantages
- Disadvantages

⇒ Use a table-generating computer program. (Recommendations: Microsoft Word or WordPerfect; a spreadsheet program such as Excel or Quattro Pro, or a presentations program such as Powerpoint, WordPerfect Presentations or Harvard Graphics).

Or

⇒ Hand-design a table using a ruler and graph paper. (This method makes a good starting point before generating your table on the computer.)

Example

Media	Characteristics	Best Use	Advantages	Disadvantages

Q&A

- Can you name two other inorganic soil additives in use by commercial growers? If so, what are their characteristics? Add them to your chart.

5. Teacher Answer Sheet

Q&A

1. Cinders and Scoria

More available in coal burning regions.
Quality variable.
Sulphates must be leached out prior to use.
Additive to peat moss.
Good porous structure.

2. Rockwool

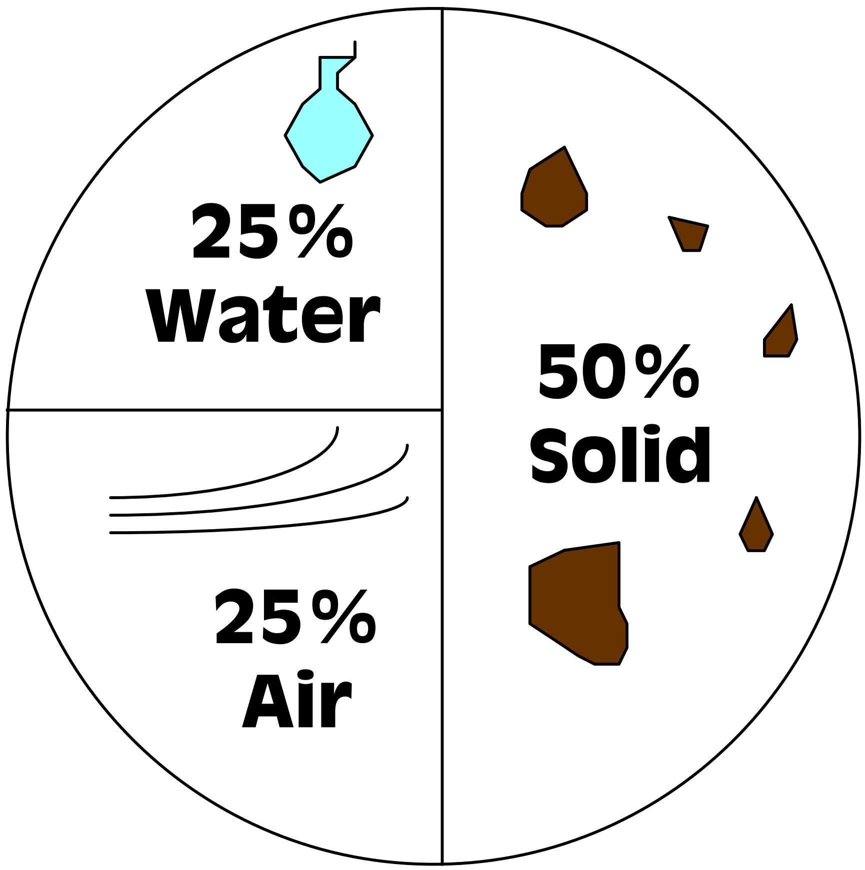
Cottony / woolly characteristics
Manufactured by subjecting rocks to very high temperatures.
Sterile
Uniform
Cottony ball-like particles
- **Hydrophilic** natural state / water attracting.
- **Hydophobic** conditioned / water repelling.
  - Increases or decreases water holding capacity of soils.

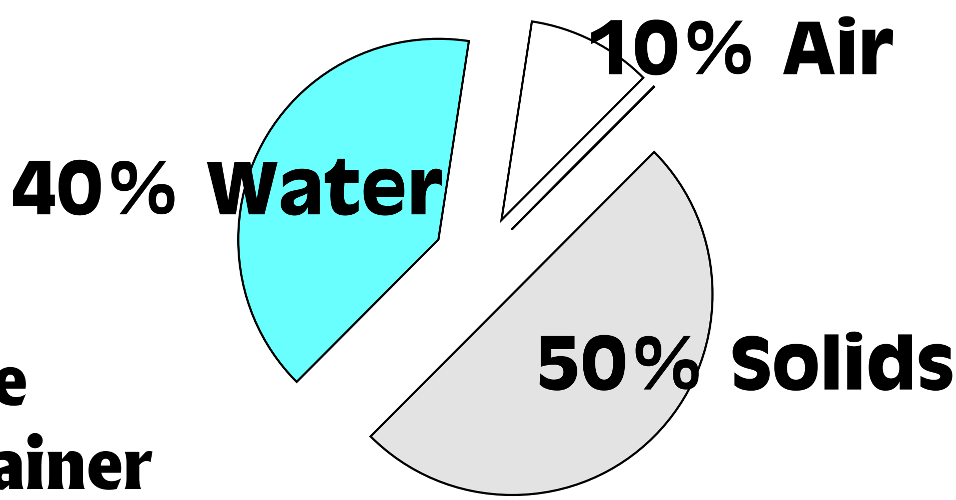
Can replace perlite.

Reference

1. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.

Ideal Growing Medium
Amended Soil or Soilless





Compare to Container Conditions

Information

6. List Several Soil Mixes Identifying Media Data for Each Soil Mix

Peat-Sand General Production or Growing Mix

Applicable under a wide range of plant growth conditions.
Materials available in almost every locality.
Moderately well-drained.
Avoid heavy irrigation.
Acid base.

The mix:

2 four cubic-foot bales sphagnum peat
12 cubic feet of washed sand
19 ounces of triple superphosphate
5 ounces of potassium nitrate (dissolve in 5 gallons of water and distribute evenly).
Moisten mix slightly to avoid need for immediate watering.

Notes

Peat in compressed bales expands to almost double the volume / yields one cubic yard of mix.
Ratio of 55% peat / 45% sand by volume.
Single superphosphate can be substituted for triple superphosphate, with amount doubled.
Peat should be ground according to container size (the smaller the container, the finer the grind).
Plants lose phosphorus over long growing periods; hence, superphosphate applications.

Soil mix pH may be elevated by adding 5 lbs of calcium carbonate.
Test with pH meter for adjustments for optimal 5.2 to 6.2 reading.
Plan to fertilize soon after potting.

Peat-Perlite Mix

Lighter than peat-sand.
Used for rooted cuttings / germinating coarse seeds / plants preferring fast draining, light soil.
Not good for anchoring plants.

The mix:

8 cubic feet of compressed sphagnum peat
8 cubic feet of perlite (coarser grind / more than 6 mesh)

5 ounces potassium nitrate (KNO_3)
4 pounds ground limestone ($CaCO_3$)
15 ounces triple superphosphate or 30 ounces single superphosphate

Peat-Vermiculite Mix

Not as well-drained as peat-perlite mix.
Used to germinate fine seed and in plug plant production.

The mix:

8 cubic feet of compressed sphagnum peat / finely ground
6 cubic feet of fine vermiculite
5 ounces of potassium nitrate (KNO_3)
4 pounds of ground limestone ($CaCO_3$)
15 ounces of triple superphosphate or 30 ounces of single supersphosphate

Retail Potting Soil Mix

Used as a potting mix for house plants.
Can be used to germinate seeds and grow transplants.

The mix:

2 four cubic-foot bales of sphagnum peat (15 feet loose peat)
5 cubic feet washed sand
4 cubic feet perlite
5 pounds calcium carbonate lime
15 ounces triple superphosphate (or single at double the rate)
Water added to moisten.
Sterilize or keep in dark to prevent algal growth.

Loams

Field soil mix predominant in silt; lower in sand and clay.
Mixed in ratio of 1:1:1 loam, peat moss and coarse sand or aggregate.
If 50% soil, cut fertilizer additives by 25% from recommendations in peat-sand mix due to presence of natural fertility.
Does not require micronutrient application.
Must be pasteurized.

References

1. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.

2. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **List Several Soil Mixes Identifying Media Data for Each Soil Mix**

Internet Resource

E.C. Geiger, Inc. - 1997 Online Catalog
Site: http://www.hortnet.com/ecgeiger/Catalog/soil_mixes/soil_mixes.html

Transparency

- **Growing Medium Factors to Consider**

6. Student Activity: List Several Soil Mixes Identifying Media Data for Each Soil Mix

Purpose

Research and identify various soil-based mixes for growing.
Identify various media within soil mixes and identify their purpose.

Procedure

Produce a table of various soil mixes and their media per the information provided and from additional research and define their uses.
Research and identify at least two other mixes from other sources: the internet, professional growers, and/or soil mix producers.
Identify sources of information.
List according to the example provided. Tables may be computer-generated or hand-drawn on graph paper.

Example provided:

Peat-Sand Mix	Proportional Ingredients	Uses

Q&A

1. Describe the type of soil texture commonly used in soil-based growing media.
2. Why is unamended soil rarely used in growing?

(Provide answers in space below . . .)

6. Teacher Answer Sheet

1. Describe the type of soil textures commonly used in soil-based growing media.

   Loam mixtures of intermediate-sized particles higher in silt and lower in sand and clay mixed with the appropriate amounts of organic matter and inorganic aggregates to satisfy plant requirements.

2. Why is unamended soil rarely used in growing?

   Lacks proper balance between air and water when used in a container.

Reference

1. Schroeder , C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Growing Medium Factors to Consider

Chemical , Physical, & Economic Factors

Chemical:

- Nutrient storage capacity

Physical Factors:

- Water-holding capacity
- Aeration
- Bulk density (anchorage & support for plant)
- Particle size distribution
- Uniformity
- Shrinkage

Economic (costs of):

- Components
- Availability
- Reproducibility

Information

7. Identify the Correct Fertilizers to Add for Various Soil Mixes

Two Fertilizer Categories

Inorganic (chemical)

More quickly available.

Derived from simple compounds.

Element present in small quantities but available immediately to the plant.

Organic

Derived from plant and animal tissue.

Require more modification before plant absorption.

Element present in abundance but available in small amounts at any one time.

Amendment availability of nutrients to plants depends upon:

pH

Soil organisms contained, if any.

Amendment compound stability and complexity.

Concentrations of elements in compound

Soil composition

Soil composition affects mineral availability to plants

Soil pH

Element concentration

Soil organisms

Water holding capacity

Factors may be interrelated:

Soil pH affects microorganisms;

Microorganisms determine nitrogen availability to plant.

High pH decreases solubility of iron compounds, causing chlorosis.

Low pH creates insolubility of iron compounds, creating toxic conditions.

Large supplies of one element may limit the physical opportunity of another to be near the root zone.

Complete Fertilizer

Contains all three primary fertilizer nutrients: nitrogen, phosphate, potash.

May have select nutrients.

Incomplete Fertilizer

Lacking in one or more primary nutrients.

Active Ingredient
Total % of nutrients applied.
Inert Ingredient
Filler that allows deposition of the fertilizer.

Reading the Analysis
E.g. 16-4-8 means 16 % nitrogen, 4% phosphate, 8% potash.

Pre-plant amendments to soil mixes
Dolomitic limestone
Provides calcium and magnesium for plant growth.
Neutralizes acidity of compounds such as pine bark and peat moss.
Application 5 to 8 pounds per cubic yard of potting media.
Lower rates for acid-loving plants.
Adjustments based on:
Water quality
Plant growth
pH of growing media
Ideal pH of plant
Availability of micronutrients in media.
Micronutrients
Prevents cholorosis and stunting of plant growth.
Found in commercial preparations.
Good for one year.
Superphosphate
Highly soluble and readily leaches.
Requires additional and frequent supplementation.

Controlled release fertilizer
Used as pre-plant amendment if growing medium will be used for a short period of time.
One or more of the nutrients have limited solubility.
Available to plants over extended periods.
One or more applications results in a full season of nutrition.
Based on a growing temperature between 70 and 80^0F.

Longevity of a supplement depends upon:
Time of application
Irrigation rates
Temperature of the growing medium.
E.g. complete fertilizer applied at the rate of 3 to 4 pounds of nitrogen per cubic yard of growing medium supplies sufficient nutrients for nine to 12 months.

Quick-release fertilizer

Low cost.
Readily soluble.
Applications made at regular intervals.
Applied when foliage is dry but removed before irrigation.
Not recommended for pre-amendment.

Liquid feed

Used by injection to irrigation systems.
Supplement controlled releases fertilization programs.

All amendments:

Follow label directions for **content analysis, use and application**.

References

1. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.
2. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
3. University of Wisconsin-Madison. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activities

- **Identify the Correct Fertilizers to Add for Various Soil Mixes**

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt (p. 179):

- **Salt Effects on Plants**

Internet Resource

Illinois Cooperative Extension Service Horticulture Solutions Series, "Soils and Fertilizers"
http://www.ag.uiuc.edu/~robsond/solutions/hort.html

Transparencies

- **Fertilizer Types**

From Agricultural Science and Technology 510:

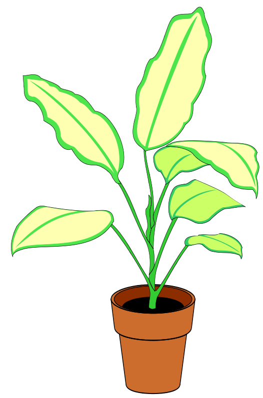
- **Information Commonly Found on a Fertilizer Bag**
- **Fertilizer Analysis**
- **Plant Nutrient Blends**

7. Student Activity: Identify the Correct Fertilizers to Add for Various Soil Mixes

Purpose
To identify fertilizers appropriate for soil amendment in order to provide plants with the appropriate nutrient levels under various conditions.

Procedure
Describe the appropriate fertilizers to use in the following soil mixes.

Peat-Sand General Production or Growing Mix
Peat-Perlite Mix
Peat-Vermiculite Mix
Retail Potting Soil Mix



From the *Horticulture Edition of the Western Fertilizer Handbook* (Interstate):
Landscape Container Mix
Greenhouse or Foliage Plant Mix

Q&A
Given the total analysis of a fertilizer type:
1. What is the dominant nutrient supplement provided in raw bone meal?
2. What primary nutrient would urea supply to a plant?
3. What primary nutrient is lacking in wood ash supplementation?

Provide all answers on the lines below:

Peat-Sand General Production or Growing Mix

Peat-Perlite Mix

Peat-Vermiculite Mix

Retail Potting Mix

Landscape Container Mix

Greenhouse or Foliage Plant Mix

Q&A

1.
2.
3.

7. Teacher Answer Sheet

Peat-Sand:
19 ounces triple superphosphate
5 ounces potassium nitrate dissolved in 5 gallons of water and distributed evenly.

Peat-Perlite:
5 ounces potassium nitrate
4 pounds limestone
15 ounces triple superphosphate or 30 ounces single superphosphate

Peat-Vermiculite:
5 ounces potassium nitrate
4 pounds ground limestone
15 ounces triple superphosphate or 30 ounces single superphosphate

Retail Potting Mix:
5 pounds calcium carbonate lime
15 ounces triple superphosphate

Landscape Container Mix:
Per each cubic yard:
4 ounces potassium sulfate
6 ounces potassium nitrate

Greenhouse or Foliage Plant Mix:
Per each cubic yard:
2 pounds single superphosphate
4 ounces potassium sulfate
4 ounces potassium nitrate
5 pounds hoof and horn meal or blood meal

Q&A

1. Phosphorus
2. Nitrogen
3. Nitrogen

References

1. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.
2. Soil Improvement Committee, California Fertilizer Association. (1990). *Horticulture Edition: Western Fertilizer Handbook*. Danville, IL: Interstate.

Fertilizer Types

Type	Nitrogen Analysis	Phosphorus Analysis	Potassium Analysis
Milorganite	5	2	0
Tankage	8-10	5-12	0
Raw Bone Meal	2-4	22-25	0
Steamed Bone Meal	1-2	22-30	0
Sheep Manure	2-3	1	1-2
Cotton Seed Meal	8	2	2
Tobacco Stems	2	0	8
Hard Wood Ashes	0	2	8
Soft Wood Ashes	0	2	4
Linseed Meal	5	2	2
Castor Bean Meal	5	2	2
Soybean Meal	6	3	1
Peat Soil	2-4	0	0
Ammonium Chloride	26	0	0
Ammonium Suophate	20	0	0
Ammonium Nitrate	35	0	0
Nitrate of Soda	16	0	0
Muriate of Potassium	0	0	45
Potassium Phosphate	0	15	40
Potassium Nitrate	12	0	40
Rock Phosphate	0	25	0
Sulphate of Potash	0	0	50
Super Phosphate	0	20	0
Triple Superphosphate	0	45	0
Calcium Nitrate	15	0	0
Diammonium Phosphate	20	53	0
Mono Ammonium Phosphate	12	60	0
Sodium Nitrate	16	0	0
Urea	45	0	0
Urea-Formaldehyde	38	0	0

Source: Horticulture Solutions Series / Illinois Cooperative Extension Service / Board of Trustees of the University of Illinois (1995).

Information

8. Describe the Importance of Sterilizing a Potting Mix

9. Sterilize a Potting Soil Mix

Soil Pasteurization

Soil or sand

Used in a planting media.

Used in container growing.

Usual treatment: heated to 180^0F for 30 minutes before mixing with media.

Temperature range from 140^0-180^0F maintained at least 10 minutes but no more than 30 minutes.

Importance of sterilization

Practical means of controlling diseases in the root zone.

No media should be considered disease free unless analyzed and tested.

Especially important if using field soil in planting medium.

Sterilization Types

Steam generation

Chemical fumigants

Chloropicrin (tear gas)

Formaldehyde

Methyl bromide

Vapam (sodium methyl dithiocarbamate)

Soil must be allowed to air out after treatment.

Methyl bromide shortest aeration period but still extremely hazardous to humans.

Destroys common fungi.

Effective against most weed seeds and nematodes.

Fumigated media must be enclosed in a gasproof chamber.

Formaldehyde fumigant for inorganic soils, propagation benches, & storage facilities.

Water-soluble

Penetrates soil mass to depth of wetting.

10 to 14 days allow gas to dissipate.

Vapam controls most fungi, insects, nematodes, & weeds.

Water-soluble

Applied to medium surface or by injection.
Seal with additional water application.
Best with temperature range of 60-70^{0}F.
Aerated by turning soil 5-7 days after treatment.
Use as planting material in two weeks.

Chloropicrin treatment in airtight chamber. Highly corrosive.
Effective fumigant and herbicide.
Media should be damp, well aerated, at 65-70^{0}F.
At least 24 hours; preferably 48 hours for complete dissipation.
Plant after seven days.

Aeration periods of soil fumigants
Vary with soil temperature, characteristics of soil, and moisture content.
(Always follow recommendations of manufacturer.)
Media should be warm, damp and well aerated.
Optimum temperature for fumigation is close to 70^{0}F.

Soil Pasteurization:
Steam Treatment
Heat Treatment

Economical with large batches of soil.
Kills microorganisms and weed seeds.

Allows beneficial nitrifying bacteria to survive.
Aids in nitrification of ammonia.
Lower temperature minimizes problem of excess ammonia release.
Aerated steam best used for lower temperature range.

Post-treatment
Sterilized or pasteurized media placed in clean, sterilized containers.
Stored in sterilized area.

References

1. Davidson, H. & Mecklenburg, R. (1981). *Nursery Management: Administration and Culture*. Englewood Cliffs, NJ: Prentice-Hall.
2. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Container Plants*. Mills, WY: Andmar.

Student Activity

- **Describe the Importance of Sterilizing a Potting Mix**

Student Lab

- **Sterilize a Potting Mix**

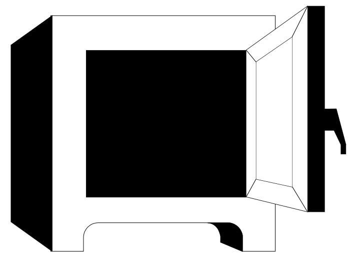
Internet Resource

Illinois Cooperative Extension Service / Horticulture Solutions Series / Soil Sterilizing
http://www.ag.uiuc.edu/~robsond/solutions/horticulture/docs/soilster.html

Transparency

- **Heat Treatment of Soils**

8. Student Activity: Describe the Importance of Sterilizing a Potting Mix



Purpose
Review the reasons for sterilizing potting soil.

Procedure
Answer the following questions before participating in the student lab for this section.
(*Answer the questions in the space below* . . .)

1. What are the main elements sterilization treatments hope to eliminate from potting soil?
2. What beneficial organisms will be destroyed at temperatures over 140^0F? . . . over 160^0F?
3. What are the alternative sterilization techniques to steam generation / heat treatments?
4. What is the usual treatment temperature for heat-generated soil sterilization?
5. Describe the post-treatment process.

8. Teacher Answer Sheet

1. Bacteria, fungi, insects, weed seeds, nematodes, pathogenic organisms.
2. Earthworms . . . nitrifying bacteria.
3. Chemical fumigants:
   - Chloropicrin (tear gas)
   - Formaldehyde
   - Methyl bromide
   - Vapam
4. 180^0F for 30 minutes before mixing with media.
5. Sterilized or pasteurized media placed in clean, sterilized containers. Stored in a sterilized area.

References

1. Davidson, H. & Mecklenburg, R. (1981). *Nursery Management: Administration and Culture*. Englewood Cliffs, NJ: Prentice-Hall.
2. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Container Plants*. Mills, WY: Andmar.

9. Student Lab: Sterilize a Potting Soil Mix

Purpose

- Demonstrate the correct procedure for sterilizing a potting soil mix with an electric soil sterilizer or by heat treatment with a conventional oven.
- Observe professional soil sterilization procedures.

Procedure

Electric soil sterilizer
- Fill the sterilizer to the top of the box, following the manufacturer's directions for your unit.
- Plug the sterilizer cord into an electric outlet.
- Set the thermostat according to the correct sterilizing temperature desired for the level of soil sterilization desired.
- The indicator light will glow until the batch is done.
- When the indicator light turns off, leave the soil in the sterilizer for another 15 minutes.
- Pick the sterilizer up and the soil will drop through the open bottom.

Heat treatment with a conventional oven
Sterilization at low temperature:
- Place moist soil in a kitchen cooking bag (or in a baking pan covered with aluminum foil).
- Set the oven temperature at 200^0F.
- Place the cooking bag or baking pan on a flat sheet in the oven with a meat thermometer inserted through the bag or foil to the center of the soil.
- Check the oven every 10 minutes until the thermometer registers 140^0F. Remove the soil from the oven at 140^0F. Higher temperatures will destroy nitrifying bacteria.

Sterilization at higher temperature:
Same methodology except . . .
- Heat in oven at 350^0F for 45 minutes. Forego the thermometer and the check for soil temperature.
- Soil has a strong smell when cooked. Ventilation is advised.

Always place the soil in clean, sterilized containers or clean bags. Store in a clean area.

Follow-up Activity

Visit a professional greenhouse operation. Request permission to observe their sterilization techniques and the equipment used. Write a brief report detailing:
- Type of equipment used.
- Observation notes on use of equipment (how-to).
- General temperatures used for sterilization.
- Techniques for handling and storage of sterilized potting media.

10. Student Activity: Properly Mix Potting Soil

Purpose
Properly prepare a soilless media mix.

Procedure
Please wear water-repellent, protective gloves during this activity.

Materials for the Cornell "Peat-Lite" Mix C
(Used for seed germination)
- 1 bushel (8 gallons) shredded German or Canadian sphagnum peat moss
- 1 bushel (8 gallons) Vermiculite no. 4 (fine)
- 1 ½ ounces (4 level tablespoons) ammonium nitrate
- 1 ½ ounces (2 level tablespoons) powdered Superphosphate (20%)
- 7 ½ ounces (10 level tablespoons) ground dolomitic limestone
- Non-ionic wetting agent

1. Blend together the ammonium nitrate, Superphosphate and dolomitic limestone until they are thoroughly mixed.
2. Prepare the non-ionic wetting agent according to the label instructions.
3. Spread the peat moss out on a clean plastic sheet and sprinkle with the water prepared with the non-ionic wetting agent.
4. Break up the peat moss into particles ½ inch or smaller.
5. Alternate mixing the Vermiculite with the peat moss until well-mixed.
6. Sprinkle the blended fertilizers over the top.
7. Blend all ingredients by tossing until thoroughly mixed.

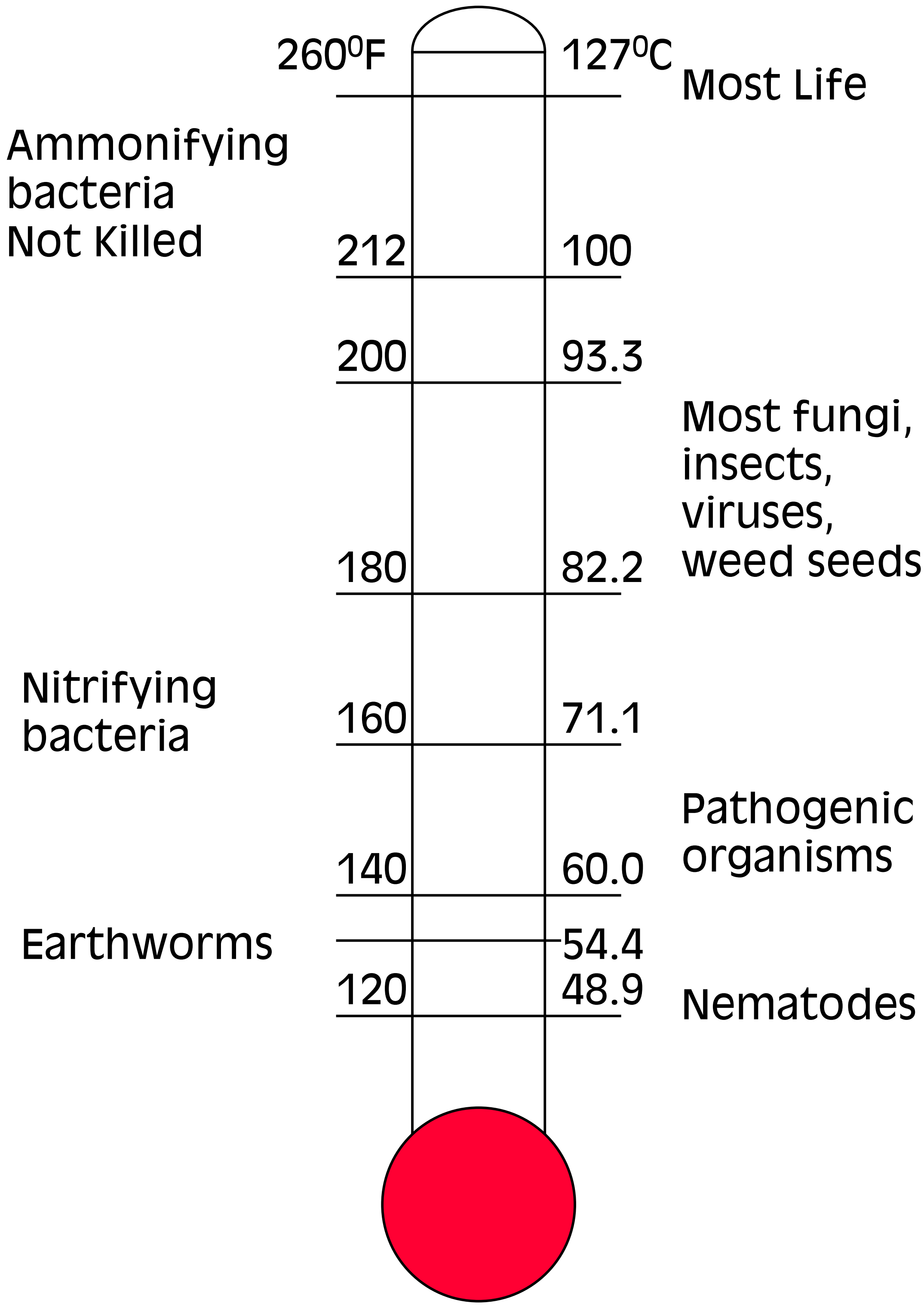
Follow-up Activity

Testing the Mix
Plant Wisconsin "Fast Plant" seeds in your potting soil, some in sand, and some in untreated topsoil from your yard. Keep a daily record of the plant growth in all three mediums. After two weeks, which plants are tallest? Do an observation of the untreated topsoil by sifting through the soil and looking at it under the microscope and record your observations. Predict which soil will grow the plants best in one week, two weeks, three weeks, and after four weeks. Record the results. Did your hypothesis match the actual results? Why or why not?

References

1. Hartmann, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. University of Wisconsin-Madison. *Exloring with Wisconsin Fast Plants*. (1995). Dubuque, IA: Kendall / Hunt.

Heat Treatment of Soils



15 minutes will destroy most organisms at temperatures listed.

Ag 514 A - Potting Soil and Media

Agricultural Science and Technology
Botany / Horticulture Plant Science

Unit Examination

Name ______________________________ Score ______________

Fill in the Blanks

1. The four components of soil are:

(1)	(3)
(2)	(4)

2. Rock material or peat from which soil profiles originate is called:

____

3. Acid or low pH levels occur when the concentration of ________________ions increases.

4. Soilless rooting material in which plants grow is called:

____

Multiple Choice

5. Which of the following is NOT a type of root system?

   A. Specialized
   B. Fibrous
   C. Diffused
   D. Tap

Please continue . . .

6. Which of the following is a function of the roots in plants?

   A. Propagate or reproduce (in some plants).
   B. Conduct photosynthesis to produce food for the plant.
   C. Protect the plant against frost damage.
   D. Store water for respiration.

7. A neutral soil pH is:

   A. 7.0
   B. 6.0
   C. 8.0
   D. 7.5

8. Soils with a pH below 7.0 are called:

   A. Neutral
   B. Alkaline
   C. Basic
   D. Acidic

9. A soil with low pH can be improved by using:

   A. Potassium fertilizer
   B. Pesticides
   C. Lime
   D. Anhydrous ammonia

10. Partially decomposed vegetation collected from marshes, bogs, or swamps is called:

   A. Peat moss
   B. Limestone
   C. Vermiculite
   D. Sphagnum moss

11. Limestone is made up of:

   A. Sodium chloride (NaCl)
   B. Calcium carbonate ($CaCO_3$)
   C. Magnesium sulphate ($MgSO_4$)
   D. Potassium chloride (KCl)

Please continue . . .

12. Which of the following is NOT an advantage of using soilless media.

    A. Provides a uniform mixture for plant growth.
    B. Is sterilized to eliminate diseases, insects, or weed seeds.
    C. Is lightweight and easy to use.
    D. Has high mineral content.

Matching

_____	13. Aerial roots	A. Primarily in monocots
_____	14. Organic	B. Volcanic origins
_____	15. Vermiculite	C. Heat-treated mica
_____	16. Perlite	D. Fertilizer category
_____	17. Fibrous roots	E. Suspended in air

Thank you! Please return the test sheets to your instructor.

Ag 514 A - Potting Soil and Media

Agricultural Science and Technology
Botany / Horticulture Plant Science

Unit Examination - Instructor Copy

Name _______________________ Score __________

Fill in the Blanks

1. The four components of soil are:

(1) **Minerals**	(3) **Air**
(2) **Water**	(4) **Organic matter**

2. Rock material or peat from which soil profiles originate is called:

Parent material

3. Acid or low pH levels occur when the concentration of ______H+______ions increases.

4. Soilless rooting material in which plants grow is called:

Plant media

Multiple Choice

5. Which of the following is NOT a type of root system?

   A. Specialized
   B. Fibrous
   C. Diffused
   D. Tap

Please continue . . .

6. Which of the following is a function of the roots in plants?

   A. Propagate or reproduce (in some plants.)
   B. Conduct photosynthesis to produce food for the plant.
   C. Protect the plant against frost damage.
   D. Store water for respiration.

7. A neutral soil pH is:

   A. 7.0
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   C. 8.0
   D. 7.5

8. Soils with a pH below 7.0 are called:

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   D. Acidic

9. A soil with low pH can be improved by using:

   A. Potassium fertilizer
   B. Pesticides
   C. Lime
   D. Anhydrous ammonia

10. Partially decomposed vegetation collected from marshes, bogs, or swamps is called:

    A. Peat moss
    B. Limestone
    C. Vermiculite
    D. Sphagnum moss

11. Limestone is made up of:

    A. Sodium chloride ($NaCl$)
    B. Calcium carbonate ($CaCO_3$)
    C. Magnesium sulphate ($MgSO_4$)
    D. Potassium chloride (KCl)

Please continue . . .

12. Which of the following is NOT an advantage of using soilless media.

    A. Provides a uniform mixture for plant growth.
    B. Is sterilized to eliminate diseases, insects, or weed seeds.
    C. Is lightweight and easy to use.
    D. Has high mineral content.

Matching

__E__	13. Aerial roots	A. Primarily in monocots
__A__	14. Organic	B. Volcanic origins
__C__	15. Vermiculite	C. Heat-treated mica
__B__	16. Perlite	D. Fertilizer category
__D__	17. Fibrous roots	E. Suspended in air

Thank you! Please return the test sheets to your instructor.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 B - Soil Fertility

Unit Objectives

1. List four sources of plant nutrients.
2. List the primary and secondary plant nutrients and describe the function of each for plant growth.
3. Match nutrients to their correct plant deficiency symptoms.
4. Select from a list of factors that influence the use of fertilizers.
5. Match dry, liquid, and gaseous fertilizers with their correct description and use.
6. Identify and discuss methods of fertilizer application.
7. Discuss methods and procedures involved in collecting a representative soil sample.
8. Complete a soils test report form, and make fertilizer recommendations using the test analysis data.
9. Complete a soluble salts test.
10. Calculate problems comparing fertilizer cost by comparing cost per pound of nutrients.

Information

1. List Four Sources of Plant Nutrients

2. List the Primary, Secondary and Micronutrients of Plants and Describe the Function of Each for Plant Growth

3. Match Nutrients to their Correct Plant Deficiency or Toxicity Symptoms

Four Sources of Plant Nutrients

- **Water**
- **Light**
- **Air**
- **Soil**

Water

- 90% of a plant's weight.
- Plant food is dissolved in water and moved throughout the plant in water (translocation).
- Photosynthesis uses water.
- Plant uptake is via water from the soil.
- Transpiration creates 90-95% of a plant's water loss as water vapor exiting through leaf stomata.
- Lost largely due to excess water in soil.
- Transpiration cools and moistens the air around the plant.

Light

- Must be present for green plants to manufacture food.
- Light requirements vary between plant types.
- Photoperiodism
  - Plant growth responses to different times of night and day or relative lengths of night and day.
    - Long / short day or indifferent plant flowering according to day length.
- Plant growth toward the light due to production of growth hormones on shady side (therefore, stem is longer on shady side).

Air

- **Temperature effects plant growth.**
  - Plant types have different temperature preferences.
  - Below freezing temperatures halt plant growth or kill plants.

Humidity

Plants grow best in 40-80% humidity.
Amount of moisture in the air.
Hot, dry conditions create wilting or death.
High humidity creates fungal conditions.

Gases and air particles

Carbon dioxide vital to plants for food production.
Increases crop yields.
Sulfur dioxide damages crops by reducing growth or killing plants.

Soil

Plants receive nutrients from water in the soil.
Nutrients come from decayed plant and animal matter, and mineral content of soil.
Chemical interactions from oxygen in soil fix nitrogen and make this important nutrient available to plants through water in soil (see **Nitrification**, *infra*).

Macronutrients include primary and secondary nutrients.

Primary Plant Food Nutrients

Nitrogen
Phosphorus
Potassium

Secondary Plant Nutrients

Calcium
Magnesium
Sulfur

Micronutrients

Boron
Chlorine
Copper
Iron
Manganese
Molybdenum
Zinc

(Needed in even lower amounts)

Aluminum
Fluorine
Nickel
Sodium

Primary nutrients most important nutrients for plant growth.

(**N-P-K** listed as quantities available to plant by percentages on fertilizer bags. Other % is filler material used to disseminate nutrients.)

Primary nutrients must be present in large amounts.
Secondary nutrients must be present in moderate amounts.
Micronutrients are essential but needed in small amounts.

Nitrogen

(Commercially available in four forms)

Nitrate of soda $NaNO_3$

Highly soluble
Lowers soil acidity
16% nitrogen

Ammonium nitrate NH_4NO_3

Not as soluble
Gradually available
33% nitrogen

Ammonium sulfate $(NH_4)_2SO_4$

More acidic
Gradually available
21% nitrogen

Urea formaldehyde

Organic nitrogen
More gradually available than inorganic nitrogen
38% nitrogen

Nitrogen formation

Aminization protein and allied compounds broken down into amino acids / soils organisms acquire energy from this digestive process & use in cell structure.
Ammonification conversion of ammonia compounds into ammonia and ammonium compounds.
Mineralization aminization & ammonification reactions.

Nitrification

Ammonical forms of nitrogen changed to nitrate by bacteria.
Nitrosomonas and *Nitrosococcus* bacteria convert ammonia to nitrite.
Need warm temperatures, oxygen, moisture and optimum pH level (between 5.5 & 7.8).

Denitrification

Nitrogen lost from the soil to the atmosphere.
Anaerobic conditions (caused by excessive moisture or soil compaction, or both) create a situation where bacteria in the soil remove oxygen from nitrate to meet their needs, creating nitrous oxide (N_20), nitric oxide (NO) and nitrogen (N_2).
Creates loss of nitrogen available to plants from soil.

Nitrogen fixation

Nitrogen combined with hydrogen or oxygen for plant utilization.
Fixed by soil organisms living on legume root nodules or free-living; also by lightning.

Nitrogen cycle

Returns nitrogen to soil by plant and animal waste.

Leaching

Primary loss of soluble nitrogen.
Negative charge repels soil particles.

Nitrogen deficiency:

Slow growing plants.
Stunted plants.
Chlorosis in older leaves.
Copper coloring or "firing" of older leaves.

Phosphorus (commercial forms - % of phosphate):

Superphosphate (20%)
Treble superphosphate (46%)
Rock phosphate (25-35%)
Ammonium phosphate (48%)

Held by soil particles.
Component of DNA & RNA.
Encourages cell division.
Flower and seed formation.
Hastens maturity.
Encourages root growth / development of root systems.
Necessary for release of energy for plant processes.
Makes potassium easily available.
Increases resistance to disease.
Improves quality of grain (seed), root and fruit crops.
Modifies fast, soft growth from nitrogen and early maturity from potassium.
Held tightly by soil particles.

Insufficient phosphorus:

Purple coloring on undersurface of leaves
Reduced flower, fruit and seed production
Susceptibility to cold.
Susceptibility to disease.
Poor quality fruits and seeds.

Potassium (in % available as):

Muriate of potash (60%)
Sulfate of potash (49%)

Nitrate of potash (44% potassium & 13% nitrogen)

Increases resistance to disease.
Encourages stronger, healthier root system.
Essential for starch formation and translocation of sugars.
Necessary for development of chlorophyll through photosynthesis.
Essential for tuber development.
Encourages efficient use of carbon dioxide.
Activates plant enzymes.
Regulates opening & closing of leaf stomata.
Regulates water uptake by plant root cells.

Indication of potassium deficiency:

Burn or scorching around leaf margins (more with older leaves).

Secondary Nutrients

Calcium

Found in plant growth regions; essential in formation of new cells.
Counteracts toxic effects of oxalic acid.
Absorbed by plants as the calcium ion (Ca^{++}).
Influences absorption of potassium & magnesium and other nutrients.
Increases pH.

Indication of calcium deficiency:

Burned tips of young leaves.
Death of terminal buds and root tips.
Extremely dark green foliage.
Premature blossum & bud shedding.
Weak stems.
Blossom-end rot on tomatoes, peppers & melons; bitter pit or cork spot on apples & pears. Sweating, discolored spots on fruits.

Magnesium

Ion form of uptake (Mg^{++}).
Essential for photosynthesis.
Activates plant enzymes.

Deficiencies:

Chlorophyll contains magnesium; is translocated in plant to younger leaves if calcium deficient.
Sandy soils are magnesium deficient.
Symptoms include chlorosis in older leaves and marginal yellowing in leaf mid-ribs.
Upward curling leaves along margins.

Sulfur

Uptake as ion ($SO_4^{=}$).

Also absorbed from air.
Contained in three amino acids (cystine, methionine, cysteine).
Essential for:
Protein synthesis.
Legume root nodule formation.
Odor-causing.

Deficiencies widespread.
Symptoms include yellowing of young leaves.
Smallness / spindly plants.
Retarded growth rate of plants.

Micronutrients

Zinc
Essential enzyme component in plants.
Controls synthesis of indoleacetic acid (plant growth regulator).
Absorbed as zinc ion (Zn^{++}).

Deficiency indications:
Terminal growth areas affected.
Decrease in stem length and rosettes of plants.
Fruit bud formations are reduced.
Leaf mottling (or interveinal chlorosis).
Twigs die back after first year of growth.

Iron
Required for the formation of chlorophyll in plant cells.
Activator for respiration, photosynthesis, & nitrogen fixation.
Plants uptake iron as ferrous ions (Fe^{++}).

Deficiency indications:
Deficiency can be induced by high levels of manganese or lime in soils.
Mottling of young leaves. Sharp distinctions between veins and interveinal areas.
Twigs die back.
Severe deficiency results in death of entire limbs or the entire plant.

Manganese
Enzyme activator in plant growth.
Symbiotic assist with iron in chlorophyll formation.
High amounts of manganese in soil may reduce iron availability.
Manganese uptakes in plants as an ion (Mn^{++}).

Manganese deficiency:
Mottling of young leaves.

Mottling is gradual between veins and interveinal areas.

Copper

Enzyme activator.
Assists plant in vitamin A production.
Plant takes up copper in the form of two ions (Cu^{+} & Cu^{++}).
Can be toxic; need must be established.

Defiency:

Stunted growth.
Terminal tree shoots exhibit dieback.
Pigmentation is poor.
Leaf tips wilt (eventually die).
Oranges show formation of gum pockets around their central piths.

Boron

Works in plants as a differentiator of meristem cells.
Regulates metabolism of carbohydrates.

Deficiency:

Continuous supply is needed by plant.
Creates “witches-broom” effect with cause of terminal bud death and lateral bud development.
Leaves on plants thickened, curled, wilted and chlorotic.
Soft spots on fruit and in tubers.
Blossom reduction / improper pollination.

Molybdenum

Taken up by plants as molybdate ion $MoO_4^{=}$.
Required for transformation of nitrate nitrogen into amino acids.
Helps legumes fix atmospheric nitrogen.

Deficiency:

Stunting growth and wilting.
Scorching around margins; leaf cupping or rolling.
In cauliflower, creates “whiptail.”
In citrus, causes yellow spotting.

Chlorine

Absorbed by plants as chloride ion (Cl^{-}).
Required for photosynthesis.

Deficiencies are rare, but include:

Wilting and chlorosis.
Lateral root branching to excess.

Leaf bronzing.
Tomatoes and barley exhibit chlorosis and necrotic symptoms.

A balance of nutrients is essential in plant nutrition.
Excess of one nutrient can create reduced uptake of another nutrient.

References

1. Reiley, H.E., & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
2. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
3. Soil Improvement Committee California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.

Student Activity

- **Plant Nutrient Model**

Internet Resources

- *Daisy Soil Plant System Simulation Model* http://www.agsci.kvl.dk/planteer/daisy/poster.htm
- University of Hawaii, Soil and Environmental Chemistry *Acid Soils in Hawaii: Problems and Management* http://agrss.sherman.hawaii.edu/staff/hue/acid.html

Transparencies

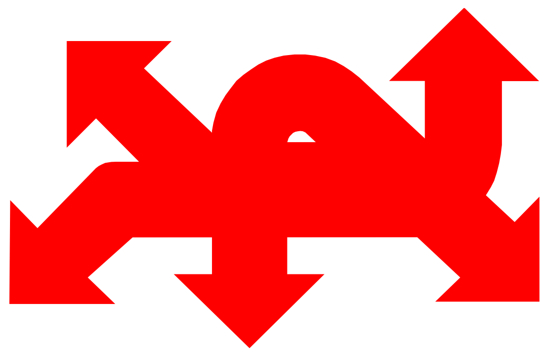
From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 B - Soil Fertility*:
- **Chemical Elements Essential to Plant Growth**
- **Ten Essential Elements**

1-2-3. Student Activity: Plant Nutrient Model

Purpose

- List Four Sources of Plant Nutrients
- List the Primary, Secondary and Micronutrients of Plants and Describe the Function of each for Plant Growth
- Match Nutrients to their Correct Plant Deficiency or Toxicity Symptoms
- Demonstrate an understanding of how a plant interacts with its environment in receiving nutrients.
- Demonstrate an understanding of how a plant thrives with or deteriorates without essential plant nutrients.

Materials needed



Refer to “Daisy” site
(http://www.agsci.kvl.dk/planteer/daisy/poster.htm)
Poster sheet
Markers
Construction Paper
Stencils
or
Computer presentation or drawing program

Procedure

Create a model using poster board or on a computer which demonstrates how a plant receives nutrients from its environment, what those nutrients are, and the effects of deficiency on the plant.

The model should show:

1. The four sources of plant nutrients
2. How the plant uptakes or receives the nutrients
3. What the function of those nutrients are for the plant
4. What happens to the plant when it is deprived of those nutrients

The model can have a “before” and “after.”

References

1. British Museum of Natural History. (1982). *Introducing Ecology: How Nature Works*. London: Cambridge University Press.
2. Hensen, S., Jonsen, H.E., Nielsen, N.E., & Svendsen, H. *Daisy Soil Plant System Simulation Model* [On-line]. http://www.agsci.kvl.dk/planteer/daisy/poster.htm

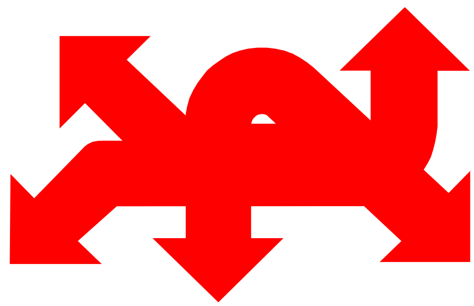
1-2-3. Student Activity: Plant Nutrient Model (Teacher Information)

Purpose

- List Four Sources of Plant Nutrients
- List the Primary, Secondary and Micronutrients of Plants and Describe the Function of each for Plant Growth
- Match Nutrients to their Correct Plant Deficiency or Toxicity Symptoms
- Demonstrate an understanding of how a plant interacts with its environment in receiving nutrients.
- Demonstrate an understanding of how a plant thrives with or deteriorates without essential plant nutrients.

Materials needed

Refer to "Daisy" site
(http://www.agsci.kvl.dk/planteer/daisy/poster.htm)
Poster sheet
    Markers
    Construction Paper
    Stencils
or
Computer presentation or drawing program



Procedure

Create a model using poster board or on a computer which demonstrates how a plant receives nutrients from its environment, what those nutrients are, and the effects of deficiency on the plant.

The model should show:

1. The four sources of plant nutrients
2. How the plant uptakes or receives the nutrients
3. What the function of those nutrients are for the plant
4. What happens to the plant when it is deprived of those nutrients

The model can have a "before" and "after."

Students should be encourage to develop the model as creatively as possible (for instance, if they wish to make the model interactive).

Depending upon the number of students in the class, this activity may be appropriate as a group project, as long as the members of the group have distinct roles in the development of the model.

Project can be divided among students (or student groups) according to the demonstration of:

- Nutrient sources
- Primary nutrients
- Secondary nutrients
- Micronutrients

A word about Daisy:
Daisy is a mathematical simulation model. It is used here to demonstrate how a model can look, rather than an attempt to replicate it. Students should be encouraged to develop their models at their own level, demonstrating only what is required for this activity.

References

1. British Museum of Natural History. (1982). *Introducing Ecology: How Nature Works*. London: Cambridge University Press.
2. Hensen, S., Jonsen, H.E., Nielsen, N.E., & Svendsen, H. *Daisy Soil Plant System Simulation Model* [On-line]. http://www.agsci.kvl.dk/planteer/daisy/poster.htm

Information

4. Select from a List of Factors that Influence the Use of Fertilizers

5. Match Dry, Liquid, and Gaseous Fertilizers with their Correct Description and Use

6. Identify and Discuss Methods of Fertilizer Application

Factors that Influence Use of Fertilizers

Rooting characteristics of plant species.
Nutrient demands of plants during different stages of the plant's growth.
Physical and chemical characteristics of the **soil and** the **fertilizer** applied.
Soil moisture availability to plants.
Irrigation system type, particularly if irrigation is the major source of water to the plants.

Multiple applications by several different methods.
Plants utilization of nutrients.
Changes nutrients undergo within the soil may affect their availability.

Fertilizer

Material used to provide plants with the nutrients they need.
Adding to growing medium.
Absorbed by roots of plants.

Application

Growing medium.
Leaf spray.

Forms

Solid
Liquid
Gaseous

Plants can be damaged by too much, too little, or the wrong fertilizer.

Elemental fertilizer

Provides one plant nutrient.

Complete fertilizer

Contains all three primary plant nutrients
May have select micronutrients

Incomplete fertilizer

Lacks one of the primary nutrients.

Active ingredient

Total percentage of nutrients applied.

Inert ingredient

Filler material as base allowing application of the fertilizer.

Fertilizer analysis

Percentage by weight.
Three number designation: grade.
Composition of active ingredients in fertilizer formulation: 16-4-8 means 16% nitrogen, 4% phosphate, 8% potash.
Total 16-4-8 = 28% active ingredients.
28 minus 100% = 72% inert ingredients.

Fertilizer ratio

Relative proportion of the primary nutrients.
16-4-8 is a 3-1-2 ratio.
Zero in a grade means an incomplete fertilizer.

Commercially Available Forms of Nitrogen

Calcium nitrate

15.5% nitrogen & 19% calcium
White, highly soluble.

Nitrate of soda $NaNO_3$

Highly soluble.
Lowers soil acidity.
16% nitrogen

Ammonium nitrate NH_4NO_3

Not as soluble.
Gradually available
33% nitrogen

Ammonium sulfate $(NH_4)_2SO_4$

More acidic.
Gradually available.
21% nitrogen

24% sulfur
Crystals in bulk blends should be the same size as other components.

Ammonium nitrate-sulfate

Double salt of ammonium nitrate & ammonium sulfate
Blend of nitric & sulfuric acids with ammonia.
Usually blend is 30% nitrogen & 6.5% sulfur.

Urea

46% nitrogen dry
80% nitrogen wet
Soluble
Less corrosive to equipment
Used as a protein supplement in ruminant feed.
Incompatible with ammonium nitrate in unequal solutions.

Urea formaldehyde

Organic nitrogen.
More gradually available than inorganic nitrogen.
38% nitrogen

Anhydrous ammonia

82% nitrogen
Gaseous ammonia
Lighter than air.
Readily absorbed in water.
Requires pressure containers.
Natural gas is source of hydrogen.
Deep, direct soil application.

Aqua Ammonia

Anhydrous ammonia dissolved in water.
20% nitrogen
Requires low-pressure tanks.
Injected below soil or water surface.

Nitrogen Solutions

Ammonium nitrate and urea in equal solutions.
Stabilizes compounds, creating increased nitrogen availability.

Pressure Solutions

Have appreciable vapor pressure due to more free ammonia present than solution can contain.

Non-pressure Solutions

Non-ammonia nitrogen solutions.

Salts

Reaction of an acid with a base.
Salts break up into cations and anions when dissolved in water.
Nitrogen & Potash compounds have a high index of salts / can cause plants to wilt or die.

Salting Out Point

Precipitation of dissolved salts contained in solutions at specific temperature drops.

Over-fertilization with nitrogen:

Lowers plant resistance to disease
Lengthens and weakens stems
Softens fruits, lowering quality
Delays maturity & hardening off, increasing winter damage

Under-fertilization of nitrogen:

Chlorosis (yellowing of leaves)

Chlorosis damages a plant's ability to make use of the process of photosynthesis, preventing the formation of chlorophyll.
Older leaves yellow and die. Nitrogen is transferred to younger leaves because nitrogen is in short supply.
Creates stunted root growth and stunted top growth.

Phosphate Fertilizers

Phosphoric acid

52% phosphate
Produces by-product gypsum during production.

Superphosphoric acid

70% phosphate
Molecular structure contains mor ethan one atom of phosphorus.

Normal superphosphate

20% phosphate & 12% sulfur

Concentrated supersphospate

45% phosphate
Granular form

Nitrogen-Phosphates

Ammonium Phosphates

Ammoniation of phosphoric acid.
Granulated -
Common forms used:
monoammonium phosphate 11-52-0
diammonium phosphate 16-48-0 or 18-46-0
ammonium phosphate-sulfate 16-20-0
Liquid -
Common forms used:
8-24-0
9-30-0
10-34-0
11-37-0

Nitric Phosphates

Ammoniated, dried and granulated.

Most of the phosphate is in the form of dicalcium phosphate
Form made in Western Europe contains equal amounts of nitrate and ammonium forms of phosphate.

Potash

Soluble and insoluble forms.
Occur primarily as chlorides and sulfates.
Potassium nitrate and potassium sulfate used when chlorides can injure plants, or when chloride is built up in soil.

Secondary Nutrients

Calcium

- Soil and foliar sprays
- Soil amendments (lime and gypsum)
- Manure
- Irrigation water

Magnesium

- Epsom salts (magnesium sulfate)
- Potassium-magnesium sulfate
- Magnesium nitrate (foliar applicant)
- Dolomitic lime (magnesium & calcium)
  - **Lime ($CaCO_3$)**
    - Acts as a plant food and diminishes soil acidity (raises pH).
    - Furnishes calcium, enhancing formation of plant cell walls.
    - Affects availability of other plant food elements.
    - Releases phosphorus.
    - Diminishes iron & aluminum.
    - Activates soil organisms & releases plant food.
    - Improves soil structure.

Sulfur

- Lowers pH in overly-alkaline soils.
- Brings pH level to near neutral or acidic.
- Sources:
  - Elemental sulfur
  - Gypsum
  - Sulfuric acid
  - Ferrous sulfate
  - Ferric sulfate
  - Calcium polysulfide solution
  - Ammonium polysulfide solution
  - Ammonium bisulfite solution
  - Ammonium thiosulfite solution
  - Manure
  - River and rain water

Pesticidal sulfur

Micronutrients

Inorganic salts

Copper sulfates
Iron
Manganese
Zinc
Borates (sodium tetraborate used as source for boron)
Water-soluble.
Boric acid & sodium octaborate used as foliar sprays.
Molybdates
Water-soluble ammonium
Sodium molybdate
Molybdic oxide

Synthetic Chelates

Chelating compound combines with metal ion forming ring structure between a portion of the chelating agent & the metal.
Delays precipitation of the metal ions in the soil (creates insoluble compound).

Natural Organic Complexes

Metal compounds / by-products of the wood pulp industry.
Readily broken down by soil microorganisms.
Used as foliar sprays and mixed with fluid fertilizers.

Organic

Sludge danger of toxic lead & cadmium build-up in soil.
Compost

Special Purpose Fertilizers

Coated (barrier to solubility).
Urea (nitrogen source)
Sulfur used as coating.
Resin coating
Thermoplastic coatings
Limited water solubility.

Uncoated organic

Slow-release

Limited water solubility with chemical or microbial decomposition / release of nutrients.
Organic nitrogen / bacterial degradation
Ureaforms
Methylene ureas
Isobutylidene-diurea / chemical degradation.

Nutrient Conversion Factors

(Nutrients in fertilizers are reported in elemental form except phosphorus & potassium.)

$P \times 2.29 = P_2 0_5$

$P_2 0_5 \times 0.43 = P$

$K \times 1.2 = K_2 0$

$K_2 0 \times 0.83 = K$

Homogenous

Granule / pellets with same formulation.

Bulk blends

Mixes of two or more fertilizers.

Blending methods and spreading may result in uneven distribution due to differences in weight and particle size.

Liquids and Suspensions

Nitrogen solutions, phosphoric acid & liquid mixes.

Liquid mixes

Neutralizing phosphoric acid with ammonia.

Suspensions

Saturated solutions with crystals of plant nutrients (or other materials) suspended in solution.

Dry materials

Ammonium nitrate
Urea
Ammonium sulfate
Phosphates & potash

Liquid materials

Anhydrous ammonia
Aqua ammonia
Urea / ammonia nitrate solutions
Ammonium nitrate solution
Urea solution
Phosphoric & superphosphoric acids
Clear liquid & fluid suspensions
Sulfuric acid
Sulfur materials for liquid formulations

Applications

Surface

Broadcast method

Distributing liquid or dry materials over the soil surface.

Drop spreader / spinning spreader (dry)

Liquid spreader speed of spreading determined by rate of flow.

Tank, pressure gauge, regulator, pump, pipes, hoses, fittings, nozzles, boom mounted on truck, ATV, trailer, tractor, or float mount (over water).

Injection

Fertilize below surface by injection tube.
Channels deliver materials to plant root zones.
Prevents wind-blown or rain removal.

Band Placement (field application)

Place to the side or below seed or established plants.
Used for dry or liquid application.

Irrigation

Sprinkler
Spitter
Trickle
Drip
Dual-wall tubing systems

Dry fertilizer should be pre-dissolved before entering system.

Foliar

For quick response to problems.
Micronutrient application.
Applied by spraying or overhead sprinkler systems.
Adjust pressure when hand spraying. Spray droplet size should be regulated according to plant size.
Low nutrient concentration rates are used to prevent injury to foliage.
Morning applications are best.

Dry / controlled release granular

Incorporation into the planting medium.

When fertilizer does not leach readily.
Used as starter fertilizers.
Moisten and use immediately.

Topdress

Application to the top of the medium.
Done on long term crops.
Supplements other methods.

Quick release

Readily soluble.
Applications made at regular intervals.
Applied when foliage is dry.
Can cause foliar burn if not removed before irrigation.
Less expensive initially; more expensive over the long term.

Soluble liquid

Introduced by irrigation.
Dissolved in warm water in storage tank connected to irrigation system.

Fertilizer proportioner

Introduces and meters the concentration of soluble liquid fertilizer.

Indicator dye in liquid fertilizer indicates application.

Gaseous fertilizers

Carbon dioxide fertilization

Injected into greenhouse air by CO_2 generators.

References

1. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
2. Soil Improvement Committee California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.

Student Activity

- **Read the Labels**

Internet Resources

Alberta Fertilizer Guide. Alberta Agriculture, Food, & Rural Development
http://www.agric.gov.ab.ca/agdex/500/4100001.html

Fertilizer: Nutrient. North Dakota Extension News
http://www.ext.nodak.edu/extnews/procrop/fer/nutrient.html

Ric Jensen. (1995). Predicting Nitrogen Mineralization May Improve Fertilizer Use.
http://agcomwww.tamu.edu/agcom/news/Stories/TWRI/NITROGEN.HTM

U.S. Geological Survey Technology Transfer Information Partnerships. Controlled Release Fertilizers Using Zeolites.
http://www.usgs.gov/tech-transfer/factsheets/94-0666b.html

Environmental Working Group. (1996). Pouring It On: Nitrogen Use and Sources of Nitrate Contamination.
http://www.ewg.org/pub/home/Reports/Nitrate/NitrateUse.html

Transparencies

- **Choosing Applications**

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 B - Soil Fertility*:

- **Information Commonly Found on a Fertilizer Bag**
- **Fertilizer Analysis**
- **Plant Nutrient Blends**

4-5-6. Student Activity: Read the Labels

Purpose

- Identify plant food elements and percentage of available nutrients as listed on fertilizers.
- Identify whether the source is a dry, liquid or gaseous fertilizer.
- Match the application type for the fertilizers identified.

Materials needed

- Notebook
- Flip chart pages
- Markers

Procedure

Students will visit a local garden supply store and/or a local greenhouse to find and identify at least one each of the following fertilizer types:

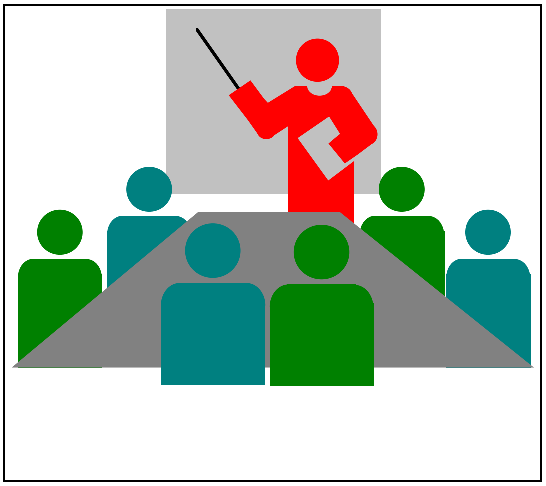
- Dry
- Liquid
- Gaseous

In the notebooks record:

1. Brand name and manufacturer.
2. Size of bag (weight) or container.
3. Grade
    - Plant food elements listed
    - Percentage of available nutrients, including micronutrients.
4. Percentage of filler.
5. Acid forming tendency.
6. Application type and methods of application recommended (list all).
7. Descriptions of best use.
8. Safety information.
9. Ask the store manager (and record):
10. Which type of dry and liquid fertilizers are your best sellers? Why?
11. At the greenhouse: did the management utilize gas fertilization?
12. If so, had they compared growth rate success ratios between houses with the gas and houses without? What were their findings?

In class:

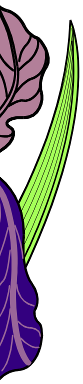
In small group discussion, choose a facilitator, a recorder, a presenter, and reporters. The *facilitator* organizes the flow of the group discussion. Others in the group serve as *reporters*, reporting the group's findings to the recorder. The *recorder* writes down key words, phrases, and findings on the flip chart paper provided by your teacher. The *presenter* presents the group's findings to the entire class, with the use of the flip chart paper displayed for the entire class.



As a group, answer the following questions:

- Compare the information regarding best sales among brands. Were there consistent trends? If so, were the same reasons why they were consistent shared among the group's findings?
- Compare the information regarding use of gas for fertilization in greenhouses. Were the results for this type of fertilization largely in favor of, or not in favor of its use? Why?
- Present your findings to the class.

Notes



Choosing Applications

Considerations Before Fertilizing

- Plant rooting characteristics
- Nutrient demands at different growth stages
- Physical & chemical characteristics of:
    - Soil
    - Fertilizer
- Availability of moisture
- Irrigation system

Information

7. Discuss Methods and Procedures Involved in Collecting a Representative Soil Sample

8. Complete a Soils Test Report Form, and Make Fertilizer Recommendations Using the Test Analysis Data

9. Complete a Soluble Salts Test

10. Calculate Problems Comparing Fertilizer Cost by Comparing Cost per Pound of Nutrients

Soil Tests

Test for pH, phosphorus, potassium, calcium, magnesium, and sulfur.
Soil tests must be representative of the area.
Quantifies potential limitations in fertility and irrigation of a soil..
Indicates nutrient levels in soils.
Used to develop an amendment program.

Amendment Program should include information on:

Plant / crop soil use history.
Potential soil production.
Land management practices.

Tests for soil chemical properties:

Assess the availability of essential elements for plant growth.
Assess chemical properties affecting:

Available nutrients
Plant growth
Physical properties of soils.

Soil tests used on a regular basis:

Monitor production
Measure trends and changes.

Choose the laboratory for submission.

University, private, or industry.
Ideal qualities of labs:

High standards of analysis
Fertilizer and amendment recommendations
Answers to soil fertility problems / low yields
Quick turnaround response times.

Soil Sampling

Field samples:

Divide field into uniform (same soil type) areas.
Assign an identification number.
Record the numbers on a map of the sample areas.
Obtain instructions and information sheets from laboratory.
Use a clean plastic bucket.
Prepare and collect samples, carefully following instructions.
Sample 10 to 20 sites within each uniform area.

Collection Depth:

Surface
Subsoil (for soluble salts and levels of nutrients moving through the root zone)
Deep (for unexpected growth patterns / chemical or physical properties)

Time:

Determined by information needs.

Advance of Planting

(e.g.) Fertilizer needs for annuals

Immediate delineation

(e.g.) Cause of poor plant growth
(e.g.) Evaluating salt / sodium hazards

Keep accurate records of:

Areas sampled.
Fertilizer use.
Amendments.
Pesticide use.
Crop / plant growing area histories.

Problem Areas:

Collect samples from the problem areas and the areas of good plant growth.
Take samples at all depths.
Send to the laboratory with a problem description.

Soils Test Report Form

Fill out the soil test report form completely, answering all questions.
Submit with labeled samples according to field area origin (identification numbers).

Applying the results:

Maintain nutrients at full growth yield levels (High Rating) from germination to maturity to support top growth yields, lower unit production costs, and increase profits.
Soil test “medium” results: bring up nutrient level rates to a high rating and check periodically to maintain fertility.
A balanced fertility program optimizes a crop’s efficient use of soil and water.
Proper recommendations depend on field research relating nutrient soil levels to how a plant responds to a certain nutrient.
Laboratories can determine total nitrogen and organic matter **reserves**.
Nitrogen changes and movement in soil makes assessing nitrogen needs difficult.
Deep sampling (two feet or more) for **annual nitrate-N** gives a better representation.
Depth of sampling varies with crop, climate and soil type.
Soil test regularly to build and maintain at high levels.

Soluble Salts Test

Measure suitability of water for irrigation.
Monitor changes in soil from irrigation.
Salt content of soil.
Sodium status of soil.
Rate of water penetration into soil.
Presence of toxic elements.

Results

Relative tolerance of plants to salt.
Suitability of soil for certain crops.

Presence of Salts

High water table.
Salt water contamination occurence.
Poor quality of irrigation water.

Dissolved salts / sodium determination

Dissociate into electrically charged particles / ions.
Positive / cations (sodium, calcium, magnesium, potassium)
Negative / anions (chlorides, sulfates, bicarbonates, carbonates)
Concentrations reported in:
Ppm (parts per million) for total dissolved solids (1 milligram of salt per kilogram of solution)
Milliequivalents per liter (me / L) measures the chemical equivalent of an ion.

Total salt content

Reported as electrical conductivity (EC).
Measured with an electric conductivity meter.
The more salt in the water, the better the conductivity.
EC is reported as decisiemens per meter (dS / m).
deci - one-tenth

siemen - reciprocal of one ohm (equal to the conductivity of a circuit or an element having the resistance of one ohm).

TDS total dissolved solids (evaporating known weight of water to dryness and weighing the remaining salt).

Multiply EC by 640 = ppm of total dissolved solids (TDS).

Multiply EC by 10 = me / L of total salts.

Electrical conductivity is used to measure the salt content of soils (EC_e), measuring from a saturated soil extract.

Greater than 4 decisiemens per meter (at 25^0C) soil contains appreciable quantities of soluble salts to interfere with plant growth.

Percent sodium

Ratio of sodium to the total cations in milliequivalents.
Soil with large amounts of sodium are associated with clay.
Wet clay is nearly impervious to water.
Dry clay forms hard clods.
Sodic soils form “slick spots” high in exchangeable sodium.

Saline soil

Interferes with plant growth.

Sodic (alkaline) soil

Sodium attaches to clay particles.
Interferes with plant growth.

Non-saline sodic soil

Free of soluble salts.

Saline-sodic soil

Sufficient soluble salts to restrict plant growth.

Salinity

Salt moves in the direction of water.
Accumulation of soluble salts in the root zone.
All plants have a maximum tolerance of salt.

Salinity Reduction

Intentional leaching increased irrigation of growing media / area is needed to remove excess salt from the root zone.

Decreasing salinity of irrigation waters.

Sodium Reduction

Increase calcium by adding gypsum or other soluable calcium salt.

Reduce bicarbonate in the water by adding sulfuric acid, sulfur dioxide, or other acidifying amendment.

Sodium permeability

Soil dispersal or coagulation creating reduced water penetration.

SAR sodium adsorption ratio relative activity of sodium ions as they react to clay.

Value of 10 safe for most nursery soils. Greater than 15 interferes with plant growth.
pH is usually less than 8.5.
SAR adjustment
Measured from saturated soil extract.

Evidence of salt accumulation
Leaf burn.
Salts crystallize around orifices of drip irrigators.
Concentrations on tops of beds, border checks or berms; in containers on top of planting media surface and edges of wetting surface.
Evidence of sodium accumulation
Whitewash on leaves.
Impermeability of soil.

Calculating Fertilizer Costs

Maximizing fertilization with environmentally sound methods:
Best Management Practices
Maximize yields
Increase plant resistance to drought, disease, insects, stress
Lower unit costs
Higher profits

Efficient use of fertilizer
Rapid plant growth produces soil-holding groundcover.
Root systems are healthier, holding soil and absorbing water efficiently.
Plants use nutrients & water more efficiently, increasing residue.
Residue recyles nutrients / organic matter back into soil and increases soil retention.

Fertilizer represents a small percentage of total production costs.
With efficient use, returns are high.
Maximum economic yield (MEY) unit costs at highest net return.
Sets off negatives (unexpected problems) and expands margin of profit.

Cost Calculation
On basis of cost per pound of nutrient.
From information on fertilizer bag:
Divide Price of Fertilizer Per Pound of Material by Guaranteed Percentage.

(E.g.) Fertilizer analysis: 20-10-10 (40%)
Fertilizer cost: $150 per ton or 7.5 cents per pound (to get cents per pound, divide 150 by 2000 [pounds in a ton])

7.5 cents divided by 40 % = $18.75 per pound of nutrient

Calculating costs of materials with only one nutrient.

(E.g.) Fertilizer analysis: 45-0-0 (45%)
Fertilizer cost: $240 per ton or .12 cents per pound
.12) .45 = 26.6 cents per pound

Calculating Fertilizer Application

Information needed:
Amount of nutrient application
Available fertilizers
Method of application.

(E.g.) Amount of nutrient application
40 lbs N per acre
40 lbs P_2O_5 per acre
20 lbs K_2O per acre

Available fertilizers
34-0-0 (ammonium nitrate)
18-46-0 (diammonium phosphate)
0-0-60 (potassium chloride)

Formula:
Amount of nutrient application per acre divided by percentage of nutrient in fertilizer used = Amount of fertilizer application per acre

With single nutrient formulas:

Potash
20) .60 = 33 lbs per acre of 0-0-60

With multiple nutrient formulas:

Phosphate
40) 46 = 87 lbs per acre of 18-46-0

Then: Multiply % of nitrogen supplied by 18-46-0
87 x .18 = 16 lbs N per acre

Subtract pounds of additional nitrogen needed
40 - 16 = 24 lbs N needed
Divide lbs of nitrogen requirements from ammonium nitrate %
24) 34 = 71 lbs per acre of 34-0-0

Total requirements:

87 lbs per acre of 18-46-0
71 lbs per acre of 34-0-0
<u>33 lbs per acre of 0-0-60</u>
191 lbs per acre total

References

1. Idaho State Division of Vocational Education. (1991). *Agricultural Science and Technology 510 Botany / Plant and Soil Science*. Moscow, ID: Author.
2. Soil Improvement Committee California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.

Student Activity

- **Interpreting a Soil Survey Map**

Student Labs

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 B - Soil Fertility*:

- **Soil Fertility Assignment Sheet #1**
- **Soil Fertility Assignment Sheet #2**
- **Soil Fertility Assignment Sheet #3**
- **Soil Fertility Assignment Sheet #4**
- **Soil Fertility Assignment Sheet #5**

Internet Resources

Locating Your Land Holdings in the Soil Survey Report
http://hammock.ifas.ufl.edu/txt/fairs/16451

THE SOIL ORDERS
http://atlantic.evsc.virginia.edu/~alm7d/soils/ids.html

USDA-NRCS Northwest Regional Management Office (MO)
http://www.or.nrcs.usda.gov/soil/mlra.html

Transparencies

- **SAR**

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 B - Soil Fertility*:

- **Soil Sampling (A,B,C,D,E,F,G,&H)**
- **Soil Sampling: Number Each Sample and Record Its Origin**
- **Soil Sample Bag**
- **Soil Test Request and Report Form**
- **Compare Cost of Per Pound of Nutrient**
- **Calculate Amount of Fertilizer to Apply**

7-8-9-10. Student Activity: Interpreting a Soil Survey Map

Purpose

- Understand how soil survey maps are helpful indicators of soil productivity.
- Interpret a soil survey map.

Information

Soil survey maps provide:

Summary of major soil types in a set area.
Aerial photographs of areas to scale.
Major soils identified and mapped with boundary lines.
Summary of land uses and limitations.

Materials Needed

- County or regional soil survey map
- Notebook

Procedure

- Choose a property in your area that you wish to research with the soil survey map.
- Locate the property on the soil survey map.
- With the information provided, identify the soil types on the property.
  (Write out the code and refer to the index for the soil description.)
- Record your findings in the notebook.

Additional information may be found on the Internet (see *USDA - NRCS Northwest Regional Management Office [MO]* under "Internet" on your information sheet for this section).

Q&A

(*Record your answers in your notebook . . .*)

- **What are the land use recommendations for the area? . . . the limitations?**
- **What are the apparent plant growth environment problems associated with this type of soil (if any . . .)?**
- **In general, what type of nutrient amendments would this soil normally require?**

dium Adsorption Ratio

s the relative activity of sodium ions react with clay.

$$\frac{Na}{\sqrt{(Ca + Mg) / 2}}$$

Proportion of sodium on the clay fraction of soil.

$$\frac{Na}{\sqrt{(Ca + Mg) / 2}} \quad [1 + (8.4 - pHc)]$$

Added effects of precipitation and calcium solution in soils.

R is a good index of sodium d permeability problems.

Ag 514 B - Soil Fertility
Unit Test

1. The four sources of Plant Nutrients are

____ _______________________________________

____ _______________________________________

2. ______________ and _______________ are two of the factors that influence the use of fertilizers.

Multiple choice

3. Micronutrients

   a. must be present in large amounts.
   b. are the most important nutrients for plant growth.
   c. are essential but only needed in small amounts.
   d. must be present in moderate amounts.

4. Which of these is NOT a primary nutrient?

   a. Calcium
   b. Nitrogen
   c. Phosphorus
   d. Potassium

5. In a fertilizer analysis, the fertilizer ratio 16-4-8 would indicate

   a. the pH levels of the active and inert ingredients in an elemental fertilizer.
   b. a 16%-4%-8% ratio of active ingredients in a fertilizer composition.
   c. a solubility factor of 4 parts aqua ammonia to 8 parts water in 16 liters of water.
   d. the pressure required to distribute 16 gallons of a 4:8 saturated fertilizer solution.

Match the Primary, Secondary or Micronutrient deficiency with its subsequent characteristics.

____ 6. Nitrogen
____ 7. Phosphorus
____ 8. Potassium
____ 9. Sulfur
____ 10. Magnesium
____ 11. Iron
____ 12. Boron

A. Upward curling of leaves along margins
B. Chlorosis in older leaves
C. Soft spots on fruit in tubers
D. Mottling of young leaves
E. Susceptibility to cold
F. Retarded growth rates of plants

G. Burns or scorching around leaf margins, especially in older leaves

True or False

____ 13. Soil tests are used on a regular basis to measure trends and changes.

____ 14. Submitting a soil sample with a soil test is not required if the soil test form is completed and submitted.

____ 15. Fertilizer represents a moderate to high percentage of total production costs.

____ 16. In the cost calculation of fertilizer, the Price of Fertilizer Per Pound of Material is divided by the Guaranteed Percentage.

In what order should these Soil Sampling steps go?

____ 17. Fill out the soil test report completely, answering all questions.

____ 18. Divide field into uniform (same soil types) areas.

____ 19. Obtain instructions and information sheets from laboratory.

____ 20. Assign an identification number to each sample area.

____ 21. Submit test form with labeled samples according to field are origin.

____ 22. Prepare and collect samples, carefully following instructions.

____ 23. Record the numbers on a map of the sample areas.

Ag 514 B - Soil Fertility
Unit Test
Answer Key

1. The four sources of Plant Nutrients are

____ ____

Answers: Water, Light, Air, Soil

2. ______________ and _______________ are two of the factors that influence the use of fertilizers.

Answers can include:
Rooting characteristics
Nutrient Demands of plants
Physical and chemical characteristics of the soil and the fertilizer applied
Soil moisture
Irrigation system type

Multiple choice

3. Micronutrients

   a. must be present in large amounts.
   b. are the most important nutrients for plant growth.
   c. **are essential but only needed in small amounts.**
   d. must be present in moderate amounts.

4. Which of these is NOT a primary nutrient?

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   c. Phosphorus
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   b. **a 16%-4%-8% ratio of active ingredients in a fertilizer composition.**
   c. a solubility factor of 4 parts aqua ammonia to 8 parts water in 16 liters of water.
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__B__ 6. Nitrogen
__E__ 7. Phosphorus
__G__ 8. Potassium
__F__ 9. Sulfur
__A__ 10. Magnesium
__D__ 11. Iron
__C__ 12. Boron

A. Upward curling of leaves along margins
B. Chlorosis in older leaves
C. Soft spots on fruit in tubers
D. Mottling of young leaves
E. Susceptibility to cold
F. Retarded growth rates of plants
G. Burns or scorching around leaf margins, especially in older leaves

True or False

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__F__ 14. Submitting a soil sample with a soil test is not required if the soil test form is completed and submitted.
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__T__ 16. In the cost calculation of fertilizer, the Price of Fertilizer Per Pound of Material is divided by the Guaranteed Percentage.

In what order should these Soil Sampling steps go?

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__1__ 18. Divide field into uniform (same soil types) areas.

__4__ 19. Obtain instructions and information sheets from laboratory.

__2__ 20. Assign an identification number to each sample area.

__7__ 21. Submit test form with labeled samples according to field are origin.

__5__ 22. Prepare and collect samples, carefully following instructions.

__3__ 23. Record the numbers on a map of the sample areas.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 C - Organic Matter and Fertilizers

Unit Objectives

1. Match terms and definitions associated with organic matter.
2. List sources of soil organic matter.
3. List the importance of organic matter to plant production.
4. Describe how organic matter is produced.
5. List the factors affecting the rate of organic matter decomposition.
6. Identify how soil temperature, aeration, moisture, and reactions affect the biology of soil and the rate of decomposition.
7. List the basic ways in which nutrients obtained from organic matter affect the soil.
8. Identify the factors that cause the loss of organic matter from soil.
9. Name the types of organic matter which can be applied to soil.
10. List the types of manure that can be produced.
11. List the functions of growing a crop to produce organic matter.
12. List the purposes of mulching.
13. Select the organic and inorganic mulches that are available.
14. Select the factors to consider when choosing mulching material.
15. List the four physical properties of soil.
16. Identify soil particles according to size, and discuss what methods are used to determine soil texture.

17. Discuss the functions of soil related to plant growth, development and maintenance.

18. Discuss how acidity and alkalinity effect the soil and methods of correcting pH problems.

19. Identify the advantages and disadvantages of using actual soil versus potting soil.

20. Match terms and definitions associated with organic fertilizers.

21. List the disadvantages of organic fertilizers.

22. Select other sources of organic fertilizers.

23. Discuss the value of humus and organic fertilizers to soil fertility and plant growth.

24. Demonstrate the ability to construct a compost pile.

Information

1. Match Terms and Definitions Associated with Organic Matter

2. List Sources of Soil Organic Matter

3. List the Importance of Organic Matter to Plant Production

Organic Matter

- Decayed or decaying remains of plants and animals.
  - (E.g.) leaves, bark, manure.
- Soil organisms
- Substances used by soil organisms.
- Microbial bacteria

Nutrients released for plant growth depend upon:

- **Temperature** (macro and micro environment)
- **Moisture**
- **Aeration**
- **Soil pH**
- **Microbial population of soil**
- **Quantity of plant residues**
- **Chemical nature of plants returned to soil**

Chemical Composition of Soil Organic Matter

Sources of food for microorganisms:

- **Polysaccharides**
  - Cellulose
  - Hemicelluloses
  - Sugars
  - Starches
  - Pectin
- **Lignins**
  - Woody plant materials
- **Proteins**
  - Contain nitrogen
- **Fats**
- **Waxes**

Decomposition is aided by:

Bacteria
Fungi
Actinomycetes (mycelium-forming bacteria)
Earthworms and insects
Ingest organic residue and soil, passing it through their bodies and generating castings which bind soil.
Transport microbes, distributing them throughout the soil.

Humus
Final product of decomposition.

Importance of Organic Matter to Plant Production
Improves:
Aeration
Water infiltration
Drainage
Soil structure opens up tight pore spaces in soil.
Soil moisture-holding capacity.
Provides:
Negatively-charged colloids.
Holds and exchanges:
Nutrient cations.
Stabilizes:
pH of soil
Soil micronutrient availability.
High in nutrient value.

Organic Matter as Energy
Soil organisms require organic matter.
Ammonia produced as by-product of soil organisms is nitrified by microbial bacteria.

Soil microbes Versus Plants
Both require nitrogen.
Microbes can rob availability of nitrogen to plants if insufficient nitrogen exists in soil.
Maintaining balance is essential for plant growth.

References

1. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
2. Ortho Books. (1989). *Gardening in Dry Climates*. San Ramon, CA: Author.
3. California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.

4. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.

Student Activities

- **Writing the Researcher**

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley (p.77):

- **Living in the Soil**

Internet Resources

Soil Organic Matter
http://res.agr.ca/ecorc/program3/pub/status/soilom.htm

Benefits of Adding Organic Matter
http://hammock.ifas.ufl.edu/txt/fairs/29671

Walz, J.Y., Ph.D. The Effect of Natural Organic Matter Between Colloidal Particles.
http://www.mcl.tulane.edu/cbr/DoD_Projects/Walz_home.html

Transparency

- **The Carbon Cycle**

1-2-3. Student Activity: Writing the Researcher

Purpose

- Understand the contribution of organic matter to soil.
- Understand how research generates questions as much as answers.
- Discover how writing generates active thought and learning.

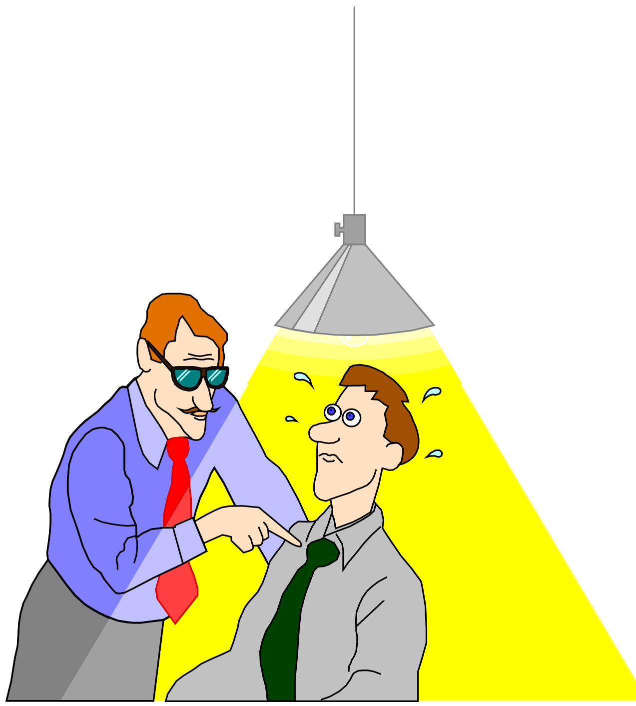
Procedure

- Use the internet to research current studies on organic matter in soil (one research project is listed under Internet Resources for this section).
- After reading the research project description and/or results, generate and write questions to researchers about their research.

    Include in your questioning strategy:

    ⇒ Any curiousity you have about how the researchers arrived at their decisions to study (fill in the blank).

    ⇒ Play the devil's advocate with the researchers. Ask them, "What if?" questions related to the results of their studies.



- Write a brief report detailing your questioning strategy and results. Cite your internet sources.
- Present your questions and responses to the class, choose one project response, and add what you would have studied if the project had been your own.

    Include:

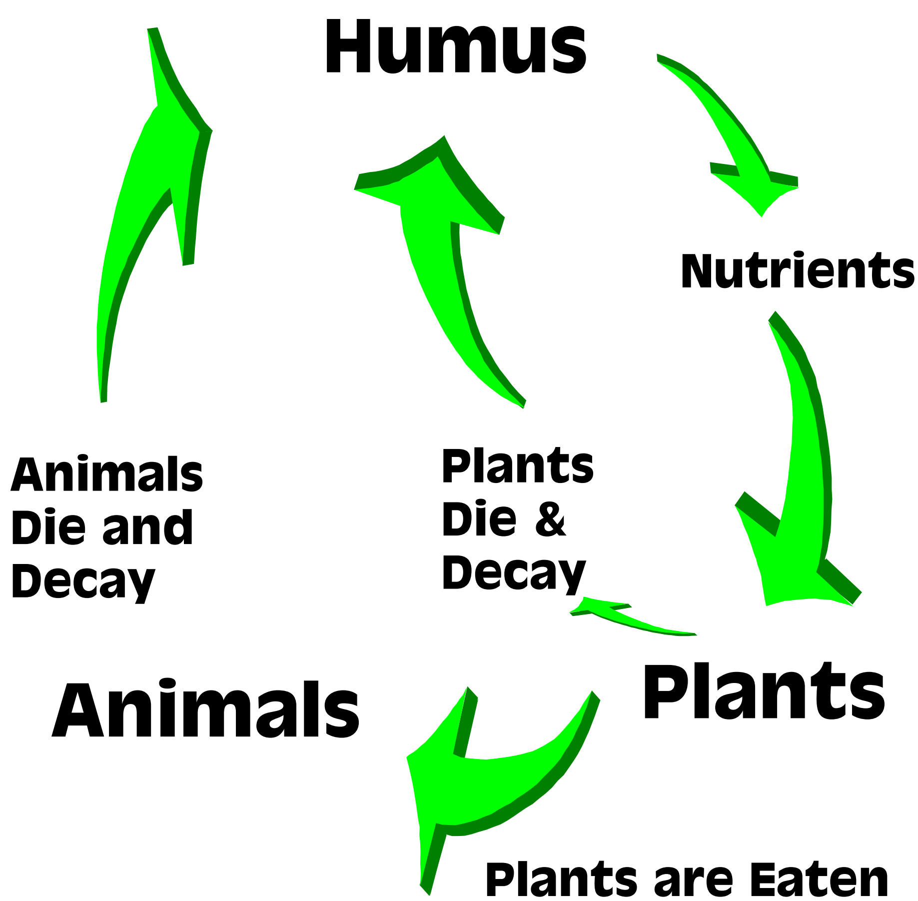
    ⇒ Attempt to resolve the problem in a different way.

    ⇒ What would you hypothesize for your results?

    ⇒ Invite the class to debate your hypothesis.

Notes

The Carbon Cycle



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Information

4. Describe How Organic Matter is Produced

5. List the Factors Affecting the Rate of Organic Matter Decomposition

6. Identify How Soil Temperature, Aeration, Moisture, and Reactions Affect the Biology of Soil and the Rate of Decomposition

Organic matter is produced in three steps:

- **Degradation**
- **Conversion**
- **Curing**

Degradation

Organic materials are broken down by the process of :

- Microorganisms consuming proteins and carbohydrates.
- Microorganisms feed and multiply.
- Create heat energy.
- Release water and carbon dioxide.
- Microorganisms reach dormancy or consummation by other microorganisms.
- Soil temperature rises.

Conversion

- Soil temperature drops.
- Microorganisms tolerant of lower temperatures complete the degradation process.
- Microbes will consume soil nitrogen to the point of plant deprivation.

Curing

- Microbial activity slows.
- Soil temperature cools.
- Larger invertebrates consume, move, and excrete throughout the soil.

Factors Affecting Rate of Organic Matter Decomposition

The Activity of Organisms

Utilization by organisms of carbon and nitrogen.

- Carbon for energy.
- Nitrogen for growth and reproduction.

Undigested remains are humus.

Feeding Patterns (the decomposition food chain)

Digestion excrement of one organism becomes food for another.
Organic material undergoes progressive, continuous digestion-produced decomposition.
End product is humus.

Decomposition rate is directly proportional to the numbers of organisms present in the soil.

Microbe population increases as food is available.
Greater numbers of microbes more rapidly break down organic matter.
Ratio of carbon and nitrogen materials available is important to the rate of decomposition.

Carbon

Dried leaves
Grass straw
Wood chips / bark
The ratio of carbon to nitrogen in humus is about 15 to 1.
Organisms need the proper ratio to break down materials.
Too much carbon takes more time to generate a population large enough to consume materials.

Nitrogen

Animal manure
“Green” plant materials
Nitrogen balances carbon.
Heat generated from microbial activity speeds up the process of decomposition.
Without enough nitrogen decomposition slows and the soil temperature cools.

Air

Oxygen is needed for organisms to live and reproduce.
Feed on surfaces with air contact.
Smaller particles allow more air contact.
Anaerobic conditions allow decomposition but very slowly.
Different bacteria work in anaerobic conditions.

Moisture

Balance of moisture important.
Too little moisture - slows decomposition.
Too much moisture - floods air spaces - creates smell due to forced air out.
(i.e., wetland muck)
Ideal ratio: 40 to 60 percent moisture (damp).

Bacteria Do the Work

Three main types:

Psycrophiles

Prefer cool soil temperatures (to 28^{0}F).

Digest carbon.
Generate heat.

Mesophiles

Digest carbon.
Prefer 60^0 to 70^0F.
Can raise temperature over 100^0F.

Thermophiles

Work above 100^0F.
Temperature kills pathogens and seeds.
Prefer 131^0 to 140^0F.
Above 160^0F kills thermophiles and other beneficial organisms.
Eventually soil cools and mesophiles decompose remaining organic material.

Actinomycetes

Transitional between bacteria and fungi.
Microorganisms break down organic matter in the latter half of decomposition.
Reduce lignin and more resistant materials.
Secrete digestive enzymes which help decompose cellulose, protein, and starch.

Fungi

Break down cellulose and lignin (resistant woody parts).

Large Invertebrates

As they feed, break raw materials into smaller pieces.
Make materials easier for microorganisms to process.
Distribute microorganisms by transport microorganisms from one site to another.
Excrete organic material.
Move to outer surface of soil when temperature rises by microbial activity.
Return when soil cools.

Soil Food Web:

Mites & springtails eat fungi.
Nematodes eat bacteria.
Pseudoscorpions eat mites, springtails, and nematodes.
Pseudoscorpions eaten by other invertebrates.
Beetles, millipedes, sowbugs, slugs, and snails eat plant tissue.

References

1. California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.
2. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
3. Ortho Books. (1992). *Easy Composting*. San Ramon, CA: Author.
4. University of Wisconsin-Madison. (1993). *Bottle Biology*. Dubuque, IA: Kendall / Hunt.

Student Activities

From *Bottle Biology*, Kendall / Hunt (p. 33):
- **Soil Meditations**

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley (p. 69)
- **Space Travelers**

Internet Resource

Cornell Composting Science & Engineering
Invertebrates of the Compost Pile
http://www.cfe.cornell.edu/compost/invertebrates.html

Transparencies

- **Breakdown: the Soil Organisms**
- **Microorganisms and the Rate of Decomposition**

Breakdown: The Soil Organisms

The Microorganisms

Chemical Breakdown:
Bacteria
Fungi
Actinomycetes

The Larger Invertebrates

Feed, Move and Transport, Excrete

(e.g.)

Earthworms
Centipedes
Mites
Nematodes
Pseudoscorpions
Rove beetles
Sowbugs
Springtails
Symphylans

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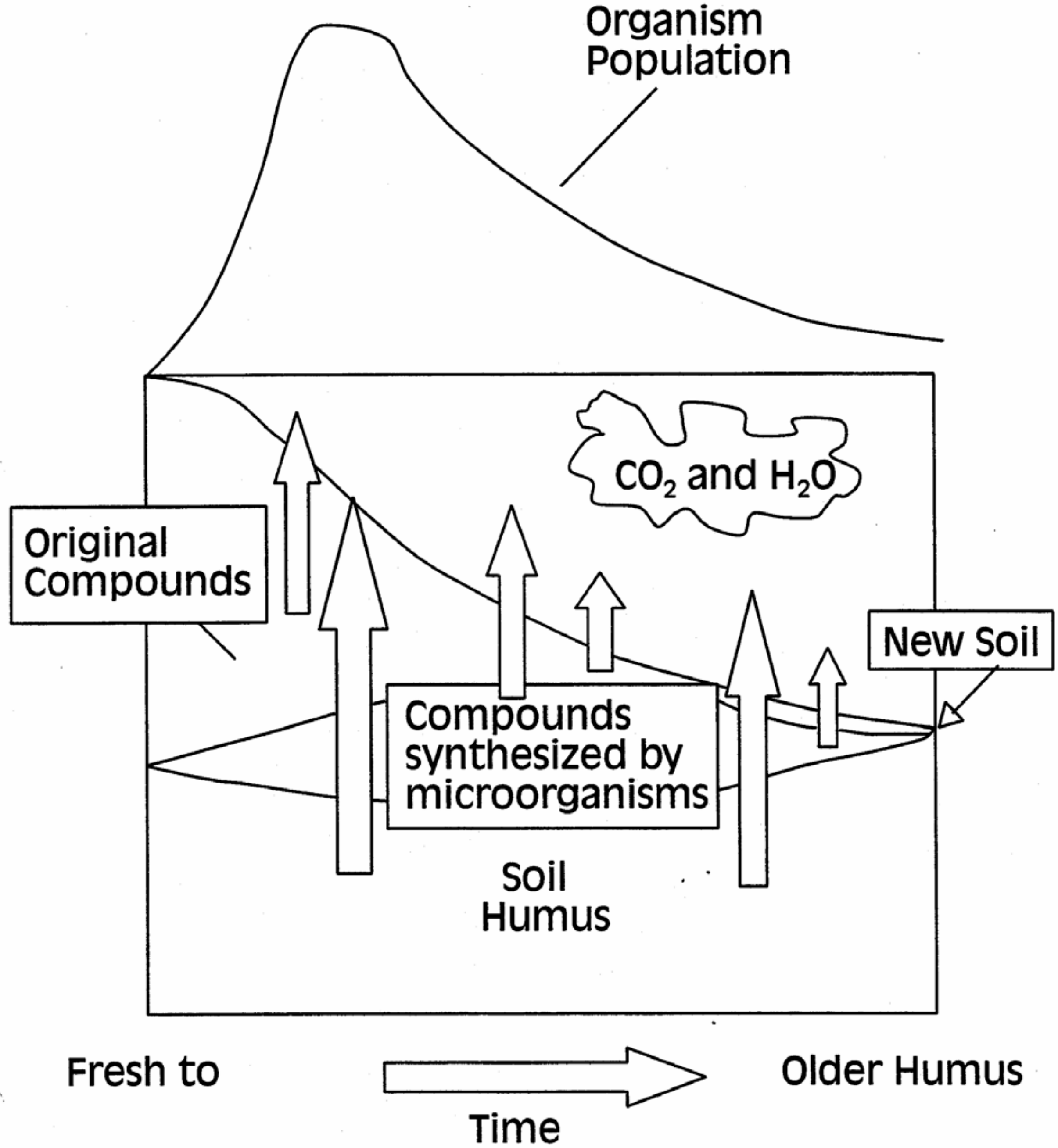
Microorganisms and the Rate of Decomposition



TM.514.C5

Information

7. List the Basic Ways in Which Nutrients Obtained from Organic Matter Affect the Soil

8. Identify the Factors that Cause the Loss of Organic Matter from Soil

9. Name the Types of Organic Matter Which Can be Applied to Soil

10. List the Types of Manures that Can be Produced

11. List the Functions of Growing a Crop to Produce Organic Matter

Benefits of Organic Matter to Soil

Physical properties of soil are improved.
- Better pore structure / drains efficiently, yet holds air and soil moisture.
- Clay, silt, and sandy soils become more like loam.

Addition of microorganisms to soil:
- Decompose organic matter in soil.
- Convert nitrogen, phosphorus, potassium, calcium, and micronutrients into soluable forms for plants to absorb.
- Addition of nitrogen-fixing bacteria.
- Manufacture antibiotics that protect plants from disease.

Contribution of nutrients:
- Carbon/nitrogen ratio depends on source of raw materials.
- Slower, long-term release of nutrients.
- Organic matter is food source for existing soil microorganisms.
- Acids formed as a by-product of decomposition help break down rock particles in soil, releasing more nutrients to plants.

Balanced soil chemistry
- Avoids extremes of alkalinity or acidity.
- Increases buffering capacity - ability to resist change in pH.
- Bonds micronutrients:
  - Iron, zinc, copper, manganese made available to plants.

Moderates soil temperature

Microbial activity stimulates warmer soil for better seed germination in spring.
Cooler summer temperatures due to increased aeration and moisture-holding capacity.
Maintains more ideal soil temperature for plant growth: 65^0 to 85^0F.

Influences plant health

Consistent supply of water, air, and nutrients results in uniform root growth.
Larger population of beneficial soil microorganisms control harmful microorganisms.
Healthier plants are more pest-resistant (weaker plants are more subject to predation).
Controls harmful soil fungal growth with larger populations of beneficial soil bacteria and fungi.
Toxicity of decomposed leaf compounds to harmful organisms (i.e., decomposed pine needles kill nematodes).

Loss of Organic Matter in Soil

Vegetation removal

Erosion

Leaching due to soil texture.

Sandy soils lose more water and oxidize the rest.

Adsorption by plants.

Rate of Organic Decay

Most organic materials entering the soil carry large amounts of carbon and small amounts of nitrogen.
Competition for available nitrogen is high between soil microbes and plants.
Microbial activity to break down influx of carbon requires nitrogen to build their energy level.

Nitrate depression:

Reduced nitrogen availability to plants when microbial activity is high during carbon breakdown.
Nitrification picks up when carbon dioxide formation is reduced from reduction in microbial activity.

Stabilization:

At bottom of cycle nitrogen is available to plants.

Managing the carbon/nitrogen ratio is therefore very important to amending soils with organic matter.

Figuring the Organic matter to nitrogen ratio:

Organic matter content is 1.7 times the carbon content in soil.
If a carbon to nitrogen ratio of 11.7 to 1 is assumed,
Then the organic matter to nitrogen ratio is 11.7 X 1.7 = 20:1

Temperature and rainfall

Warm climates accelerate decay and the disappearance of organic material.
Increasing moisture favors nitrogen and building organic matter.
A balance, therefore, is reached where the average annual temperature is cooler and moisture is uniform.

Vegetation Type

Vegetation higher in nitrogen-fixing ability (legumes) increase nitrogen in soil.
Grasses cycle faster, regenerating soil organic matter more efficiently than a forest cover.

Types of Organic Matter Which Can be Applied to Soil

Sod and green manure
Animal manure
Compost
Piling up kitchen**,** garden, and yard waste and permitting them to decompose from six weeks to six months, depending upon temperature, moisture, and material size.
Some farm manures are better composted before application.
Organic amendments
Bark or sawdust
Peat moss
Need to supplement with nitrogen.
Sawdust lowers pH / need to supplement with lime in acid soils.
Bark and sawdust
Used as mulch.
Mixed with soil to improve aeration and drainage.
Peat moss
Used in container production as propagation medium or to improve aeration and drainage.

Types of Manure

Green manure
Improves soil structure.
Increases fertility by addition of organic matter.
Reduces weed populations.
Grasses in combination with legumes excellent for improving nursery soils.
Animal manures
Source of slow-release nutrients.
Stable manure has low concentrations of plant nutrients.
Must apply at high rates or frequently.
Application in late winter and cultivated into soil in spring.
Weeds are a problem.

Poultry manure is higher in nitrogen but decays rapidly, releasing ammonia and causing plant injury.
Both manure types are best by composting prior to use.

Functions of Crops Producing Organic Matter (Green Manure)

Grasses
Supply organic matter.
Root soil.
Cycle quickly.
Legumes
Improve drainage.
Fix nitrogen.
Green manure types:
Annual ryegrass
Alfalfa
Field corn
Foxtail millet
Soybeans
Sorghum
Sudan grass
Sudan-sorghum hybrids
Wheat over-seeded with clover.

References

1. Brady, N.C. (1974). *The Nature and Properties of Soils* (8^{th} ed.). New York: Macmillan.
2. Davidson, H. & Mecklenburg, R. (1981). *Nursery Management: Administration and Culture*. Englewood Cliffs, NJ: Prentice-Hall.
3. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
4. Ortho Books. (1992). *Easy Composting.* San Ramon, CA: Author.
5. University of Wisconsin-Madison. (1993). *Bottle Biology*. Dubuque, IA: Kendall / Hunt.

Student Activity

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley:
- **The Matchmaker** (p. 93)

Student Labs

From *Bottle Biology*, Kendall / Hunt:
- **Decomposition Column** (p. 11)

- **Rot Race: A Decomposition Experiment** (p. 15)
- **What Is All That Rot?** (p. 16)

Internet Resources

Soil Organic Matter
http://hammock.ifas.ufl.edu/txt/fairs/17729

Organic Matter
http://hamock.ifas.ufl.edu/txt/fairs/177553

Watersheds Organic Matter
http://h2osparc.wq.ncsu.edu/info/norganics.html

Transparencies

- **Temperature / Moisture Effects on Organic Matter**

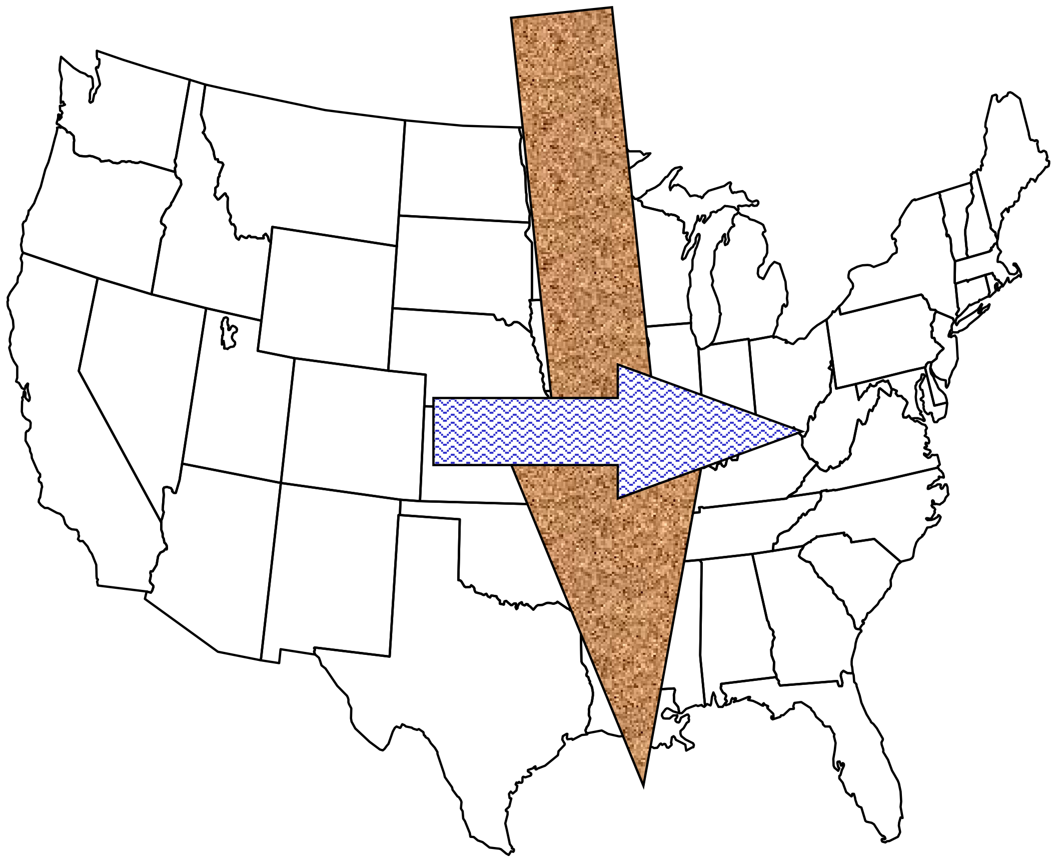
From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 A - Elementary Study of Soils*:

- **Soil Profile**

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 B - Soil Fertility*:

- **Nutrient Sources**

As the average temperature increases, soil organic matter decreases due to increased decay rates.



As the average moisture level increases, soil organic matter increases due to better growth.

Information

12. List the Purposes of Mulching

🕮

13. Select the Organic and Inorganic Mulches that Are Available

🕮

14. Select the Factors to Consider when Choosing Mulching Material

Purpose of Mulching

- Retain soil moisture by reducing runoff:
  - Protect against sheet erosion, gullies, and rills.
  - Protect against seed & fertilizer displacement.
- Allow more moisture absorption by soil.
- Reduce soil moisture loss by preventing evaporation.
- Keep soil cool.
- Protect roots from heat, cold, or drought.
- Keep fruit clean.
- Allow earlier planting.
- Protect seeds during germination.
- Allow plant establishment.
- Weed control.

Organic and Inorganic Mulches

Organic

From living material (i.e.):

- Tree bark
- Pine needles
- Rice hulls
- Peat moss
- Wood chips
- Corn cobs
- Coco bean hulls
- Straw
- Sawdust
- Manure
- Chopped leaves

Stubble (keep refuse of previous crop in field)
Grass clippings
Seaweed (rinse first)

Inorganic

From non-living material (i.e.):

Gravel
Crushed stone
Sand
Brick chips
Paper (not considered organic as a mulch)
Plastic

Paper and plastic mulches are used in truck and vegetable gardens and pineapple growing for row culture.

High in cost but very effective in:

Control of weeds
Conserving moisture
Encouraging rapid growth
Eliminating need for cultivation.

Factors to Consider when Choosing Mulching Material

Organic

Regional availability.
Decay quickly in the landscape.
Require a yearly top dressing for aesthetics and due to decay.

Inorganic

More permanent.
Seldom require top dressing.
Wide variety of materials generally available.

Some mulches should be used with caution.

Juglone - walnut leaves / highly toxic to plants.
Phenols - maple leaves / inhibit root growth.
Acidic - pine needles / good for acid-loving plants / not for neutral or alkaline situations / control soil fungi (i.e. fusarium).

Leaves which should be composted first for use in general conditions:

Acacia
California bay
Camphor
Cypress
Eucalyptus
Madrone
Oak
Pine
Pittosporum
Red cedar

Walnut

Mulch thickness

Inorganic:

More than 4 inches thick can smother soil (restricts oxygen).

Organic:

Leaves break down fast / start with 6 to 8 inch layer / breaks down to 2 to 4 inches.

Wood chips break down slowly / start with 2 to 3 inches.

Spread mulch on moist (but not saturated) soil.

When to mulch:

Fall

Garden beds.

Around trees and shrubs.

Work previous year's mulch into soil.

Spring

Remove mulch to warm soil.

Replace mulch when plants are established.

Leave mulch around trees and shrubs.

Add mulch

When top dressing thins.

Mulch Problems

Cold soil into spring.

Remove to warm up.

Instability

Siting mulch on slopes or windy areas.

Use heavier materials.

Mice

Keep organic mulch two inches from trunks of trees and shrubs.

Put down after ground freezes.

Slugs and snails

Prefer wood chips and bark.

Use pest control measures.

References

1. Brady, N.C. (1974). *The Nature and Properties of Soils* (8th ed.). New York: Macmillan.
2. California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.
3. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
4. Ortho Books. (1992). *Easy Composting*. San Ramon, CA: Author.

5. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activities

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley:

- **What's to Worry?** (p. 96)
- **Splash** (p. 99)
- **A Day at the Races** (p. 101)

Internet Resources

NebGuide
Cooperative Extension, Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
http://ianrwww.unl.edu/ianr/pubs/extnpubs/hort/95-1257.htm

Various Mulches Available
http://aggie-horticulture.tamu.edu/plantanswers/earthkind/ekgarden20.html

Protecting Trees from Winter Injury
NDSU Extension Service Horticulturists
http://ndsuext.nodak.edu/extnews/askext/treeshr/1416.htm

Transparencies

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 C - Soil Conservation*:

- **Soil Detachment by Raindrops**
- **Water Erosion**
- **Erosion Caused by Running Water**
- **Factors Influencing Soil Erosion**

Information

15. List the Four Physical Properties of Soil

16. Identify Soil Particles According to Size, and Discuss What Methods Are Used to Determine Soil Texture

17. Discuss the Functions of Soil Related to Plant Growth, Development, and Maintenance

18. Discuss How Acidity and Alkalinity Effect the Soil and Methods of Correcting pH Problems

19. Identify the Advantages and Disadvantages of Using Actual Soil Versus Potting Soil

The Four Physical Properties of Soil

- **Air**
- **Water**
  - **Available capillary water**
    - **Water held around soil particles in pore spaces available for plants.**
    - **Clay particles provide the surface area for clinging water.**
  - **Gravitational water** (downward motion);
  - **Free-moving** (moves in all directions);
  - **Unavailable capillary** (can only be moved as vapor).
- **Minerals**
  - Sand
  - Silt
  - Clay
- **Organic Material**
  - Decayed remains of plants and animals.

Combined in varying amounts in different types of soils.
Variety of moisture levels in soils.

Soil Particles According to Size

Sand

Largest mineral particles.
Soils more than 85% sand are classified as sand.
Sand assists soil drainage.
Too much sand may not hold enough moisture for plant growth.

Silt

Particles smaller than sand.
Formed by water and other action that breaks minerals down.
River bottomland (the land along the watercourse of a river valley) is high in silt deposits due to overflowing waters.

Clay

Smallest-sized particles.
At least 30% clay.
Fill spaces between sand and silt particles.
Holds water; keeps soil moist.
Slow drying, forming a hard, compact surface known as hardpan.
Hardpan is not good for plant growth.
Restricts root growth and moisture adsorption.

Loam

Particles of intermediate size.
Equal parts sand, silt, and clay.
If more sand, sandy loam.
If more silt, silty loam.
If more clay, clayey loam.
Usually contains high amounts of organic matter.
Loam is excellent soil for plant growth.

Methods Used to Determine Soil Texture

Soil texture

Determined by proportions of sand, silt, and clay present in soil (mechanical analysis).

Determination by feel:

- Loose, large particles, and crumbly - sandy
- Wet, ribbonlike - clayey
- Moist, clingy, finer particles than sand - silty
- Holds together when squeezed yet breaks apart easily - loam

Determination by color (lighter colors generally sandy; darker brown colors more toward loam; grey - clay).

Determination of organic content.

Soil triangle

Method of classifying soil on the basis of mineral content / texture.

Twelve textural classes:

1. Clay
2. Sandy clay
3. Silty clay
4. Clay loam
5. Silty clay loam
6. Sandy clay loam
7. Loam
8. Sandy loam
9. Loamy sand
10. Sand
11. Silt loam
12. Silt

Exchange capacity

Ability to hold plant nutrients.

Related to amount & kind of clay in soil.

Water-holding capacity

Determined by particle size distribution.

Fine-textured soil holds more water than coarse-textured soil.

More compact.

Slower movement of air and water throughout.

Difficult to "work" soil.

Soil structure and organic matter

Four primary types / shape and arrangement of aggregates:

Plate-like or platy

Particles arranged on a horizontal plane

Puddling or pond-like

Prism-like / prismatic / columnar

Particles arranged around a vertical line

Bounded by flat, vertical surfaces

Arid

Block-like / angular blocky / subangular blocky

Equal lengths of all three dimensions

Humid

Spheroidal / granular / crumb

Rounded aggregates

High content of organic matter

Formed by decomposition of organic matter - stable.

Formed by physical forces of freezing, thawing, drying - unstable / decompose rapidly.

Functions of Soil Related to Plant Growth, Development, and Maintenance

Moisture - availability to plant by soil / nitrogen-fixing ability / moisture-fixing ability.

Aeration - pore space allows air to flow in and out; release of carbon dioxide.
Heat transfer - warming and cooling to maintain moisture balance and good germination conditions.
Impeding or promoting root growth - too much clay in soil can impede root growth by reducing pore space; little or no clay reduces nitrogen-fixing ability of soil and moisture bind necessary for root adsorption.

Acidity and Alkalinity Effects on Soil

The relative concentrations of hydrogen ions (H^+) and hydroxyl ions (OH^-) in the soil solution indicate **the range of active acidity in the soil solution** as measured in **pH values**.

pH Values Can Indicate:

Acid soil
With a higher concentration of hydrogen ions.
Alkaline soil
With a higher concentration of hydroxyl ions.
Neutral soil
The two kinds of ions (H^+ and OH^-) are present in equal amounts.

Soil Reaction to Ph and Methods of Correcting Ph Problems

Nutrient availability
Varies at different pH levels.
Primary nutrient maximum availability is between 6.5-7.5 with a high availability of other nutrients.
High alkalinity can affect nutrient availability. **Sulfur is added to lower pH.**
Use of nitrogen fertilizers contributes to **soil acidity.**
Improves nutrient uptake in high pH soils (overly alkaline) but decreases nutrient uptake in low pH soils.
Hence, the necessity for **soil testing.**

Solubility of toxic substances
Cations removed from soil by leaching are replaced with acid-forming hydrogen & aluminum which is toxic to plants.
Liming the soil - calcium carbonate acts as a **buffering agent** to acidification.

Root cell pH must be in the correct range for the plant to insure good uptake ability of soil solution-held nutrients and water
Cation exchange capacity of soil
Is the measure of the quantity of cations that can be adsorbed or held by a soil.
Clay particles and organic matter
Carry a net negative charge.

Cations (positively charged) are attracted to and held by clay and organic matter.

Calcium, magnesium, potassium, ammonium are cations essential to plant growth.

Sodium and hydrogen are cations affecting nutrient and moisture availability to plants.

Highly acid soils have a high percentage of adsorbed hydrogen.

Neutral or favorable pH (6.0 to 8.0 range) is predominant in calcium ions.

Sodium ions - resist water.

Calcium ions - favor water.

Adjusting pH for cation exchange capacity:

Mineral soils with a high exchange capacity are more fertile; they resist loss of plant nutrients by leaching.

Soil microorganisms

Bacteria, fungi, actinomycetes, and algae

- Effect fertility level of soil.
- Decompose organic material.
- Fix nitrogen from the atmosphere.
- Release nutrients to plants.

Heterotrophic bacteria

Decomposers

Autotrophic bacteria

Obtain energy from the oxidation of minerals.

Nitrification - oxidation of ammonium to nitrate nitrogen - provides nitrogen for plant growth.

Convert atmospheric nitrogen into useful forms.

Nodule bacteria (rhizobia)

Live in conjunction with roots of legumes.

Derive energy from carbohydrates of host plants.

Fix nitrogen from soil atmosphere.

Free-living bacteria (azotobacter and clostridium)

Fix atmospheric nitrogen.

Biological activity is favored at near or neutral pH, with good soil aggregation and structure.

Advantages and Disadvantages of Using Actual Soil Versus Potting Soil

Potting Soil

Advantages:

Combined with organic material (bark, peat moss, leaf mold, compost) and mineral matter (soil, sand, perlite, vermiculite) mixed in desired proportions produce best porosity, drainage, and moisture retention.

Sterilization lessens the danger from soilborne disease.

Disadvantages:
When soilless, dry out fast.
Need frequent fertilization.
Leach from frequent watering.

Soil

Advantages:
Soils high in organic matter release nutrients slowly to plants.
Have good water-holding capacity.
Good aeration.
Good source of nitrogen.
Disadvantages:
Soils not high in organic matter do not have complete availability of nutrients.
May need pH adjustments per soil and plant type.
May need additional fertilization and organic amendments.
May need increased watering due to need for moisture, and to rid soils of excess salts.
Due to swing cycle in available nitrogen caused by microorganisms, temporary nitrogen depletion and stunted plant growth may result.
Organic matter amendments to soils can lower soil pH, increasing acidity over time.

References

1. California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.
2. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
4. Sunset Books. (1995). *Sunset Western Garden Book* (6th ed.). Menlo Park, CA: Author.

Student Activities

- **If I were a Schefflera . . .**

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley (p. 75):
- **Water, Water Everywhere**

From *Bottle Biology*, Kendall / Hunt (p. 40):
- **Film Can Mysteries: How Dense is Dirt?**

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 A - Elementary Study of Soils*:
- **Assignment Sheet #1 - Using the Textural Triangle**

Student Lab

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 A - Elementary Study of Soils*:

- **Laboratory Exercise #3 - Determine Soil Textural Class by Mechanical Analysis**
- **Laboratory Exercise #4 - Determine Soil Textural Class by Feel**
- **Laboratory Exercise #5 - Studying Soil Samples**
- **Laboratory Exercise #6 - The Origin and Meaning of Color in Soil**

Internet Resources

Soil pH: What It Means
http://www.esf.edu/pubprog/brochure/soilph/soilph.htm

Teacher Information

Lesson Plan: Titration
http://www.sonoma.edu/cthink/K12/k12class/9-12/titra.nclk

Eckert, D. & Sims, J.T.
Recommended Soil pH and Lime Requirement Tests
http://bluehen.ags.udel.edu/deces/prod_agric/chap3-95.htm

Transparencies

From *Agricultural Science and Technology, Botany / Plant and Soil Science, 510 A - Elementary Study of Soils*:

- **The Relative Sizes of Sand, Silt, and Clay Particles**
- **Soil Texture**
- **Characteristics of the Various Soil Classes**
- **Permeability Related to Nutrient Capacity**
- **The Texture Triangle**
- **Soil Structure**
- **Hard Pans Effect on Soil Depth**
- **pH Scale for Soil Reaction**
- **Ion Exchange of Soil Particles**

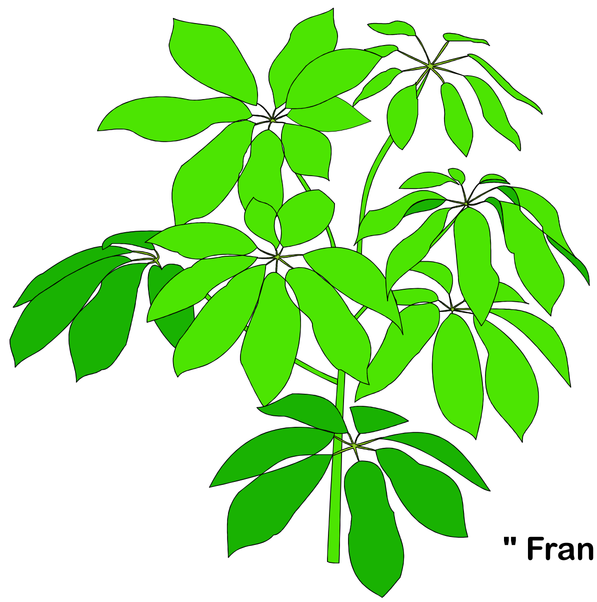
Student Activity: If I Were a Schefflera. . . ?

Purpose

- Understand native soils and their advantages for plants.
- Devise a potting soil mix with similar advantages for plants.
- Understand that the right soil combined with other environmental factors results in a healthy growth environment.

Materials

- Notebook
- Plant of choice
- Container
- Potting soil ingredients
- Fertilizer ingredients
- Plant tag
- Hand-out sheet



" Frank "

Procedure

- Choose one plant for a container planting.
- Research the plant's native history.
- Write a journal entry in your notebook about your plant of choice, indicating the origins of the plant and what elements the plant enjoyed from its home soil and environment. This is called a "living history" of the plant.
- Create a potting soil mix based on what you have learned about the plant's needs.
- Keep a record of the mix in your journal, identifying its components and the amounts of each.
- Specify any fertilization the plant might need and at what intervals.
- Note in your record what other environmental elements the plant might need in its non-native environment as a container plant; i.e., humidity, partial shade, etc. and how those elements might replicate the original environment of the plant.
- Pot up your plant of choice in the potting soil you have created.
- Create a "care tag" for your plant, specifying the plants moisture, light, and fertility needs. In addition, it may be helpful to point out the plant's total space needs for optimum growth.
- Do a hand-out sheet for your classmates. This should include the living history of your plant and its care.

Be creative!

⇒ Name your plant.
⇒ Make your care tag an adventure in graphics.
⇒ Do the same with your hand-out sheet.

Optional activity:

- ⇒ Plant sale!
- ⇒ Valentine's day . . .
- ⇒ Mother's day . . .
- ⇒ Hold a plant care workshop at a senior citizens center and give your plants to the residents. Follow up with the center and help with advice and care for the plants.

References

1. Sunset Books. (1995). *Sunset Western Garden Book* (6th ed.). Menlo Park, CA: Author.
2. Ortho Books. (1990). *Greenhouse Plants*. San Ramon, CA: Author.

Internet Resources

Plant Tracker
http://www.axis-net.com/pfaf/

Florabundance Plant Encyclopedia
http://homearts.com/affil/gardb/main/plantc1.htm

Gardening.com Plant Encyclopedia
http://gardening.com/Encyclopedia/Default.htm


Information

20. Match Terms and Definitions Associated with Organic Fertilizers

21. List the Disadvantages of Organic Fertilizers

22. Select Other Sources of Organic Fertilizers

23. Discuss the Value of Humus and Organic Fertilizers to Soil Fertility and Plant Growth

24. Demonstrate the Ability to Construct a Compost Pile

Organic Fertilizers

Naturally occurring materials derived from plants (carbonaceous compounds) or animals.
Multielement compounds.
Release nutrients through decomposition.

Disadvantages

Organic fertilizer analysis is low - large amounts are needed.
Nutrient release through decomposition can vary.
May contain weed seeds.
Strong odors may be associated with decomposition.
Sludge may contain metals which are toxic to plants.

Sources

Blood meal
Hoof and horn meal
Bonemeal
Cotton seed meal
Kelp or seaweed
Peanut hulls
Fish emulsion
Manure (e.g.)
- Cow

Horse
Chicken
Sheep
Swine
Bat

Mushroom compost
Tobacco stems
Wood ashes
Sewage sludge (activated - microorganisms added)

Other Sources of Organic Fertilizers

Synthetic organic fertilizers

Manufactured products that are slow-release organic nitrogen compounds:

Release by osmotic barrier:
Resin/plastic-coated NPKS

Release by slow breakdown of sulfur coating:
Sulfur-coated urea (SCU)

Release by solubility and bacterial degradation:
Methylene ureas (MU)

Release by effects of water solubility on particle size:
Isobutylidene-diurea (IBDU)
Urea-formaldehyde (UF)

Value of Humus and Organic Fertilizers to Soil Fertility and Plant Growth

1. Slow release of nitrogen for a longer supply of the nutrient over time.
2. Improves nutrient and moisture-holding capacity in all soils, particularly sandy soils.
3. Improves root distribution patterns.
4. Directly influences the physical and biological properties of the soil.
5. Serves as a source of energy for microorganisms responsible for conversion of minerals into forms available for plant growth.
6. Improves plant quality.
7. Improves tilth and soil structure.
8. Reduces tendency of clay soils to “pond” when wet or “bake and cake” when dry.
9. Improves water penetration in clay soils.
10. Improves aeration.

Constructing a Compost Pile

Replicating nature’s process of decomposition.
Interrelated feeding patterns of microorganisms fuel the process.
Consume carbon for energy and nitrogen for growth and reproduction.
Need to add proper mix of nitrogen and carbon-bearing materials to the compost pile.

Pile height:

4 to 6 feet inside an enclosure.

Enclosure types:

Wire bins
Slatted bins (1 to 3 for movement from pile to pile)
Tumblers

Materials

Carbon

Dried leaves, straw, wood chips

Nitrogen

Grass clippings, stable animal manure, kitchen scraps.

Handling

Air

Turn the compost pile with a composting fork.
Move bin to bin, pile to pile or toss if pile is still small enough.
Use a compost tumbler (looks like a miniature cement mixer).
Make air vents with perforated PVC pipes inserted into piles or use aerating tools (same principle: paddles on ends move compost around).

Temperature

Do not turn the pile when the temperature inside the pile is between 104^0 and 131^0F.
Turn between 131^0 and 140^0F.
This method prevents destroying beneficial organisms and allows the pile to cool down and heat up, maintaining optimum bacterial activity.

Water

Water pile after turning to slightly moist but not wet. Too wet closes air space.
Mix wet with dry materials.
Cover to retain moisture.

Compost is ready to use when reduced to:

Homogenous, fine-grained material.
Looks and smells like humus.
Time: anywhere from six weeks to six months depending upon temperature, moisture, and size of materials.

Sheet Composting

Layer organic waste over an area.
Till in: leaves, grass clippings, manure, and food waste.
4-6 inches of layer in fall.
2-3 inches in spring one month before planting.

Cover with soil.

Double-digging

Incorporates sheet composting and digging a bed.
Dig a trench 1 foot wide and 1 shovelful deep.
Add a 2-to 4-inch layer of organic material at the bottom of the trench.
Replace with topsoil.

Vermicomposting

Composting with worms.
Used in a passive pile (left alone to rot).

Earthworms:

Worms consume organic material and process it through their bodies.
Leave nutrient-rich castings.
Secrete calcium carbonate - helps moderate soil pH.
Loosen and aerate soil.
Tunnels provide access for other invertebrates to get into soil and help with the decomposition process.

Composting worms:

Eisenia foetida (can't live in soil)
Lumbricus rubellus (can survive in a soil medium but not *just* soil)
More efficient.
Voracious.
Must maintain fresh waste material for them to eat.
Stay above soil. Do not hibernate.
Keep compost bin in a warm area - 55^0 to 77^0F.

The Worm Box

Line with organic bedding material.
Add garden soil.
Add kitchen waste.
Periodically remove the compost and add new bedding.
Expose the worm box to light.
Worms will move to the center of the box.
Remove compost from around the edges.
Add fresh bedding.

Anaerobic compost

Waste must be contained in a closed environment.
Anaerobic bacteria do the breakdown.
Recommend tied off trash bags.
Moisten materials.
Turn bag every two weeks.
Expose all sides to sun.
Check after a few months.
If it still smells bad, repeat procedure for another two months.

References

1. Brady, N.C. (1974). *The Nature and Properties of Soils* (8th ed.). New York: Macmillan.
2. California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.
3. Davidson, H. & Mecklenburg, R. (1981). *Nursery Management: Administration and Culture*. Englewood Cliffs, NJ: Prentice-Hall.
4. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
5. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
6. Sunset Books. (1995). *Sunset Western Garden Book* (6th ed.). Menlo Park, CA: Author.
7. Ortho Books. (1992). *Easy Composting*. San Ramon, CA: Author.
8. University of Wisconsin-Madison. (1993). *Bottle Biology*. Dubuque, IA: Kendall / Hunt.

Student Activities

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley (p. 91):

- **What Good is Compost?**

From *Bottle Biology*, Kendall / Hunt (p. 18):

- **Worm Composting: Never Underestimate the Power of a Worm**

Internet Resources

Eric S. Johnson
Welcome to the Rot Web!
http://net.indra.com/~topsoil/Compost_Menu.html

Missouri Department of Natural Resources
Solid Waste Management Program
Worm Composting System
http://www.state.mo.us/dnr/deq/swmp/worm1.htm

Waste Reduction at Home
Composting
The Science of Composting
http://www.gvrd.bc.ca/waste/bro/swcnr.html

Carbon / Nitrogen Ratios for Composting Materials
http://www.gvrd.bc.ca/waste/bro/swcnr.html

Transparencies

- **Do Not Add to the Compost Pile**
- **Types of Compost**

Types of Compost

HOME COMPOST

Grass and
Plant trimmings
Garden & Kitchen Wastes

BIOSOLID COMPOST

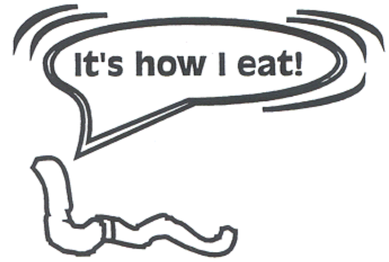
Municipal waste as sludge

AGRICULTURAL COMPOST

Stable manure
Crop residue
Forest products

VERMICOMPOST

Decomposition assisted
by worms.



TM.514.C24b

Do Not Add to the Compost Pile

Coal or Charcoal Ashes

Diseased Garden Plants

Glossy Paper / Colored Ink

Invasive Weeds:

Morning Glory
Buttercup
Quack Grass
Cheat Grass

Meat and Dairy Products

Pesticide-treated Materials

Pet Litter

TM.514.C24a

Ag 514 C - Organic Matter and Fertilizers

Agricultural Science and Technology
Botany / Horticulture Plant Science

Unit Examination

Name ______________________________________ **Score**________________________

1. Decomposition of organic matter is aided by:

   A. Insects
   B. Bacteria
   C. Earthworms
   D. All of the above

2. The final product of decomposition is:

   A. Soil
   B. Humus
   C. Clay
   D. Silt

3. Organic matter is produced in which order?

   A. Degradation, conversion, curing
   B. Conversion, degradation, curing
   C. Degradation, fermentation, curing
   D. Curing, degradation, fermentation

4. List four (4) factors which affect the rate of organic matter decomposition.
   (*List on the following lines . . .*)

Please continue . . .

5. Which of the following types of organic matter is high in nitrogen?

   A. Dried leaves
   B. Grass straw
   C. Animal manure
   D. Wood chips

6. Organic matter affects soil pH by:

   A. Increasing soil acidity
   B. Releasing hydrogen ions
   C. Increasing alkalinity
   D. Increasing buffering capacity

7. Organic matter can be lost from soil by:

   A. Removing plant residues
   B. Irrigation
   C. Bleaching by the sun
   D. Drying by air and sun

8. Which type of crop increases nitrogen in soils?

   A. Grasses
   B. Legumes
   C. Fiber crops
   D. Tuber crops

9. Crops that are planted to add organic matter to the soil are called:

   A. Green manure
   B. Compost
   C. Organic amendments
   D. Peat moss

10. List four (4) purposes of mulching soils:
    (*List on the following lines . . .*)

Please continue . . .

11. What are the two types of mulches? (*List on the following lines* . . .)

12. One problem with using wood chips as mulch is:

    A. They retain moisture
    B. They get infested with slugs and snails
    C. They can produce an odor
    D. They can add harmful lignin to soils

13. List the four physical properties of soil:
    (*List on the following lines* . . .)

14. Describe how the type of soil texture (e.g., sand, silt, clay, loam) affects the water holding capacity of soils: (*Describe on the following lines* . . .)

Sand -

Silt -

Clay -

Loam -

15. Which type of soil structure has particles arranged in a vertical line?

    A. Platy
    B. Blocky
    C. Granular
    D. Columnar

16. Which type of soil structure is usually high in organic matter content?

    A. Platy
    B. Blocky
    C. Granular
    D. Columnar

Please continue . . .

17. Blood meal, bonemeal, cotton seed meal, and peanut hulls are all considered:

    A. Organic matter
    B. Organic fertilizers
    C. Humus
    D. Animal by-products

Thank you! Please return the test sheets to your instructor.

Ag 514 C - Organic Matter and Fertilizers

Agricultural Science and Technology
Botany / Horticulture Plant Science

Unit Examination - Instructor Copy

Name ______________________________________ **Score**_______________________

1. Decomposition of organic matter is aided by:

   A. Insects
   B. Bacteria
   C. Earthworms
   D. All of the above

2. The final product of decomposition is:

   A. Soil
   B. Humus
   C. Clay
   D. Silt

3. Organic matter is produced in which order?

   A. Degradation, conversion, curing
   B. Conversion, degradation, curing
   C. Degradation, fermentation, curing
   D. Curing, degradation, fermentation

4. List four (4) factors which affect the rate of organic matter decomposition.
   (*List on the following lines . . .*)

Temperature	**Microbial population**
Moisture	**Quantity of plant residues**
Aeration	**Chemical nature of plants returned to soil**
pH	

Please continue . . .

5. Which of the following types of organic matter is high in nitrogen?

   A. Dried leaves
   B. Grass straw
   C. Animal manure
   D. Wood chips

6. Organic matter affects soil pH by:

   A. Increasing soil acidity
   B. Releasing hydrogen ions
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9. Crops that are planted to add organic matter to the soil are called:

   A. Green manure
   B. Compost
   C. Organic amendments
   D. Peat moss

10. List four (4) purposes of mulching soils:
    (*List on the following lines . . .*)

Please continue . . .

Keeps soil cool
Allows for earlier planting
Retains soil moisture
Weed control
Reduces soil erosion
Protects roots from heat, cold, or drought
Protects seeds during germination
Allows plants to become established

11. What are the two types of mulches? (*List on the following lines* . . .)

Organic
Inorganic

12. One problem with using wood chips as mulch is:

   A. They retain moisture
   B. They get infested with slugs and snails
   C. They can produce an odor
   D. They can add harmful lignin to soils

13. List the four physical properties of soil:
(*List on the following lines* . . .)

Air
Water
Minerals
Organic matter

14. Describe how the type of soil texture (e.g., sand, silt, clay, loam) affects the water holding capacity of soils: (*Describe on the following lines* . . .)

Sand -

Silt -

Clay -

Loam -

Please continue . . .

Sandy soils have a large amount of air space and drain easily.
Silt can be easily washed away by flood waters.
Clay holds water well and is slow to dry.
Loamy soils can hold enough water to promote plant growth without being too wet.

15. Which type of soil structure has particles arranged in a vertical line?

    A. Platy
    B. Blocky
    C. Granular
    D. Columnar

16. Which type of soil structure is usually high in organic matter content?

    A. Platy
    B. Blocky
    C. Granular
    D. Columnar

17. Blood meal, bonemeal, cotton seed meal, and peanut hulls are all considered:

    A. Organic matter
    B. Organic fertilizers
    C. Humus
    D. Animal by-products

Thank you! Please return the test sheets to your instructor.

Information

From *Agricultural Science and Technology, Botany / Plant Growth and Development, 512 C - Plant Processes:*

1. List the Important Plant Functions in Food Manufacture and Growth

2. Explain Why Photosynthesis is an Important Plant Process

3. Explain the Chemical Process of Photosynthesis

4. List Factors that Affect Photosynthetic Rate

5. Explain the Chemical Process of Respiration

6. Distinguish Between Photosynthesis and Respiration Characteristics

7. Explain Transpiration and List Factors that Affect Transpiration Rate

8. Explain Osmosis and the Process of Absorption by Plant Roots

From *Agricultural Science and Technology, Botany / Plant Growth and Development, 512 B - Cells: Structure, Functions, and Division*:

9. Label the Parts of a Common Plant Cell and Describe the Function of Each Part

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 E - Plant Growth and Development

Unit Objectives

1. List the primary parts and functions of a plant.
2. Identify two types of root systems.
3. Label a drawing showing the parts of a plant stem.
4. Match stem modifications with the correct descriptive term.
5. Label the parts of a leaf.
6. Identify the parts and stages in the development of a seedling.
7. Distinguish between a monocot and a dicot.
8. Label a drawing showing the parts of a complete flower.
9. Match types of flowers to the correct botanical description.
10. List the stages of plant growth and development.
11. List conditions affecting the vegetative growth of crop plants.
12. List the requirements for good seed germination.
13. List the factors that cause poor seed germination.
14. Discuss asexual and sexual reproduction in plants.
15. List methods of pollination.

Information

From *Agricultural Science and Technology, Botany / Plant Growth and Development, 512 E - Vegetative Plant Parts*:

1. List the Primary Parts and Functions of a Plant

2. Identify Two Types of Root Systems

3. Label a Drawing Showing the Parts of a Plant Stem

4. Match Stem Modifications with the Correct Descriptive Term

5. Label the Parts of a Leaf

From *Agricultural Science and Technology, Botany / Plant Growth and Development, 512 F - Reproductive Plant Parts*:

6. Identify the Parts and Stages in the Development of a Seedling

7. Distinguish Between a Monocot and a Dicot

8. Label a Drawing Showing the Parts of a Complete Flower

9. Match Types of Flowers to the Correct Botanical Description

From *Agricultural Science and Technology, Botany / Plant Growth and Development, 512 G - Vegetative Plant Growth*:

10. List the Stages of Plant Growth and Development

11. List Conditions Affecting the Vegetative Growth of Crop Plants

From *Agricultural Science and Technology, Botany / Plant Growth and Development,* *512 H - Reproductive Plant Growth*:

12. List the Requirements for Good Seed Germination

13. List the Factors that Cause Poor Seed Germination

14. Discuss Asexual and Sexual Reproduction in Plants

15. List Methods of Pollination

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 F - Plant Growth Regulators

Unit Objectives

1. Match terms and definitions associated with plant growth regulators.
2. List the controllable plant growth processes.
3. List the way hormones influence plant growth.
4. Describe statements as true or false regarding how auxins, gibberellins, cytokinins, abscisic acid, or ethylenes affect plant growth and development.
5. Select statements that describe plant responses to auxins.
6. List the uses of auxins.
7. Identify the effects of growth regulators on plants.
8. List the important commercial uses for plant growth regulators.
9. List the effects of chemicals on plant growth.
10. List the important chemical growth regulator groups.
11. Identify as either true or false reasons for using chemical growth regulators.
12. List the environmental factors that influence plant growth.
13. List the biological factors that influence plant growth.
14. Name the photoperiod responses.
15. Select statements that describe the effects of photoperiod on plant growth.
16. Explain how plants respond to day length.
17. Select statements that either describe how to shorten or lengthen the day for plants.

18. List the techniques for physical control over plant growth.

Information

1. Match Terms and Definitions Associated With Plant Growth Regulators.

🕮

2. List the Controllable Plant Growth Processes.

🕮

3. List the Ways Hormones Influence Plant Growth.

🕮

4. Describe Statements as True or False Regarding How Auxins, Gibberellins, Cytokinins, Abscisic Acid, Or Ethylenes Affect Plant Growth and Development.

🕮

5. Select Statements that Describe Plant Responses to Auxins.

🕮

6. List the Uses of Auxins.

🕮

7. Identify the Effects of Growth Regulators on Plants.

🕮

8. List the Important Commercial Uses for Plant Growth Regulators.

🕮

9. List the Effects of Chemicals on Plant Growth.

🕮

10.List the Important Chemical Growth Regulator Groups.

🕮

11.Identify as Either True or False Reasons for Using Chemical Growth Regulators.

Plant Growth Regulators:

Natural hormones

Synthetic artificially produced

Natural (hormones) or synthetic growth regulators can control plant growth processes:

1. **Cell enlargement and division**
2. **Cell differentiation**
3. **Root and shoot growth**
4. **Lateral bud development**
5. **Fruit and leaf abscission**
6. **Tropic movement**
7. **Fruit set and enlargement**
8. **Fruit ripening**
9. **Dwarfism**
10. **Flowering**
11. **Dormancy**
12. **Germination**
13. **Senescence (plant aging)**

Hormones Influence Plant Growth

Hormones are Chemical substances produced by plant tissue.

These substances are transported to other plant parts where they direct plant growth (i.e.):

Cause stems to bend toward light

Fruit ripening

Initiate flowering.

Major hormone groups:

Auxins

Gibberellins

Cytokinins

Abscisic acid

Ethylene

Auxins

Indo-acetic acid (IAA)

Formed in growing tips, buds, and young leaves.

Controls plant response toward light (phototropism).

Promotes cell elongation.

Controls apical dominance and branching.

Induces root growth on cuttings.

Affects fruit development and ripening.

Moves from tips of plant downward toward base (not in phloem).

Synthetic Auxin

Indole-butyric acid (IBA)
Napthalene acetic acid (NAA)

Induces root formation on stems and leaf cuttings.
Used in orchards to promote uniform flowering and fruit setting.
Creates seedless fruit if used before pollination.

(2,4-D and 2,4,5-TP are controlled herbicides in low doses. Higher doses banned by U.S. Environmental Protection Agency.)

Gibberellins

Stimulate stem growth.
Induce flowering.
Regulate seed enzyme production.
Bring seeds and buds out of dormancy.
Increase fruit size.

Synthetic Gibberellins

Gibberellic Acid #3 (GA_3)
(GA_1)
Used to:

- Increase size of seedless grapes.
- Improve length and crispness of celery stalks.
- Regulate flowering times in biennials.

Cytokinins

Regulate cell division.
Found in meristems, developing tissues.

Synthetic Cytokinens

Zeaton ®
Kinetin
Benzyladenine (BA)

- Added medium in tissue culture.
- Speeds up cell division in micropropagation.
- Induces branching and fullness.
- Delays senescence:
  - Retards maturity and prevents flower drying.

Abscisic Acid (ABA)

Inhibits cell growth.
Prevents seed germination.
Stimulates opening and closing of stomata in response to water availability.
Promotes abscision of leaves (autumn).
Flower abscision (at onset of seed development).
Induces dormancy.

Synthetic Abscisic Acid

B-Nine ®

Cycocel ®

Ethylene

Water-soluble gas moves readily throughout the plant.
Produced by ripening fruits, germinating seeds, and decaying flowers.
Responsible for ripening process.
Sprayed onto fruit to induce consistent ripening.
Ethylene is produced in response to:
Wind
Breakage
Lack of oxygen in root zone.

Reasons for Using Chemical Growth Regulators

Lessens the cost of manual alteration.
Produces effects which are not available by genetic selection or physical manipulation of plant structure.
Florists and nursery managers use to promote and accelerate root formation on cuttings.
Auxins reduce the time needed to induce root initiation.

Rooting Auxins:

Indoleacetic acid (IAA)
Indolebutyric acid (IBA)
Napthaleneacetic acid (NAA)

Applied as dusts or solutions to end of cuttings.

IBA produces strong, fibrous root systems.
IAA produces bushy, stunted root systems.
IBA / NAA solution mixed with talcum powder used most often.

Procedure:
Make a fresh cut.
Treat with talcum powder or dip in for 5 to 15 seconds.
Place cuttings in rooting medium for four to eight weeks.

Cycocel reduces stem growth.
Used on plants likely to become "leggy."
Also increases number of flower buds.

Florists use chemical preservatives to improve longevity and quality of cut flowers.
Cytokinins

Absorbed by stems.
Extend vase life.
Maintain pigment colors.
Prevent leaf and stem yellowing in cut flowers.

Ethylene is produced by decaying or wilting plant tissue.
Ethylene makes florals wilt or drop their petals.

Reduction of ethylene is a method of preservation.
Reduce ethylene by removal of decaying plants.
Use disinfectant to keep area sanitized.
Ventilate plant storage areas.

Used in Turfgrass Management:

Maleic hydrazide (MH)

Controls vegetative growth by causing growth retardation.
Inhibits cell division.
Reduces mowing frequency.

Chlorflurenol (Maintain CF 125 ®)

Foliar-absorbed growth regulator.
Used in combination with MH to reduce the growth of turfgrass.
Inhibits cell division.
Controls broadleaf weeds.

Paclobutrazol (TGR ®)

Used on golf courses.
Taken into plant through root absorption.
Transported in xylem tissue to developing and dividing cells.
Inhibits cell elongation.
Controls growth.

Flurprimidol (Cutless ®)

Growth regulator.
Absorbed by foliage, stems, and roots.
Requires watering in.
Both TGR and Cutless used on putting greens to suppress annual bluegrass.

Mefluidide (Embark ®)

Absorbed by grass leaf.
Inhibits cell elongation.
Suppresses seedhead formation.
Suppresses growth.

Trinexapac-ethyl (Primo ®)

Decreases mowing frequency on the average of 50 percent over four to six weeks.
Absorbed into leaf.
Rainfast within one hour.
Decreases cell elongation and internode length.
Does not stunt growth over long periods of time.
Reversible with application of gibberellic acid.

Use by Nurseries and Landscape Companies:

Application of plant growth regulators to unwanted sprouts and suckers.
Absorbed by cut surfaces.

Maintain A ®

Asphalt tree wound paint used on suckers and sprouts.

Anti-gibberellins

Counteract effects of naturally occurring gibberellins in plant tissue.
Reduces growth rates rather than increasing them.
Clipper ® reduces internode elongation.
Reduces total growth rates of shade trees.
Remains active for up to four years.
Applied by trunk injection during growing season before pruning.

Procedure:

Drill 3/16 inch diameter holes at base of tree 2 inches deep.
Inject Clipper at 70 psi pressure into holes for three minutes.
Seal each hole with a vinyl plug (prevents back flushing).

NAA

Prevents flowering and fruit set with several applications.

MH

Inhibits fruit production of Ginkgo trees.

Off-Shoot-O ®

Chemical pruner.
Fatty acid which destroys meristematic tissue of shoot apex.
Inhibits shoot elongation.
Promotes lateral branching.
Foliar burn is a problem.

Atrinal ® or Atrimec

Used after pruning or shearing.
Apply as foliar spray after trimming to maintain shape.
Suppress flowering and fruit development.
Used primarily on ornamental olive and glossy privet.

References

1. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Selling Ornamental and Container Plants*. Mills, WY: Andmar.
2. Ortho Books. (1990). *Greenhouse Plants*. San Ramon, CA: Author.
3. Reily, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Labs

- **The Sweeter the Rose**
- **Taking Root / Taking Off!**

Internet Resources

Propagation Methods
http://hammock.ifas.ufl.edu/txt/fairs/10613

Cut Flowers - Preservatives
http://www.ag.uiuc.edu/~robsond/solutions/horticulture/docs/cutflwr1.html

Transparency

- **Movement and Synthesis of Auxins (IAA), Cytokinins, and Gibberellins**

Student Lab: The Sweeter the Rose

Purpose

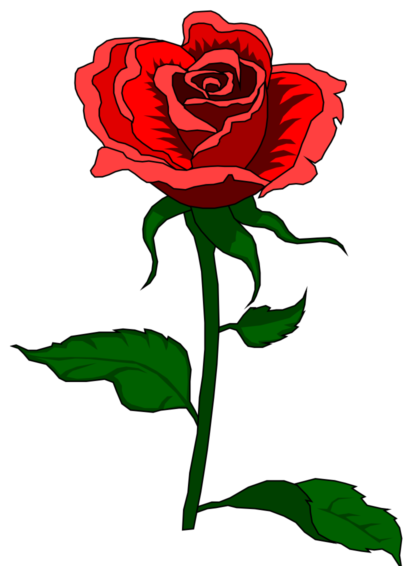
Understand the effects of chemical preservatives on cut flowers.

1. Adds nutrients to the water.
2. Contains a disinfectant to reduce or inhibit bacterial growth.
3. Contains a surfactant to break the stem seal, allowing some water uptake by the plant.

Materials

Chemical preservative for cut flowers.
Lemon/lime soda (do **not** use a diet soda)
Cut hybrid tea roses (*Rosa hybrida*) or carnations (*Dianthus caryophyllus*)
Three single stem vases, clean / sterile
Aerated room

Procedure



Use the single stem vases to place one cut flower each in one vase each containing:

1. One packet of chemical preservative
2. One 2-ounce measure of lemon/lime soda
3. Water only.

Fresh water should be at a temperature of 100^0 to 110^0F, and all three containers should have water added so that it almost reaches the top of the vases (about ¼" from the top).

Maintenance: water daily.

Hints:
Trim the stem at an angle just before placing in the solution.
Keep the flowers in a relatively cool place, away from direct heat.

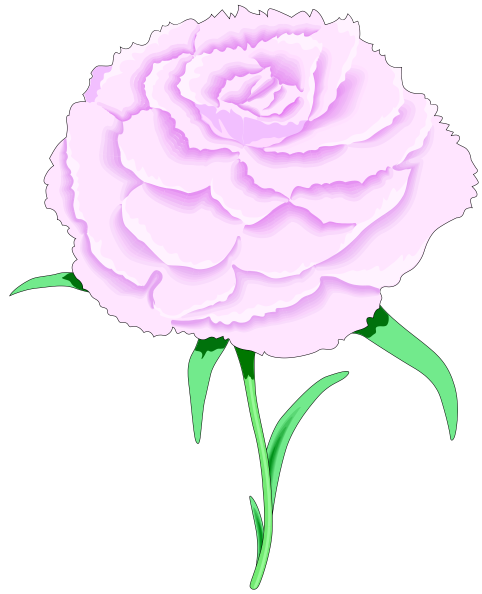
Recording the Results:
Use a notebook or journal log to record daily:

1. Amount of petal opening
2. Amount of petal color turn
3. Amount of stem/leaf wilt

- After one week, graph your results on a separate sheet by computer or by hand.
- After two weeks, graph your results, et al.
- At the end of the two-week period, put a drop of each solution from the vases on a slide and observe them under a magnifying lens. What did you find in each? Record your results in your notebook.

Compare your results with your classmates in small discussion groups.
Discuss the following:

- Which solution preserved the flowers the longest?
- What other solutions could you try to preserve the flowers?
- What other changes did you observe?
- What other factors could have contributed to your results?



Each group should choose a reporter to present the group's findings to the class.

Turn in your notebook and graphed results.

Notes

Student Lab: Taking Root / Taking Off!

Purpose

- Use natural hormones to stimulate plant growth.
- Understand which plant hormones control which areas of plant growth.

Materials

(Your instructor will direct you on choice of plant materials)

1. Three fresh leaf cuttings with stems
   IBA
2. Two transplanted plants, about one week into new growth.
   Alfalfa pellets

Procedure #1

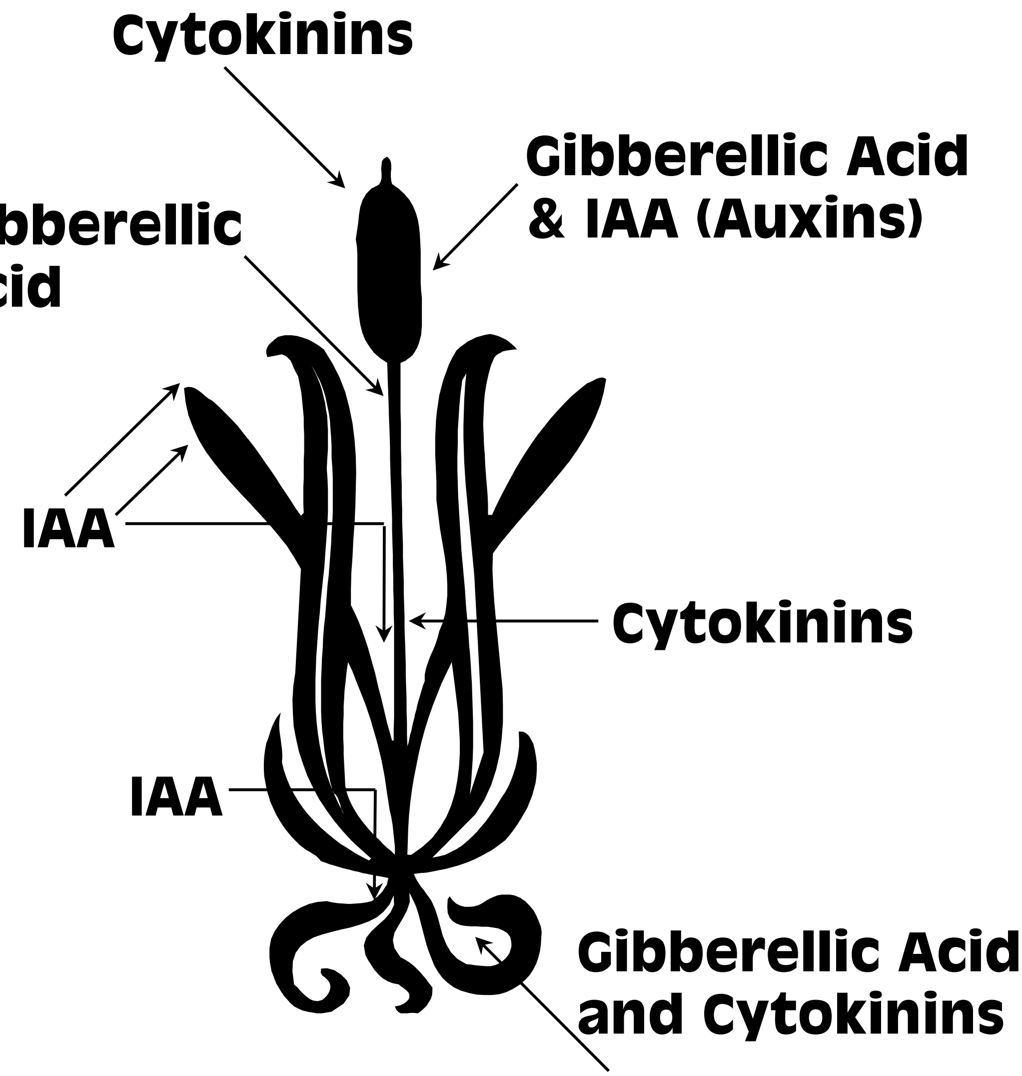
1. Apply the rooting hormone, IBA, to the bottom of the stem of two of the cuttings. Try one application with a talcum powder solution, one dipped into a solution, and one without.
2. Place the cuttings in 4 inch pots filled with a greenhouse potting mix appropriate for the plant.
3. Keep the plants moist.
4. Predict your findings in your notebook. What do you expect to happen to all three cuttings?
5. After two weeks, check the root growth of the plants.
6. Record your results in your notebook. Note any other findings other than those you expected.
7. Record the answers to the following questions in your notebook:
   - Which plant had the best results in rooting growth? Why?
   - Were there any other factors that could affect the results of your experiment?
   - Name at least three.

Procedure #2

Per class: Mix a tea solution of 1 ½ cups of alfalfa pellets per 5 gallons of water (the solution should sit for a day). Each recipe makes 80 cups (divide the recipe appropriately according to class size).

1. Water one plant with ½ cup of the tea:
   - At the beginning of your experiment.
   - After one week.
2. Water the other plant without the solution.
3. Predict your findings in your notebook. What do you expect to happen to the two plants after one week? After two weeks?
4. Record your results in your notebook at the end of two weeks. Note any changes that you did not expect to see.
5. Record the answers to the following questions in your notebook.
   - Which plant grew the most? Why?
   - Were there any other factors that could effect the results of your experiment?
   - Name at least two.

Movement and Synthesis of Auxins (IAA), Cytokinins, and Gibberellins



Information

12. List the Environmental Factors that Influence Plant Growth

13. List the Biological Factors that Influence Plant Growth

14. Name the Photoperiod Responses

15. Select Statements that Describe the Effects of Photoperiod on Plant Growth

16. Explain How Plants Respond to Day Length

17. Select Statements that Either Describe How to Shorten or Lengthen the Day for Plants

18. List the Techniques for Physical Control Over Plant Growth

Environmental Factors that Influence Plant Growth

- **Sunlight**
- **Temperature**
- **Moisture**
- **Air**
- **Nutrients**

Provided by environments in which plants live.
Plant are adapted to their environments.
Environments can be artificially created to replicate a plant's natural environment (i.e., greenhouses).
Environmental factors are the major external factors of plant growth.

Plant environments:

Atmospheric
Edaphic
Biotic

Atmospheric Environment

Above ground environment of a terrestrial plant.

Macroenvironment

Atmosphere above a plant.

Microenvironment

Area immediately surrounding a plant.

Atmospheric conditions

Temperature
Moisture
Light
Wind

<u>Air Temperature</u>

Hardy ability of plants to withstand colder temperatures.
Tender plants that succumb to colder temperatures.

Seasonal fluctuations in temperature

Sets optimum growth rate for plants and limits of plant adaptations.

Thermotropism

Plant growth response to temperature.

Thermoperiodic

Plant response to changes in day and nighttime temperatures.

<u>Moisture</u>

Most important requirement for plant growth.

Seasonal moisture and temperature variations

Crops adapted to moisture availability and a range in temperatures are grown in certain regions to take advantage of the particular fluctuations in moisture and temperature.

Turgidity

Cells harden with water.
Wilt cells become soft without water.
Watering plants can bring them back from wilt conditions if the cells are not destroyed.
Wilting point when plants cannot get enough moisture.
Permanent wilting point when plants fail to recover turgidity and die.
Protoplasm is primarily water.
Water assists in hardening plants to extreme temperature fluctuations.

Transpiration

Cools plants in hot weather.
Absorption

Transport
Release of water to the atmosphere.

Evaporation
Influenced by temperature. Changes water availability to plants. Water changes from a liquid to a gaseous state.
Evapo-transpiration / ET rate
Rate of transpiration as affected by the rate of evaporation.

Moisture is made available to plants by:
Precipitation rain and snow
Water vapor humidity
Dew accumulation of visible moisture on plant leaf surfaces (or any surface).
Condensation occurs when surface temperature is cooler than surrounding air.
Frost frozen dew.
Field moisture capacity water content of soil fills small pore spaces. As amount of moisture is reduced within pore spaces, or is held by soil colloids, it may become unavailable to plants.
Wick action capillary flow of water from lower to upper soil. Movement from fine to coarse soil is restricted unless top layer attraction is greater.
Water infiltration, **percolation**, and **gravitational movement** downward.

<u>Light</u>
Photoperiodism:
Plant reactions to light vary with how the plant is adapted to its environment.
- Artificial light systems can induce plants to respond (e.g., poinsettias).
- Cycle of day and night and seasonal changes are important to plant responses.
- Plant growth is actually controlled by the amount of darkness the plant receives. Plant growth is greater at night when temperatures are lower.

Plants are classified according to their reaction to day length:
Short-day plants
Flower under short-day conditions.
Long days of light promote vegetative growth only.
Examples: spring ephemerals (trillium); autumn-flowering plants (ragweed, asters).

Long-day plants

Need long hours of daylight to bloom (at least 12 hours).
Examples: midsummer.

Indeterminate

Plants that do not seem to exhibit favoritism toward a certain amount of light. Can complete cycles over a range of light conditions.

Other plant interactions with light:

Glossy leaves are more light reflective than dry, dull leaves.
Horizontal leaves and blades absorb more energy than vertical leaves.
Spectrum of light affects plant growth.

Red and yellow bands of the **morning** light spectrum (**angular** rays) promote **cellular elongation**.
Green and blue bands of the **midday** light spectrum promote **cellular stunting**.
Combination promotes **normal plant growth** (the effects balance each other).
Certain wavelengths trigger germination.

Internode length varies with the amount of light received (more sun, shorter length; less sun, longer length).
Plants which grow in **direct sunlight** are **compact**.
Plants which grow in the **shade** are **longer and taller**.
Light intensity controls color and size in combination with temperature.

Size for instance, a plant that grows in Alaska (indirect light) during the 24-hour summer may have a much larger bloom than the same plant in Florida (direct light).
Color that same bloom may be much lighter in color in Florida than in Alaska. Carbohydrates accumulate in cool temperatures, revealing anthocyanins and other pigments. High temperatures produce smaller, lighter-colored plants.

<u>**Wind**</u>

Beneficial

Provides cooling for plants during hot weather.
Dries plant surfaces / soil surfaces; reduces fungal growth.

Harmful

Excessive drying.
Scatters weed seeds, fungal spores, salt spray, and pollutants.
Damages or destroys plants (batters or breaks stems).

Edaphic environment

Soil and area where the roots are located.
Includes synthetic materials, native soil, organic residues.
Can include non-root plant growth.

Provides nutrients, water, gas exchange with atmosphere, & physical support of plants.

Nutrients:

16 elements needed for plant growth.
Carbon, hydrogen, oxygen; nitrogen, phosphorus, potassium; calcium, magnesium, sulfur, boron, chlorine, copper, iron, manganese, molybdenum, & zinc.
Others: aluminum, arsenic, barium, bromine, cobalt, fluorine, iodine, lithium, nickel, selenium, silicon, sodium, strontium, titanium, & vanadium.

Edaphology

Influence of soil and planting media on the growth of plants.

Soil aeration movement of atmospheric air into soil.

Diffusion movement of gases through air-filled pores from high to low concentrations.
Changes in temperature and barometric pressure promote diffusion.
Expansion and contraction of soil promotes aeration.

Soil temperature

Warm soil is important for good seed germination.
Frozen soil stops growth or kills plants.
Temperature is influenced by thermal radiation, absorption, and conductivity.
Also by plant cover.

Soil pH

Important to plant growth as a measure of soil acidity or alkalinity. Based on plant preference to acidic or alkaline conditions, pH serves as an important environmental regulator to plant growth due to:

1. Effects on nutrient availability.
2. Effect on solubility of toxic substances.
3. Effect on soil microorganisms.
4. Effect of pH on root cells, which affect the uptake of nutrients and water.

Soil salinity

Although tolerance varies, plants do not grow well in saline conditions.
Amount of salt in soil measured by soluble salt content and percentage of exchangeable sodium.

Soil biomass

Living organisms and non-living residues that make up a portion of soil matter.

Living:

Microflora

Bacteria, fungi, actinomycetes, algae

Microfauna

Protozoa, nematodes

Macrofauna

Earthworms, arthropods, gastropods, moles, gophers, mice

Non-living:

Dead organic matter

Partially and completely decomposed plant and animal remains

Residual:

Thatch

Organic material and soil

Humus

Thatch as a portion of organic residue

Layer of dead but not yet decomposed plant material between soil surface and living plants.

Soil biomass contains its own microenvironment, complete with *competition* for nutrients and resources, and *niches* for organisms that improve the soil.

Biotic Environment

Use and culture of plants by humans.

Negative:

Soil compaction, turf wear, improper cultural practices (e.g. misuse of pesticides; nonselective pruning).

Positive:

Good cultural practices fostering healthy, stress-tolerant plants.

Other Biological Factors Affecting Plant Growth:

Heredity

Male & female sex cells (gametes) contain specific characteristics which they pass to offspring.

Genetic characteristics modify the rate of plant growth.

Genes

Protoplasm located on chromosomes of cells that carry the genetic blueprint for developing cells.

Geotropism

Downward growth caused by the response of roots to the pull of gravity.

Unequal distribution of hormones induce response.

Positive geotropism downward bending of roots.

Negative geotropism upward bending by shoots.

Photosynthesis

A small amount of light is needed for photosynthesis.

Plant uses energy absorbed by chlorophyll from sunlight.

Plants produce carbohydrates from the absorbed radiation.
Organic compounds are synthesized for the plant's use by the reduction of carbon dioxide.

Physical Controls Over Plant Growth

Biological modifiers:

Pruning, pinching, root pruning, girdling, staking, hormone application.

Environmental modifiers:

Temperature, light intensity, light duration, carbon dioxide and media fertilization, watering, pest management, spacing, digging up/cold storage, transplanting.

Temperature

Indoor

Modifying optimum temperature range for root growth - 60^0-80^0F.
Reduce temperatures by shading sides of containers.
Use fiber or paper-mache containers, or light colored containers which reduce heat absorption by reflection.

Outdoor

Shield tender plants from dessicating cold winds and the direct rays of sun.
Application of antidessicants which inhibit transpiration, allowing the plant to retain moisture and increasing their resistance low temperatures.

Low temperature injury occurs from:

Early fall or late spring frosts
Extreme cold
Rapid temperature changes from warm to cold.

Injury types:

Destruction of flower buds, roots, shoots, branches, or stems
Death of plant.

Frost heaving

Roots are "heaved" out of the ground due to lack of establishment of roots in soil. Especially problematic in clay soil.
Prevent by planting fall transplants into composted or well-drained soil.
Delay planting into clay soils until spring.

Ice and snow

Damage by weight, which downwardly girdles trees and shrubs at the base.
Kills the root system.
Prevent by wire staking or fencing, providing support to the plants.

Acclimatization of plants

- Decreasing day length / gradually decreasing temperature (short days to induce cold hardiness).
- Dig up and place plants in cold storage to avoid direct exposure and to control winter temperature range.
- Choose plants hardier to the plant zone.

Managing for damage from human interaction

Running over plant leaders not evidenced by snow cover.
Restrict usage of an area where young plants are starting. Fence, use plastic sleeves or pipes to protect leaders, or post signage to warn of young plant growth.

Managing for damage by wildlife

Stripping bark, biting off young stems, rubbing bark down.
Methods of control:

Hunting and trapping by permit
Encouraging natural predators
Using non-toxic repellants.

Controlling disease, insects, weeds, and other pests

Best management practices make the best defense:

Spacing, pruning, fertilization, and watering.

BMPs:

⇒ Fertilization for healthy plants / improved resistance.
Well-fertilized plants provide more oxygen and consume carbon dioxide.
⇒ Watering appropriately - neither over- or under-watering.
⇒ Cultivar selection for the plant zone - disease and pest-free.
⇒ Avoid species prone to problems.
⇒ Proper placement to avoid host-pest problems
(e.g., cedar-apple rust, Cooley spruce gall-Douglas fir or blue spruce)
⇒ Media sterilization/pasteurizing
⇒ Composting
⇒ Cultivating and mowing to reduce weeds.
⇒ Using exclosures (e.g., screens and fences) to keep wildlife out.
⇒ Using repellants, natural predators.
⇒ With proper permits, hunting / trapping.
⇒ Targeting pesticide and herbicide applications / proper licensing for use.

Controlling Light

- Maximum / appropriate light intensity managed by greenhouse layout.
- Cleaning covers.
- Proper plant spacing on benches to avoid shading out by other plants.
- Add artificial lighting when necessary to increase light needed during winter months.
- Reducing light intensity by applying shade compounds or covering greenhouse windows with shade fabric.
- Controlling vegetative growth of plants by artificial lighting - adding incandescent light to extend day length for plants requiring it.
- Shorten days by covering plants with lightproof cover to induce flowering.

Pinching

A simple form of pruning, done with forefinger and thumb.

Three types of pruning:

Disbudding

Removal of lateral buds on stems.

Allows terminal flower to become larger.

Soft pinch

Removal of terminal bud and up to ½ inch of stem.

Produces branching.

Hard pinch

Removal of terminal bud and more than ½ inch of stem.

Reduces growth.

Takes a longer time for the plant to recover.

Pruning

Roots

Induces lateral branching and restores vigor to potted plants.

Stimulates flower bud development on some plants (e.g., wisteria).

Stem Pruning and Staking

Develops strong leaders.

Prune upper stems to improve crown structure and good stem structure.

Confine staking to lower portion of tree, allowing upper portion to sway in the wind.

Remove when tree develops wider caliper in lower portion of trunk, “tapering” toward crown.

Branchlets may or may not be removed from trunk to promote development of trunk (not removed), or smoother bark (removed).

Girdling / ringing

Scoring, bark inversion

Reduces root growth / decreases vegetative growth / induces flower bud initiation.

Scoring cutting through bark making a ring without removing the bark.

Bark inversion removing a ring of bark and replacing it in an inverted position.

References

1. California Fertilizer Association. (1990). *Horticulture Edition Western Fertilizer Handbook*. Danville, IL: Interstate.
2. Davidson, H. and Mecklenburg, R. (1981). *Nursery Management: Administration and Culture*. Englewood Cliffs, NJ: Prentice-Hall.
3. Jozwik, Francis X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.
4. Laurie, A., Kiplinger, D.C., & Nelson, K.S. (1969). *Commercial Flower Forcing* (7th ed.). New York: McGraw-Hill.

5. Ortho Books. (1990). *Greenhouse Plants*. San Ramon, CA: Author.
6. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
7. University of Wisconsin-Madison. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activities / Labs

- **The Amazing Technicolor Test**

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt:
- **Tropisms** (pp. 157-167)
- **The Hypocotyl Hypothesis** (p. 168)
- **The Crucifer Cross** (p. 169)

Internet Resources

Investigating Plant Growth Regulators
http://nasc.nott.ac.uk:8100/EXPERIMENTS/growthregulators.html

Factors Affecting Plant Growth
http://hammock.ifas.ufl.edu/txt/fairs/10896

The Salk Institute
Salk Team Identifies Gene That Drives Plant Growth
http://www.salk.edu/NEWS/cyclin.html

The Salk Institute
Salk Team Shows That Steroid Hormones, Important In Animal Development,
Are Also Significant In Growth Of Plants
http://www.salk.edu/NEWS/steroid.html

Transparency

- **Chrysanthemum A Short-Day Plant**

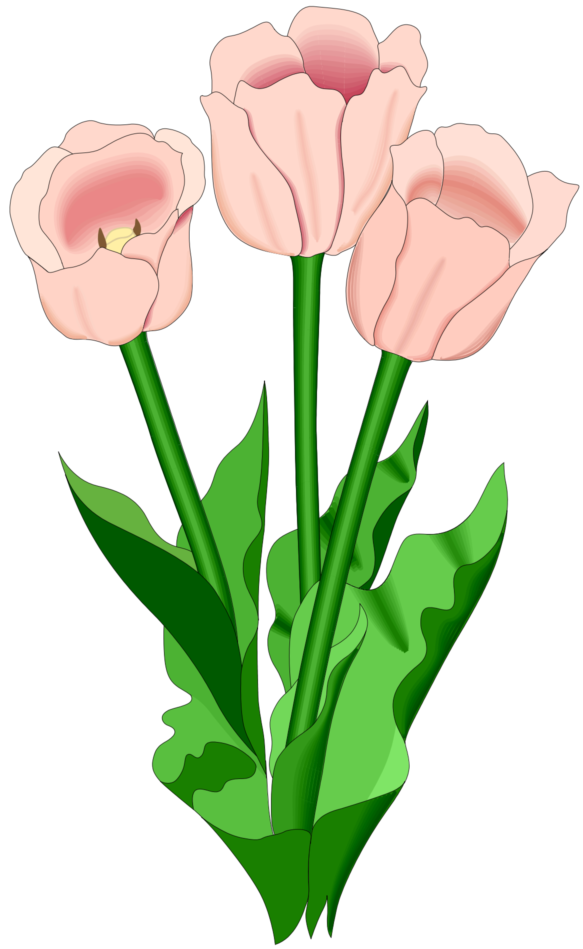
Student Activity: The Amazing Technicolor Test

Purpose

Discover the qualities exhibited by flowers as a result of temperature, light and humidity.

Materials

- Six (6) spring bulbs for forcing
  Suggestions:
  Crocus, iris, grapehyacinth, scilla, & tulip. Choose colored varieties (as opposed to white).
  For expediency, you may use prechilled bulbs.
- Pots sized to accomodate one bulb each (4 to 6 inches).
- Labels for pots.
- At least two separate rooting rooms for temperature control.
- Notebook for record-keeping.



Procedure

- Put one bulb each in a pot filled with pea gravel, nesting the bulbs about halfway into the gravel.
- Label the pots according to the plants' common and species/genus names. Be sure to include your name to identify your pots.
- Label the pots 1, 2, or 3, and proceed with the following for each pot.

(*Do not use steps 1 & 2 if you use prechilled bulbs*.)

Culture for Pot #1:

1. Chill for 6 to 8 weeks below 45^{0}F in the dark, keeping the bulbs moist.
2. Remove from cold storage.
3. Give the plant bright light for 10 to 12 hours per day.
4. Bring up the temperature above 45^{0}F slowly (over three to five days) to no higher than 60^{0}F.
5. Fertilize (quick release with each watering).
6. Maintain a cool temperature.

Culture for Pot #2:

1. Chill for 6 to 8 weeks below 45^{0}F in the dark, keeping the bulbs moist.
2. Remove from cold storage.
3. Give the plant bright light for 10 to 12 hours per day.

4. Bring up the temperature above 45^0F slowly (over three to five days) to a warm temperature (at least 72^0F, preferably up to 86^0F).
5. Fertilize (quick release with each watering).
6. Maintain the warm environment.

Culture for Pot #3:

1. Chill for 6 to 8 weeks below 45^0F in the dark, keeping the bulbs moist.
2. Remove from cold storage.
3. Give the plant very dim light only (you may use a shading cloth) for 10 to 12 hours per day.
4. Fertilize (quick release with each watering).
5. Bring up the temperature up above 45^0F slowly (over three to five days) to no higher than 60^0F.
6. Maintain a cool temperature.

Record in your notebook:

- Controlled variables for pots 1, 2, & 3 (what you manipulated differently in each pot)
- Before the experiment, devise an hypothesis. What do you expect to happen to each flower in each pot?
- Note any circumstances that occurred during your experiment that may have altered the results of the experiment (e.g., things that did not go as planned).
- Note all the changes as each plant achieves bloom.
- Be sure to include dates and times.

Primary items to look for (but note all of your observations):

∗ Bloom
∗ Stem length
∗ Internode length.

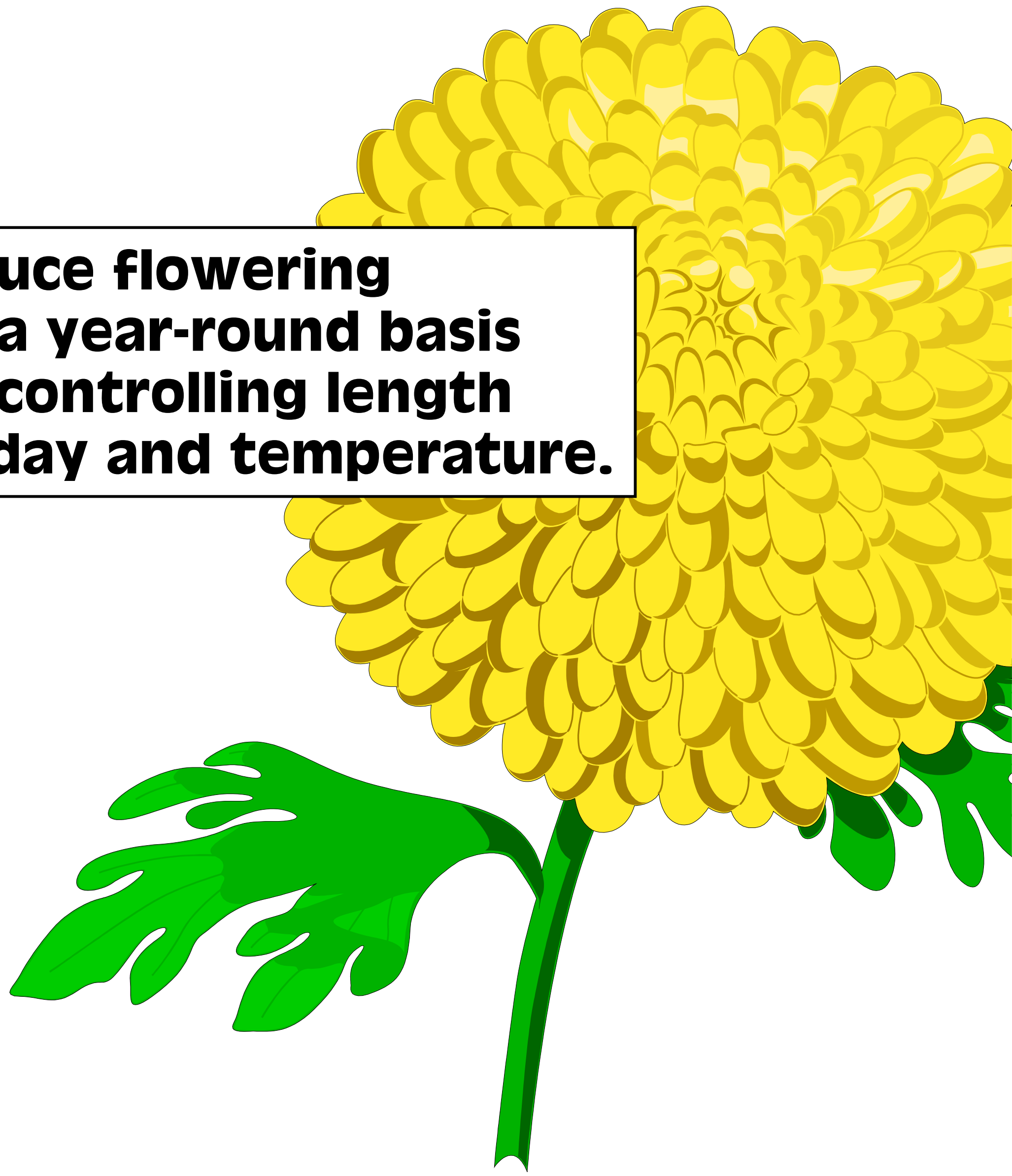
Conclude the experiment:

- Record the results of all the observations you made regarding pots 1, 2, & 3 in your notebook.
- Present your results to your classmates by writing a brief paper which includes:
  ⇒ What you were trying to discover by performing the experiment
  ⇒ Your hypothesis (what you thought might happen)
  ⇒ The variables which were manipulated & the variables which were not manipulated (your experimental controls)
  ⇒ Note any unexpected results or uncontrolled variables
  ⇒ Discuss the results you observed (tell what happened)
  ⇒ Make conclusions about the results you observed (this probably happened because . . .).
- Include the paper with your notebook and turn it in to your instructor.
- Be prepared to present your results to the class.

Chrysanthemum

A short-day plant.

Induce flowering on a year-round basis by controlling length of day and temperature.



- If a short-day plant is grown under a short day, it will flower.
- 60^0F night temperatures are requi until buds form, then reduce to 5

Ag 514 F - Plant Growth Regulators

Agricultural Science and Technology
Botany / Horticulture Plant Science

Unit Examination

Name ______________________________ **Score** ____________

List **six examples** of plant growth processes regulated by natural or synthetic growth regulators:
(*List on the following lines . . .*)

1.	4.
2.	5.
3.	6.

The **five** major hormone groups are:
(*List on the following lines . . .*)

1.	4.
2.	5.
3.	

Gibberellins:
(*Indicate as T = True or F = False*)

___Stimulate stem growth
___Induce flowering
___Regulate seed enzyme production
___Cause seeds and buds to go into dormancy
___Reduce fruit size

Please continue . . .

Ethylene is:
(*Indicate as T = True or F = False*)

___An insoluble gas that does not move readily throughout the plant.
___Produced by ripening fruits, germinating seeds, and decaying flowers.
___Responsible for the ripening process.
___Produced in response to rain, abundant oxygen in the root zone, and plant sturdiness.

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. IAA	___Indolebutyric acid
2. IBA	___Napthaleneacetic acid
3. NAA	___Indoleacetic acid

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. IAA	___Mixed with talcum powder in solution.
2. IBA	___Produces strong, fibrous root systems.
3. IBA / NAA	___Produces bushy, stunted root systems.

Multiple Choice:
(*Circle your choices*)

1. Maintain A

A. Reduces growth rates rather than increases them.
B. Prevents flowering and fruit set with several applications.
C. Is a wound paint used on suckers and sprouts.
D. Promotes lateral branching.

2. Off-Shoot-O

A. Chemically prunes.
B. Is used after pruning or shearing.
C. Reduces the total growth of shade trees.
D. Inhibits fruit production.

Please continue . . .

3. NAA

A. Is a fatty acid which destroys meristematic tissue.
B. Prevents flowering and fruit set with several applications.
C. May cause foliar burn.
D. Is used primarily on ornamental olive and glossy privet.

List the **five** environmental factors that influence plant growth:
(*List on the following lines . . .*)

1.	4.
2.	5.
3.	

The **three** plant environments are:
(*Check three*)

☐ Atmospheric
☐ Tropospheric
☐ Edaphic
☐ Adaptive
☐ Biotic

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. Short-day plants	___Are midsummer plants.
2. Long-day plants	___Can complete cycles over a range of light conditions.
3. Indeterminate	___Long days of light promote vegetative growth only.

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. Red and yellow bands of light	___Promote normal plant growth.
2. Green and blue bands of light	___Promote cellular stunting.
3. All bands of light	___Promote cellular elongation.

Please continue . . .

Give **three examples** of biological plant growth modifiers:
(*List on the following lines . . .*)

Give **six examples** of environmental plant growth modifiers:
(*List on the following lines . . .*)

List **six examples** of best management practices (BMPs) in controlling disease, insects, weeds, and other pests:
(*List on the following lines . . .*)

1.	3.	5.
2.	4.	6.

Describe the **three** forms of pinching and their purpose:
(*Describe on the following lines . . .*)

1.	
2.	
3.	

Thank you! Please return the test sheets to your instructor.

Ag 514 F - Plant Growth Regulators

Agricultural Science and Technology
Botany / Horticulture Plant Science

Unit Examination - Instructor Copy

Name ______________________________ **Score** ____________

List **six examples** of plant growth processes regulated by natural or synthetic growth regulators:
(*List on the following lines . . .*) **SEE TEACHER INFORMATION**

1.	4.
2.	5.
3.	6.

The **five** major hormone groups are:
(*List on the following lines . . .*)

1. **Auxins**	4. **Abscisic acid**
2. **Gibberellins**	5. **Eythlene**
3. **Cytokinins**	

Gibberellins:
(*Indicate as T = True or F = False*)

_**T**_Stimulate stem growth
_**T**_Induce flowering
_**T**_Regulate seed enzyme production
_**F**_Cause seeds and buds to go into dormancy
_**F**_Reduce fruit size

Please continue . . .

Ethylene is:
(*Indicate as T = True or F = False*)

_F_ An insoluble gas that does not move readily throughout the plant.
_T_ Produced by ripening fruits, germinating seeds, and decaying flowers.
_T_ Responsible for the ripening process.
_F_ Produced in response to rain, abundant oxygen in the root zone, and plant sturdiness.

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. IAA	**_2_**Indolebutyric acid
2. IBA	**_3_**Napthaleneacetic acid
3. NAA	**_1_**Indoleacetic acid

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. IAA	**_3_**Mixed with talcum powder in solution.
2. IBA	**_2_**Produces strong, fibrous root systems.
3. IBA / NAA	**_1_**Produces bushy, stunted root systems.

Multiple Choice:
(*Circle your choices*)

1. Maintain A

A. Reduces growth rates rather than increases them.
B. Prevents flowering and fruit set with several applications.
C. Is a wound paint used on suckers and sprouts.
D. Promotes lateral branching.

2. Off-Shoot-O

A. Chemically prunes.
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C. Reduces the total growth of shade trees.
D. Inhibits fruit production.

Please continue . . .

3. NAA

A. Is a fatty acid which destroys meristematic tissue.
B. Prevents flowering and fruit set with several applications.
C. May cause foliar burn.
D. Is used primarily on ornamental olive and glossy privet.

List the **five** environmental factors that influence plant growth:
(*List on the following lines . . .*)

1. **Sunlight**	4. **Air**
2. **Temperature**	5. **Nutrients**
3. **Moisture**	

The **three** plant environments are:
(*Check three*)

- ☐ **Atmospheric**
- ☐ Tropospheric
- ☐ **Edaphic**
- ☐ Adaptive
- ☐ **Biotic**

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. Short-day plants	_**2**_Are midsummer plants.
2. Long-day plants	_**3**_Can complete cycles over a range of light conditions.
3. Indeterminate	_**1**_Long days of light promote vegetative growth only.

Mix and Match:
(*Place the number of your selection on the line in front of your choice*)

1. Red and yellow bands of light	_**3**_Promote normal plant growth.
2. Green and blue bands of light	_**2**_Promote cellular stunting.
3. All bands of light	_**1**_Promote cellular elongation.

Please continue . . .

Give **three examples** of biological plant growth modifiers:
(*List on the following lines* . . .) **SEE TEACHER INFORMATION**

Give **six examples** of environmental plant growth modifiers:
(*List on the following lines* . . .) **SEE TEACHER INFORMATION**

List **six examples** of best management practices (BMPs) in controlling disease, insects, weeds, and other pests:
(*List on the following lines* . . .) **SEE TEACHER INFORMATION**

1.	3.	5.
2.	4.	6.

Describe the **three** forms of pinching and their purpose:
(*Describe on the following lines* . . .)

1. **Disbudding**	**Removal of lateral buds on stems.**
	Allows terminal flower to become larger.
2. **Soft pinch**	**Removal of terminal bud and up to ½ inch of stem.**
	Produces branching.
3. **Hard pinch**	**Removal of terminal bud and more than ½ inch of stem.**
	Reduces growth.
	Takes a longer time for the plant to recover.

Thank you! Please return the test sheets to your instructor.

Ag 514 F - Unit Exam Teacher Information

Plant growth processes controlled by natural or synthetic growth regulators:

Cell enlargement and division
Cell differentiation
Root and shoot growth
Lateral bud development
Fruit and leaf abscission
Tropic movement
Fruit set and enlargement
Fruit ripening
Dwarfism
Flowering
Dormancy
Germination
Senescence (plant aging)

Biological plant growth modifiers:

Pruning
Pinching
Root pruning
Girdling
Staking
Hormone application

Environmental plant growth modifiers:

Temperature
Light intensity
Light duration
Carbon dioxide and media fertilization
Watering
Pest management
Spacing
Digging up / cold storage
Transplanting

Ag 514 F - Unit Exam Teacher Information - continued . . .

Best management practices:

Fertilization for healthy plants / improved resistance.
(Well-fertilized plants provide more oxygen and consume carbon dioxide.)
Watering appropriately - neither over - nor under-watering.
Cultivar selection for the plant zone - disease and pest-free.
Avoid species prone to problems.
Proper placement to avoid host-pest problems
(e.g., cedar-apple rust, Cooley spruce gall-Douglas fir or blue spruce)
Media sterilization / pasteurizing
Composting
Cultivating and mowing to reduce weeds.
Using repellants, natural predators.
With proper permits, hunting / trapping.
Targeting pesticide and herbicide applications / proper licensing for use.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 G - Introduction to Sexual Plant Propagation

Unit Objectives

1. List factors to consider in selecting high quality seed.
2. Discuss conditions that exist when good seed is not selected.
3. List and describe the certifiable seed classes.
4. List information required on certifiable seed tags.
5. Discuss types and purposes of seed treatments.
6. Discuss procedures to follow in handling and storing seed.
7. Calculate the value of pure live seed.
8. Describe the general requirements for seed germination.
9. Classify germination requirements according to seed type.
10. List the materials from which flats can be made.
11. List the advantages and disadvantages of using flats for propagation.
12. List the advantages and disadvantages of starting seedlings inside flats.
13. Match terms and definitions associated with seeding in flats.
14. List the steps for seeding in flats.
15. Demonstrate different methods of seeding flats.
16. List the information that should appear on the label of a flat after it has been planted.
17. Describe the procedure to follow after seeds have germinated in a flat.

Information

1. List Factors to Consider in Selecting High Quality Seed

2. Discuss Conditions that Exist when Good Seed is not Selected

3. List and Describe the Certifiable Seed Classes

4. List Information Required on Certifiable Seed Tags

Factors to Consider in Selecting High Quality Seed

1. Are seeds grown locally? (freshness / viability enhanced)
2. Seeds should be **tested and labeled according to state regulations required** for:
   - **Trueness of name** (cultivar / species)
   - **Origin** (genetic purity)
   - **Germination percentage** (guaranteed)
   - **Pure seed percentage of total ingredients** (guaranteed)
   - **Percentage of other ingredients** (weeds/other crop seeds/inert materials)
3. Purchase seeds from a reliable dealer, ensuring:
   - Pure variety (genetic identity and purity)
   - Acceptable germination ability.
4. Hybrid varieties are favored for vigor, uniformity, and flowering.
5. Uniform heavyweight or primed seeds are the best selection.

Seed Quality

- Sorted by weight.
- Heavy seeds grow faster / produce more.
- More expensive but production is assured, recouping extra cost.

Primed / Enhanced Seeds

- Seeds soaked in potassium chloride or ethyl alcohol.
- Treatment induces growth.
- Radical growth is halted for storage.
- Seed growth is reinitiated upon planting. Allows better resistance to insects and disease.
- More uniform growth and harvest.

Good quality seed characteristics:

Genetically true to species or cultivar
Capable of high germination
Free from diseases and insects
Free from mixture with other crops, weeds, inert and extraneous materials.

Results of Poor Seed Selection
Immature seeds will not germinate.
Late harvest seeds have a poor rate of germination.
Seeds stored longer than one year lose their ability to germinate.

Certifiable Seed Classes
Breeder's seed
Originates with the sponsoring plant breeder or institution.
Provides initial source of all certified classes.
Foundation seed / Select seed
Breeder's seed progeny.
Maintains highest standard of genetic identity and purity.
Source of all other certified seed classes.
Can be used to produce additional foundation seed plants.
Registered seed
Foundation seed progeny (or within its own class, or above classes).
Produced within specified standards.
Certified for genetic identity and purity.
Certified seed
Progeny of registered seed (or within its own class, or above classes).
Produced in largest volume for growers.
Certified as satisfactory for genetic identity and purity.

Certifiable Seed Tag Identification Requirements
Certified blue tag
Registered purple tag or blue tag marked as "registered."
Foundation white tag or blue tag marked as "foundation."
Basic equivalent to foundation or registered.
Certified first generation blue tag.
Second generation reg tag.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Reily, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Investigating Seeds**

Internet Resources

Germplasm / Cultivar Releases
http://www.usu.edu/~forage/germ.htm

Certified Seed
Guide A-131
Charles R. Glover, Extension Agronomist
http://rastro.nmsu.edu/cahe/redtops/_a/a-131.html

Know What is in a Bag of Seed
Guide A-216
C.R. Glover, Extension Agronomist
College of Agriculture and Home Economics
New Mexico State University
http://rastro.nmsu.edu/cahe/redtops/_a/a-216.html

Illinois Crop Improvement Association, Inc. (ICIA) Home Page
http://www.aces.uiuc.edu/~icia/

OKRA Certification Standards
http://aac.msstate.edu/Mafes/Aosca/Stand/08-ch-02.html

Transparency

- **Seed Label Requirements**

Seed Label Requirements

Lot Number:
(Name)

Pure Seed	Variety	Kind	Germination	Origin
%	Name		%	(state)
%	Name		%	(state)

% Inert Matter
% Other Crop Seed
% Weed Seed

Must sell by: (date)
Test date: (date)
Net Weight: (lbs)

Noxious weed seed Identification
per pound (listed out)

% Containing other crop seed by name

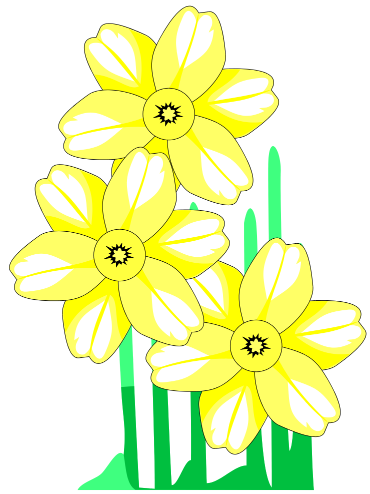
Seed Producer
Address
City/State/Zip

Notice to Consumer

TAG COLOR: Blue, red, or white

Student Activity: Investigating Seeds

Purpose



- Identify the components of seed label information.
- Discuss the importance of seed label information.
- Test at least one aspect of seed label information for accuracy by testing the percentage of germination.

Materials

- Seed packet
- Paper towels
- Small oven or heat lamp
- Notebook

Procedure

Keep a record of your test steps in your notebook.

This is one way to determine how many plants your packet of seeds may yield and other packets of the same: seed type / seed source / & date.

Seeds should be retested for percentage of germination after a period of time, due to the need for accuracy when figuring how many seeds may be needed to achieve a certain number of plants.

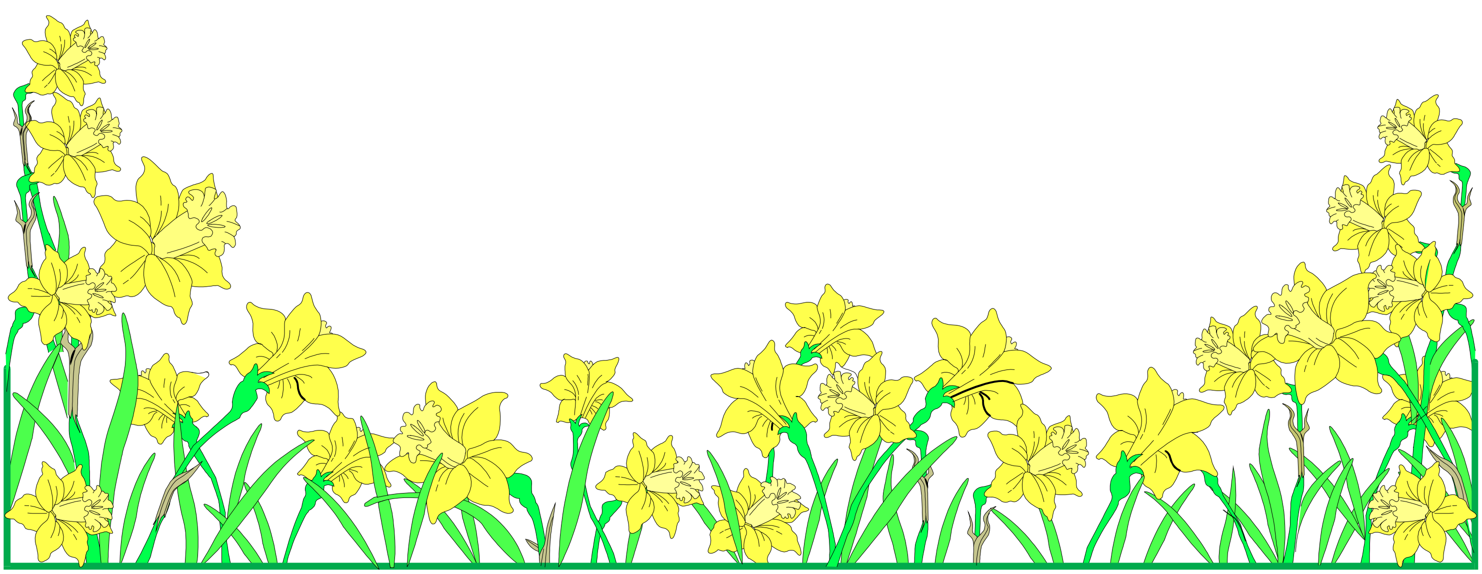
- Look at the information on the label of the seed packet.
- Locate the information under “percentage of germination.”
- Open the packet and place an even number of the seeds in a moist paper towel.
- Place the seeds within the towel in a small oven or under a heat lamp, keeping the seeds moist and at a temperature of 85^0F for 7 to 10 days.
- At the end of that time, count the sprouted seeds and divide by 100. This will be the percent of germination.
- How many plants did you intend to grow? If you wanted to grow 50 plants, multiply the percentage germinated times 50. Subtract that number from 50. The result will be the number of additional seeds you need to plant.

Q&A

1. What was the germination percentage rate guaranteed on the packet of seeds?
2. Did your test results yield the same percentage of germination as the packet label guaranteed?
3. What was the difference in percentage rates?
4. What was the length of time between the packaging date and the date when you did your test?
5. Compare your test results with your classmates. On the average, did the percentage rate of germination go down as the length of time increased?

(*Please answer on the following lines. . .*)

Name:



Information

5. Discuss Types and Purposes of Seed Treatments

6. Discuss Procedures to Follow in Handling and Storing Seed

7. Calculate the Value of Pure Live Seed

Treatments to overcome dormancy

Mechanical scarification

Process of **breaking, scratching, or mechanically altering seed coats** to make them permeable to water or gases.
Done by rubbing with **sandpaper, cutting with a file, or cracking large seeds** with a hammer.
Small seeds are scarified by turning them in disk scarifiers, i.e., drums with disks covered in abrasive paper.
If necessary, very large seeds (e.g., tree) are scarified in cement mixers filled with gravel and sand.
Seeds can be stored or planted.

Soaking in water

Placing seeds in **hot water then** removed immediately to soak in **gradually cooling water** for 12 to 24 hours.
Seeds should be planted. Storage is possible after treatment but the percentage of germination is reduced.

Acid scarification

Used to modify particularly hard or impermeable seed coats.
Seeds are **soaked in sulfuric acid then washed** for ten minutes **in running water**.
Seeds can be planted or dried and stored.

Moist-chilling stratification

Combines moistening the seeds **with the chilling period** some seeds need before germination.
Seeds are soaked for 12 to 24 hours then cold-storaged in temperatures from 35^{0} to 45^{0}F in a medium that holds moisture (e.g., sand and peat moss mixed) for one to four months.
Seeds can be planted after separation from the storage medium.
Indoor germination of seeds should be allowed to take place at cooler temperatures.

Combination treatments

Mechanical, acid, or soaking combined with moist-chilling for impermeable seed coats with double embryo or complex dormancy needs.

Moist-warm stratification can be interposed between seed coat treatment and moist-chilling to soften the seed coat in the fall for spring germination.

Moist-warm treatment works by decomposition generated by hosting microorganisms. Treatment temperature should be no lower than 50^0F. The range can be up to 86^0F (day) and 68^0F (night).

Timing plantings

Seeds requiring **cold treatments** are **fall-planted**.

Seeds requiring **warm then cool treatments** are **summer-planted**.

Ripe harvesting for planting is useful for some species that lose viability when too much time passes between harvesting and planting. Seeds coats are not allowed to dry before planting.

Dry storage

For freshly harvested seeds that need a period of dormancy. Dry in warm temperatures to assist germination (104^0F for three days or 99^0F for five days) for immediate planting.

Temperature control during germination

Alternation of daily temperatures to induce germination of freshly harvested seeds. Temperature combinations include: 59^0 to 86^0F, or 68^0 to 86^0F. Lower temperatures are held for 16 hours; higher temperatures are held for 8 hours.

These temperature fluctuations simulate seasonal temperatures.

Chemical stimulants

Hormone treatments to stimulate germination:

Cytokinins (overcomes high temperature dormancy)

Ethylene

Potassium nitrate (stimulates freshly harvested dormant seeds)

Thiourea (for seeds that do not germinate in high temperatures or darkness)

Sodium hypochlorite (particularly used to stimulate germination of rice seed)

The usual treatment is a 24-hour soaking in a water-based solution.

Light exposure

Light sensitivity disappears after dry storage for many seeds.

Light exposure after dry storage encourages germination.

Exposure should be for at least eight hours daily, at 75 to 125 foot-candles.

Seeds coats should be softened and moist.

Treatments for disease control

Disinfectants

Eliminate organisms within seeds.

Hot water (120^0 to 135^0F) for 15 to 30 minute soak. Seeds are then dried.

Formaldehyde

Steam.

Disinfestants

Eliminate organisms on seed surfaces. Good for seeds grown in sterile media.

Calcium hypochlorite

Clorox

Seed protectants

Fungicides applied to seed coats to prevent invasion by soil fungi ("damping-off").

Combinations of insecticides and fungicides are also used.

Applied before or after planting.

Handling and Storing Seed

Handling Seed

Mechanical harvesting (for seed that generally mature at the same time)

Hand picking (for seeds that mature at intervals)

Cleaning seed

Dry method:

Cleaning machines clean seeds or . . .

Dry fruits are gathered and spread to dry.

Seed threshed from pods or capsules.

Wet method:

Soaking in water for 8 to 24 hours with one teaspoon baking soda per quart.

Fruit is washed to remove pulp.

Seeds are spread to dry, then stored.

Storing

Cool, dry storage stored for next planting season at 40^0F.

No storage - immediate planting.

Cool, moist storage fruit / tree-bearing edible seeds stored for next planting season at 40 to 90 percent relative humidity.

Value of Pure Live Seed

Seed purity

Percentage of pure seed present in a seed lot.

Identified species or cultivar.

Seed viability

Percentage of seed that will germinate under standard conditions.

Pure live seed

Percent purity multiplied by the percent viability.

Difference between laboratory pure live seed (**the seed germination test**) and field pure **live seed content** is the **expected seedling mortality rate**.

Indicates how much loss of viability occurred during storage.

Other problems may occur, such as planting too deep, or unfavorable conditions(too hot or too cold; drought).
Seed certification ensures genetic purity.

References

1. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
2. Hartmann, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
5. University of Wisconsin-Madison. (1993). *Bottle Biology: An Idea Book Exploring the World Through Soda Bottles and Other Recyclable Materials*. Dubuque, IA: Kendall / Hunt.
6. University of Wisconsin-Madison. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activities and Labs

From *Bottle Biology*, Kendall / Hunt:
- **Film Can Germination** (p. 90)

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt:
- **Seed Maturation and Dispersal** (pp. 125-135)

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley:
- **Seedy Character** (pp. 112-113)

Internet Resources

Seed Treatment Alberta Agriculture, Food, and Rural Development
http://www.agric.gov.ab.ca/pests/diseases/63000102.html

Seed Treatments for Disease Control North Dakota State University NDSU Extension Service
http://www.ext.nodak.edu/extpubs/plantsci/crps/pp447w.htm

Transparencies

- **Speeding Germination**
- **Pure Live Seed Formula**

Speeding Germination

ng

Soak for a day in water.
Add a teaspoon of baking soda.

y

Create an opening
in the seed coat by nicking
or rubbing with sandpaper.

Place seeds in a sealed
plastic bag with damp peat
moss or vermiculite. Store
in the refrigerator over the
winter. Plant in the spring.

ct

Plant seeds protected
in foil packets immediately.
They are being protected
from heat and humidity.

Keep seeds from light
until you want
them to germinate.

Pure Live Seed Formul

Seed Packet Informatio

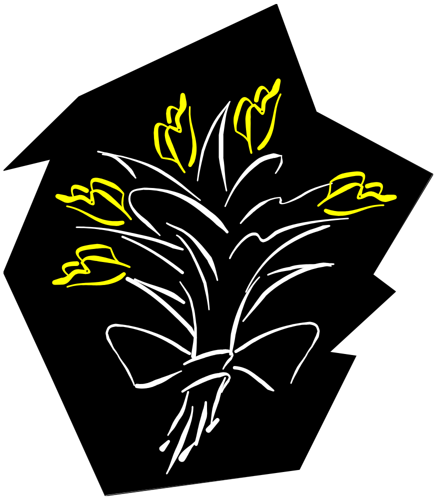
% Pure Seed Present

X

% Germination Rate

=

% Pure Live Seed



Information

8. Describe the General Requirements for Seed Germination.

9. Classify Germination Requirements According to Seed Type.

General Requirements for Seed Germination

Three conditions required for germinations:

1. **Seed must be viable**
2. **No physical or chemical barriers to germination**
3. **Environmental conditions must be right for germination.**
   Environmental conditions:
   Moisture*, oxygen, correct temperature, and light or darkness (depending on the species)
   *Seed must have continuous supply of water in order for the seed to absorb moisture for coat softening and swell for coat to split and allow initial growth.

Germination Process

Three stages:

Awakening or Activation

Water is absorbed by the seed.
Cell elongation and emergence of the radicle

Digestion and translocation

Water uptake continues, as well as respiration.
Cell systems are activated.
Protein-synthesis is taking place.
Enzymes appear.
Digested compounds are translocated to growing points.

Cell division

Cell division in separate growing points, followed by expansion of the seedling structures.
Oxygen uptake continues.
Storage tissue decreases.
Cotyledons emerge.
Radicle emerges.

Plumule (growth structure of shoot above cotyledons) is evident.
Hypocotyl (below cotyledons) and **epicotyl** (above cotyledons), parts of the seedling stem, are evident.

Initial Seedling Growth

Epigeous germination

Hypocotyl elongates and raises the cotyledon above the ground.

Hypogeous germination

Lengthening of the hypocotyl allows the epicotyl to emerge, while the cotyledons remain below the ground.

Monocots and dicots

Differ in their germination patterns.
Monocots emerge with a first singular foliage leaf.
Dicots emerge with two first foliage leaves (cotyledon) followed by true leaves in **epigeous germination**;
Or dicots emerge with true leaves appearing from a plumule while cotyledon remain below ground, enclosed in an endocarp (**hypogeous germination**).

Germination Requirements According to Seed Type

Seed types:

Dormant

Germination is prevented by internal mechanisms within the seed.
Physical and chemical barriers are present within the seed, genetically coding and timing the seed for the appropriate stage when metabolic reactions should begin.
Advantageous to the seed, in that the timing coincides with environmental conditions favorable to the seed.

Quiescent

Seed is capable of immediate germination in response to environmental factors.

Categories of Seed Dormancy

Group I Embryo is quiescent.
- **A** Hard seed coverings are impermeable to moisture.
- **B** Hard seed coverings are resistant to embyo expansion.
- **C** Seed coverings contain chemical inhibitors to prevent germination.

Group II Seeds have undeveloped embryos.

Group III Embryo is dormant.
- **A** **Shallow dormancy** inner seed coat regulates dormancy. Seeds are light and temperature sensitive.
- **B** **Intermediate dormancy** seed coat regulates dormancy.
- **C** **Deep dormancy** embryo regulates dormancy.

Group IV **Combined / double dormancy** dormancy is regulated by the seed coat and the embryo, and dormancy must be treated in sequence.

Environmental Factors

Hard seed covers

Impermeability to water.

Mechanically resistant seed coats.

Chemical germination inhibitors.

Immature embryos undergo further growth after they are separated from the plant.

Active inner seed coats and endosperm respond to light, temperature, and gases; other chemicals.

Dormant embryos respond to moist-chilling, aeration, and time.

Aeration maintains after-ripening progress. Oxygen deprivation can cause secondary dormancy.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
4. University of Wisconsin-Madison. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activities / Labs

From *Agricultural Science and Technology, Botany / Science of Plant Growth and Development, 512 F - Reproductive Plant Parts*:

- **Laboratory Exercise #4 - Development of Seed Parts into Young Plants**

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt:

- **Germination** (pp. 45-55)

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley:

- **Seed Power** (p. 119)
- **Growing, Growing, Gone** (p. 123)

Internet Resources

Seeds and Seed Germination
http://149.152.32.5/Plants_Human/seedgerm.html

Teacher Information:
Seed Germination Experiment
http://149.152.32.5/Plants_Human/seedgermlab.html

National Academy of Sciences Symposium Paper (1996) Abstract
From Seed Germination to Flowering, Light Controls Plant Development via the Pigment Phytochrome
http://journals.at-home.com/get_doc/562842/9540

Transparencies

From *Agricultural Science and Technology*, *Botany / Science of Plant Growth and Development, 512 F - Reproductive Plant Parts*:

- **A Corn Grain and Its Parts**
- **A Bean Seed and Its Parts**

From *Agricultural Science and Technology*, *Botany / Science of Plant Growth and Development, 512 H - Reproductive Plant Growth*:

- **Stages in Germination and Emergence of Corn**
- **Stages in Germination and Emergence of a Bean Seed**

Information

10. List the Materials from which Flats Can Be Made

11. List the Advantages and Disadvantages of Using Flats for Propagation

12. List the Advantages and Disadvantages of Starting Seedlings Inside Flats

13. Match Terms and Definitions Associated with Seeding in Flats

14. List the Steps for Seeding in Flats

15. Demonstrate Different Methods of Seeding Flats

16. List the Information that Should Appear on the Label of a Flat After It Has Been Planted

17. Describe the Procedure to Follow After Seeds Have Germinated in a Flat

Flat Types

Rows

Wooden boxes 14 ½ x 23 x 2 ¾ or 18 x 18 x 2 ¾ with drainage slots

Plastic with drainage holes

Styrofoam

Individual celled

Plastic or compressed peat with drainage holes

Flats should provide:

- Proper drainage
- Aeration

- Moisture retention
- Media must be in firm contact with seeds
- Temperature must be warm enough to encourage and support germination.

Media used should be correct pH and provide essential nutrients.
Media should be sterile.

Advantages and Disadvantages of Using Flats of Propagation

Direct seeding:

Seeds are sown **where they will grow**
Seeds are **subject to weather conditions** for germination and growth
Seeds need **protective chemical treatment** against insects and disease
Economical process
Used for vegetable crops, trees, and shrubs
Soil needs preparation (worked and composted)
Planting time must be exact.

Indirect seeding:

Conditions for germination are **controlled**
Media must be mixed and sterilized
Nutrients must be added to planting media
Seeds are **sown into flats and allowed to develop** to true leaf stage
Seedlings are **transplanted** after true leaves develop
Controlled conditions allow plants to **harden off in preparation for transplanting**
Plants are more mature and **can better withstand rigors** of weather and other environmental factors.

Starting Seedlings Inside Flats

Media should be **sterilized.**
Mix combinations can contain peat moss, perlite and / or vermiculite, sand, or loam soil, **at 1/3 proportions** providing drainage, moisture retention, and aeration.
Water-soluble fertilizer in low amounts must be added to sustain initial plant growth.
Media should be **moist at seed planting.**

Steps for Seeding in Flats

Sowing (three types):

1. Tap seeds out gently from packet, sowing seeds **in properly spaced rows** (see packet directions).
2. **Individual celled flats** can be sown with one or two seeds in each cell.
3. Seeds can also be **broadcast** over the surface evenly, but row planting makes transplanting easier and reduces the chance of disease.

Covering:

Cover seeds **with a fine layer** of peat moss, perlite, or fine sand.
The covering should be **about twice the size of the seed.**

Follow package directions; some seeds should not be covered.

Label the Flat with:

Name

Variety

Date planted.

(Use a waterproof marking pen.)

Watering the Flat:

Aids in germination

Acts to dissolve and make available other nutrients in the media.

To water, set the flats in a tub of water to induce capillary action.

Capillary action wicks the water through the soil pore spaces, distributing it throughout the media.

Watering from the top of the flat may wash out or bury the seeds.

If you do water from **overhead, misting is preferable.**

Cover the flats with plastic or clear glass to retain moisture.

Locating the Flat:

Place in a **semishaded area.**

Seeds requiring darkness for germination are **covered with newspaper.**

Keep at a **temperature of 65^0 to 70^0F by seating** on a propagation mat (recommended), above a heating coil, or above hot water pipes.

Germinated Seeds:

Reduce the temperature to 55^0 to 60^0F to induce the hardening-off process.

Active growth can be slowed by **reducing periods of watering.**

References

1. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
2. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
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5. University of Wisconsin-Madison. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activities / Labs

From *Bottle Biology*, Kendall / Hunt:

- **Gardening Systems** (pp. 97-99)
- **Film Can Wick Pots** (p. 100)
- **Bottle Base Reservoir** (p. 101)
- **TerrAqua Bottle** (p. 102)

- **Bottle Cap Gardens** (p. 103)
- **Film Can Garden** (p. 104)
- **Grow Bucket** (pp. 105-106)

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt:
- **Plant Growth** (pp. 57-72)

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley:
- **It's Getting Stuffy in Here** (pp. 120-121)

Internet Resources

Get Growing Now: Starting Seeds Indoors by Sara Williams University of Saskatchewan Extension Division
http://www.ag.usask.ca/cofa/departments/hort/hortinfo/misc/seeds.html
&
Starting Seeds Indoors Part 2
http://www.ag.usask.ca/cofa/departments/hort/hortinfo/misc/seeds2.html

Transparencies

- **Labeling the Seed Flat**
- **Seeding the Flat**

Labeling the Seed Fla

The “common name” of the pla
including the variety.

The latin name (Genus species)
of the plant.

The date planted.

Impatiens, Busy Lizzie

Impatiens wallerana

3 / 1 / 97

Use a waterproof marking pen
Label immediately after plantin

Seeding the Flat

Sowing (three types):

1. **Tapping out into properly spaced rows**
2. **Place one or two seeds in individual cells**
3. **Broadcast evenly over the surface.**

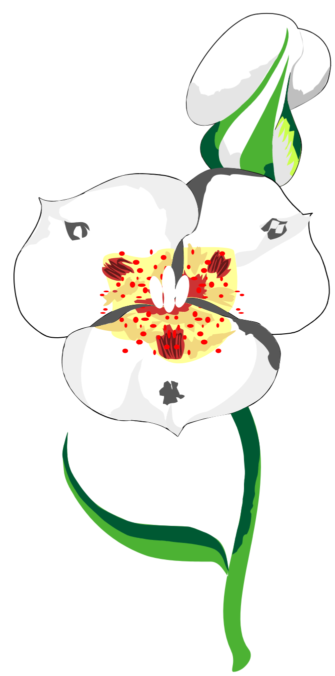
Covering:

- **Cover with a fine layer about twice the size of the seed**
- **Use peat moss, perlite, or fine sand.**

Label immediately.

Water (two types):

1. **Set in tub for capillary action.**
2. **Mist.**



Locate:

- **In a semishaded area or darkness (according to the species)**
- **On a propagation mat.**

Ag 514 G - Introduction to Sexual Plant Propagation
Unit Test

1. In order to ensure high quality seeds, seeds should be tested and labeled according to which required state regulations?

    ____
    ____

    ____
    ____

Multiple Choice

2. Another factor to consider when selecting high quality seed is

    a. the temperature at which the seed was germinated.
    b. whether the seed is uniform heavyweight or primed.
    c. if the seeds were grown locally.
    d. both b and c.

3. One characteristic of a good, quality seed is:

    a. it has been stored for over one year.
    b. it is free from diseases and insects.
    c. it has been harvested late in the year.
    d. it is mixed with other crops, weeds, inert and extraneous materials.

4. A Certified identification requires

    a. a blue tag.
    b. a purple or white tag marked as "certified."
    c. a white tag marked as "certified."
    d. no tag.

5. To eliminate organisms within seeds, first soak the seeds for 15 to 30 minutes in hot water, then after
drying, soak the seeds in

    a. calcium hypochlorite.
    b. cold water.
    c. formaldehyde.

d. Clorox.
e.

6. A disinfestant is used to

a. eliminate organisms on seed surfaces.
b. determine the viability of the seed.
c. destroy immature seeds.
d. eliminate organisms within seeds.

7. The three stages of the germination process are

a. translocation, photosynthesis, respiration
b. activation, cell division, photosynthesis
c. awakening/activation, digestion/translocation, cell division
d. awakening/activation, digestion/translocation, protein-synthesis

8. A seed will germinate if the seed is viable, there are no physical and chemical barriers, and

a. if the environmental conditions are right.
b. if the seed is kept in an airtight container.
c. if the soil is dried and treated.
d. if the seed is kept from absorbing water.

9. Monocots

a. are not a viable seed type.
b. emerge with a first singular foliage leaf.
c. emerge with two first foliage leaves.
d. allow the epicotyl to emerge.

10. A quiescent seed

a. lacks the epicotyl and true leaves.
b. does not require light in order to germinate.
c. only germinates at a temperature above 50°.
d. is capable of immediate germination in response to environmental factors.

11. Active inner seed coats

a. respond to light, temperature, and gases, as well as other chemicals.
b. emerge with the radicle.
c. contain the endocarp.

d. are not necessary in seed germination.

Matching

____ 12. Breeder's seed
____ 13. Foundations seed / Select seed
____ 14. Registered seed
____ 15. Certified seed
____ 16. Seed Purity
____ 17. Seed viability
____ 18. Pure live seed

A. Foundation seed progeny
B. Provides initial source of all certified classes
C. Produced in largest volume for growers
D. Maintains highest standard of genetic identity and purity
E. Percent purity multiplied by the percent viability
F. Percentage of seed that will germinate under standard conditions
G. Percentage of pure seed present in a seed lot

19. List five treatments used in overcoming plant dormancy.

____
____

____
____

____

Match the seed dormancy category with the most likely description.

____ 20. Group I
____ 21. Group II
____ 22. Group III
____ 23. Group IV

A. seeds have underdeveloped embryos
B. dormancy is regulated by the seed coat and the embryo
C. embryo is quiescent
D. embryo is dormant

24. Write the Pure Live Seed Formula.

Ag 514 G - Introduction to Sexual Plant Propagation
Unit Test
Answer Key

1. In order to ensure high quality seeds, seeds should be tested and labeled according to which required state regulations?
   Answers can include 4 of the 5 below:
   Trueness of name
   Origin
   Germination percentage
   Pure seed percentage of total ingredients
   Percentage of other ingredients

Multiple Choice

2. Another factor to consider when selecting high quality seed is
   a. the temperature at which the seed was germinated.
   b. whether the seed is uniform heavyweight or primed.
   c. if the seeds were grown locally.
   d. **both b and c.**

3. One characteristic of a good, quality seed is:
   a. it has been stored for over one year.
   b. **it is free from diseases and insects.**
   c. it has been harvested late in the year.
   d. it is mixed with other crops, weeds, inert and extraneous materials.

4. A Certified identification requires
   a. **a blue tag.**
   b. a purple or white tag marked as “certified.”
   c. a white tag marked as “certified.”
   d. no tag.

5. To eliminate organisms within seeds, first soak the seeds for 15 to 30 minutes in hot water, then after drying, soak the seeds in
   a. calcium hypochlorite.
   b. cold water.
   c. **formaldehyde.**
   d. Clorox.

6. A disinfectant is used to
   a. **eliminate organisms on seed surfaces.**
   b. determine the viability of the seed.
   c. destroy immature seeds.
   d. eliminate organisms within seeds.

7. The three stages of the germination process are
    a. translocation, photosynthesis, respiration
    b. activation, cell division, photosynthesis
    c. **awakening/activation, digestion/translocation, cell division**
    d. awakening/activation, digestion/translocation, protein-synthesis

8. A seed will germinate if the seed is viable, there are no physical and chemical barriers, and
    a. **if the environmental conditions are right.**
    b. if the seed is kept in an airtight container.
    c. if the soil is dried and treated.
    d. if the seed is kept from absorbing water.

9. Monocots
    a. are not a viable seed type.
    b. **emerge with a first singular foliage leaf.**
    c. emerge with two first foliage leaves.
    d. allow the epicotyl to emerge.

10. A quiescent seed
    a. lacks the epicotyl and true leaves.
    b. does not require light in order to germinate.
    c. only germinates at a temperature above 50°.
    d. **is capable of immediate germination in response to environmental factors.**

11. Active inner seed coats
    a. **respond to light, temperature, and gases, as well as other chemicals.**
    b. emerge with the radicle.
    c. contain the endocarp.
    d. are not necessary in seed germination.

Matching

__B__ 12. Breeder's seed
__D__ 13. Foundations seed / Select seed
__A__ 14. Registered seed
__C__ 15. Certified seed
__G__ 16. Seed Purity
__F__ 17. Seed viability
__E__ 18. Pure live seed

A. Foundation seed progeny
B. Provides initial source of all certified classes
C. Produced in largest volume for growers
D. Maintains highest standard of genetic identity and purity
E. Percent purity multiplied by the percent viability

F. Percentage of seed that will germinate under standard conditions
G. Percentage of pure seed present in a seed lot

19. List five treatments used in overcoming plant dormancy.

Answers can include:
Mechanical scarification
Soaking in water
Acid scarification
Moist-chilling stratification
Combinations treatments
Timing plantings
Dry storage
Temperature control during germination
Chemical stimulants
Light exposure

Match the seed dormancy category with the most likely description.

__C__ 20. Group I
__A__ 21. Group II
__D__ 22. Group III
__B__ 23. Group IV

A. seeds have underdeveloped embryos
B. dormancy is regulated by the seed coat and the embryo
C. embryo is quiescent
D. embryo is dormant

24. In the space provided, write the Pure Live Seed Formula.

% Pure Seed Present x % Germination Rate = Pure Live Seed

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 H - Care and Transplanting of Seedlings

Unit Objectives

1. Match terms and definitions associated with the care and transplanting of seedlings.
2. Describe how to care for young seedlings.
3. List the types of transplanting pots that are available.
4. List the factors to consider when choosing plant containers.
5. Describe the procedures to follow when transplanting seedlings.
6. List the steps of transplanting seedlings.
7. Demonstrate the hardening of seedlings.
8. Demonstrate the ability to properly transplant seedlings.

Information

1. Match Terms and Definitions Associated with the Care and Tranplanting of Seedlings

2. Describe How to Care for Young Seedlings

3. List the Types of Transplanting Pots that are Available

4. List the Factors to Consider when Choosing Plant Containers

5. Describe the Procedures to Follow when Transplanting Seedlings

6. List the Steps of Transplanting Seedlings

7. Demonstrate the Hardening of Seedlings

8. Demonstrate the Ability to Properly Transplant Seedlings

Care and transplanting of Seedlings

Transplant after the development of **true leaves** (beyond cotyledons).
Handle seedlings by their true leaves, not by the stems.
Use **thumb and forefinger** to hold.
Lift seedling out with a plant label, trowel, or fork.
Keep media on the seedling's roots.
Use a **dibble or forefinger** to make a hole into the new media.
Insert seedlings into the hole, **slightly deeper or at the same level** they were in the seeding media.
Press the media gently around the roots to **"nest" the seedling**.
Water the seedlings at the media surface, gently around the roots.

About Containers

Peat pot

One per plant; later transplanted directly to the garden. Seedling remains in the pot.

Market packs

Holds six to 12 plants.
Sold as a pack.
Plants can be separated from the pack and planted individually.

Jiffy 7 peat moss pellet

Expandable peat moss (about seven times original size).
Self-contained nutrient feeding.
Seeds are planted into, feeding the seedling until transplanted to a permanent site.

Large seeds directly planted into peat pots.

Peat pots are planted directly into the soil at transplant.

Choose containers according to:

- How the plants will be sold to the customer (market pack or individually)
- Sufficient plant growing space
- Ease of transplanting for the plant.

Hardening Seedlings

Involves **checking plant growth** by reducing water and cooling growth condition air temperatures.
The **accumulation of carbohydrates** makes the plant hardier.
Gradually **move the plants outside** to their permanent location in steps.
Move plants **to a lath house or cold frame** for five to seven days, depending on the species.
Summer annuals, for example, only require two to three days.
Water thoroughly / drain / before transplanting.
Retain soil around the roots when transplanting.
To aid in plant establishment, **use a booster or starter fertilizer** (at a light solution to prevent burn) before or after transplanting.

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1. Hartmann, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook*. Mills, WY: Andmar.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **The Hardy Boys and the Case of the Seedy Wilts**

Internet Resources

NebGuide
Cooperative Extension
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
Petunias
http://ianrwww.unl.edu/iaur/pubs/extnpubs/hort/93-1127.HTM

Starting Seeds Indoors: Part 4
Sara Williams
University of Saskatchewan
http://www.ag.usask.ca/cofa/departments/hort/hortinfo/misc/seeds4.html

Vegetable Transplants - Start Indoors Soon
Oregon State University
News and Communications Service
http://wwwagcom.ads.orst.edu/agcomwebfile/garden/vegetable/vegetabletransplantsstarti.html

Transparencies

- **Container Types**
- **Mixing and Transplanting**
- **Transplanting from Pots**
- **Transplanting to Pots**

Container Types

Criteria

Economy
Consumer appeal
Ease of handling
Disease-free
Quality of plant growth

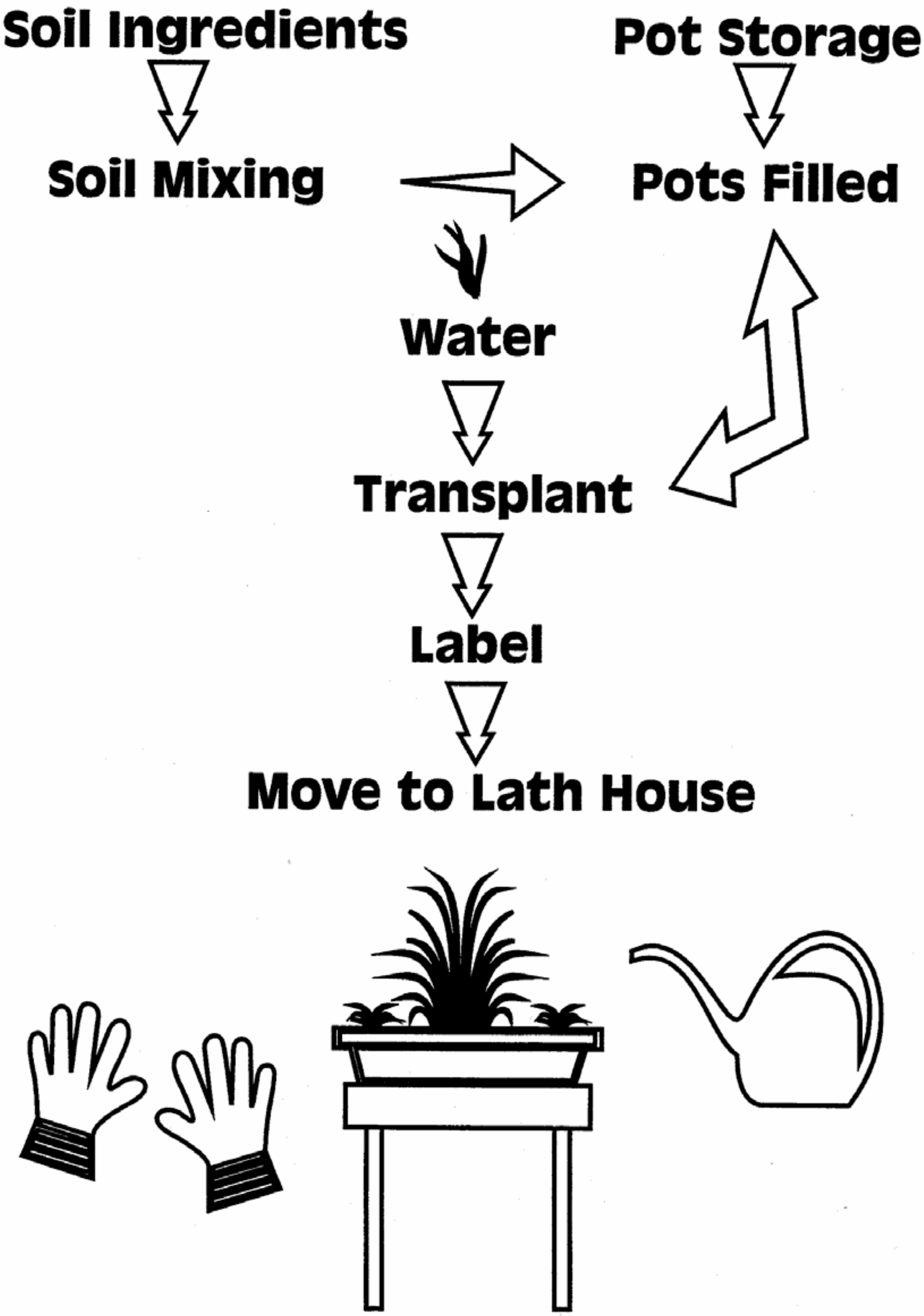
Types

Plastic
clay
Wood fiber
Peat
Styrofoam
Wooden
Metal
Paper cell units (short propagation)

Lining

Tar paper
Burlap cloth

Mixing and Transplanting



TM.514.H5

Transplanting to Pots

Procedure at potting table:

Seedlings, media on left   Pots on right

Cover drain hole with coarse material for good drainage

Hold transplant with left hand at true leaves

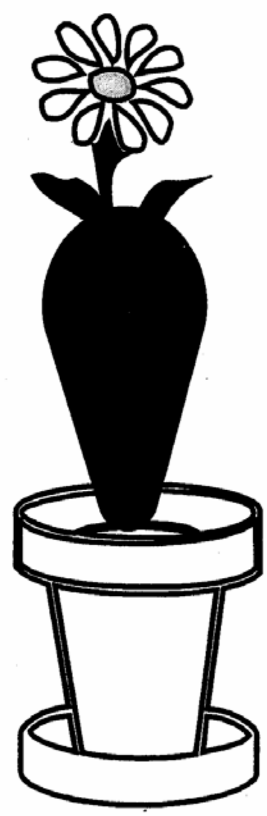
Fill pot to rim with potting media

Place seedling at planting depth

Gently press potting media around the plant

Label the flat/pot

Move plants to growing area.



Transplanting from Pots

Procedure at potting table:

Spread fingers of left hand around plant stem and over soil surface

Invert pot

Tap pot edge on table

Loosen and remove pot from root ball

Gently unwind any bound roots.

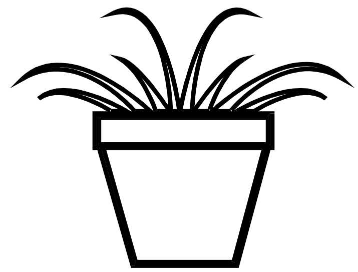
TM.514.H8

Student Activity: The Hardy Boys and the Case of the Seedy Wilts

Purpose

- Demonstrate the hardening of seedlings.
- Demonstrate the ability to properly transplant seedlings.
- Understand the requirements of plants from seedling to transplant to ensure hardy growth.

Materials



Seedlings to transplant
Six market pack flats in the six or 12 sized cells
Potting media
Plant Record Book
Notebook

Procedure

"This is the story of the Hardy Boys and the Case of the Seedy Wilts. It goes like this. One day, while cleaning up the potting shed, a greenhouse worker (we'll dub him, "GW") discovered a flat of seedlings that were badly wilted. The seedlings had been transplanted into the flat three days ago. Yet there they were, looking for all the world as though they would not make it another hour. What GW found even more interesting is that on the same bench next to the flat of the "Seedy Wilts" was another flat of seedlings planted at the same time that looked very hardy. GW dubbed this flat, "the Hardy Boys." There they sat, side by side: the Seedy Wilts and the Hardy Boys. GW decided there was a mystery afoot! (or a-flat; whichever!). What circumstances made the differences evident between the two flats? Could the Seedy Wilts be saved? Were the Hardy Boys likely to go the same way as the Seedy Wilts, given time?

How can GW solve this mystery?"

Good detectives have to do some investigation. Answer the following questions, then proceed to the activity. You should be able to solve the *Case of the Seedy Wilts* by asking questions as well as answering them.

Q&A

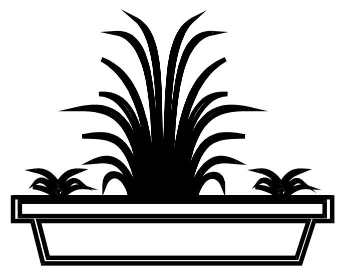
(*Answer the following questions in your notebook* . . .)

1. A good detective retraces the steps of the incident. What is the first thing GW should check for in the flat of the Seedy Wilts?
2. What comparisons can GW make with the Hardy Boys flat?
3. What can GW do to check the planting program between the two flats?
4. Make a diagnosis. State what you think happened to the Seedy Wilts flat.
5. What would you recommend GW do to prevent the same occurrence with the Hardy Boys flat?
6. What recommendations would you make for the Seedy Wilts flat?
7. Predict what will happen to the Hardy Boys flat if the seedlings were:
    - A) Planted in the same media as the Seedy Wilts flat.
    - B) Were exposed to the outdoors directly from the potting shed.
    - C) Watered again in five days after being seated in the sunshine.

Conduct your own experiment to solve the mystery of the Hardy Boys and the Case of the Seedy Wilts:

Flats One & Two
- Mix two batches of soil for your planting media. Use sterilized media for one flat, and unsterilized media for a second flat, keeping the ingredients basically the same.
- Keep a record of each step in your planting process, including what ingredients you mix as a planting media, which flat has sterilized media, and which batch has unsterilized media.
- Fill one six-celled flat with sterilized media, and one with unsterilized media.
- Plant your seedlings according to the correct steps for transplanting:
    1. Make a hole in the media with a dibble or your forefinger.
    2. Hold the seedling by the true leaves, not the stem.
    3. Plant the seedling to a depth a little lower or the same as its germination tray height.
    4. Press the media around the roots.
    5. Gently water the seedlings at the surface level.

Flats Three and Four
- Mix two more batches of soil using sterilized media.
- Repeat the steps, filling and planting two more market packs.
- Place one flat in a lath house or cold frame, and one flat outside.



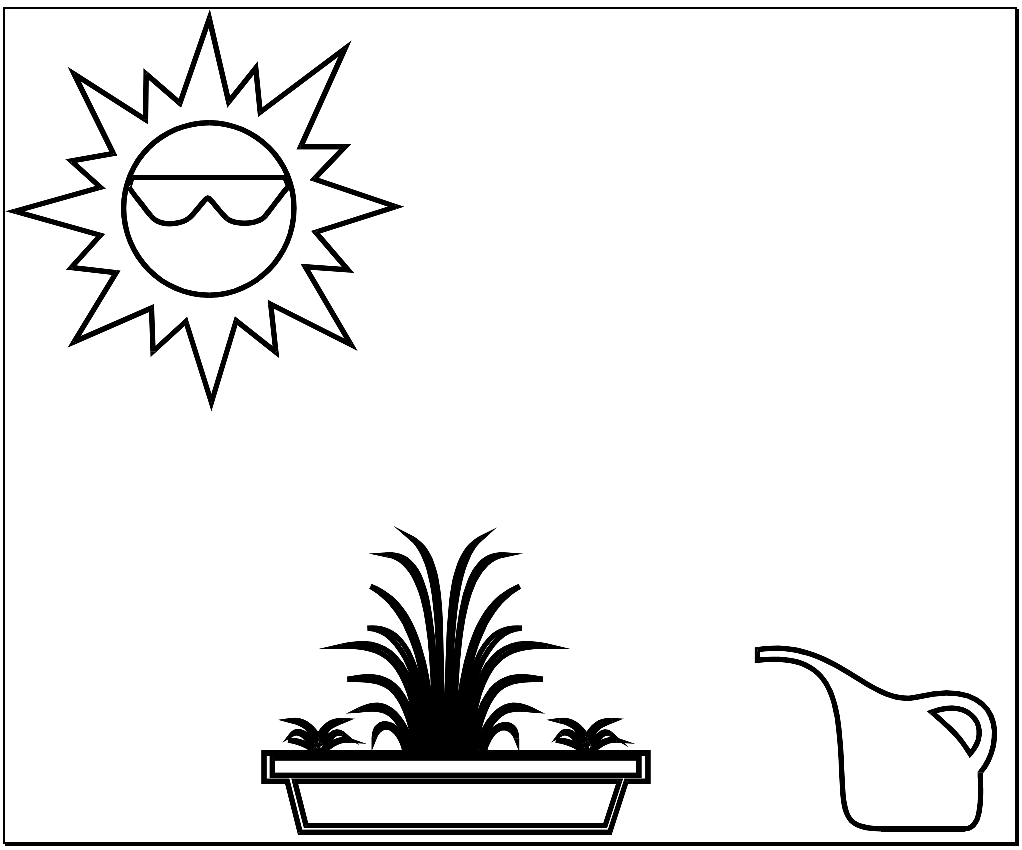
Flats Five and Six
- Mix two more batches of soil using sterilized media.
- Repeat the steps, filling and planting two more market packs.
- Place both flats in a lath house.
- Make sure one flat has consistently moist soil. Do not overwater.
- Allow the other flat to dry out.
- Record how many days it takes for the flat to dry out.
- Record the changes in the plants.
- Compare the two flats.
- Record what happens if you remoisten the soil in the flat that has been allowed to dry out.
- Repeat the procedure with the same flats one more time.
- Record what happens to the plants and compare the differences between the two flats.

Monitor all the flats daily. Keep a record of daily changes in your notebook, and the maintenance records for all six flats.

Compare your results to the Hardy Boys and the Case of the Seedy Wilts. (*Answer the following questions in your notebook . . .*)

1. Based on your results, what could have happened to the Seedy Wilts?
2. What might happen to the Hardy Boys?
3. Could GW have prevented the Seedy Wilts? How?

4. Under what circumstances could GW save the Seedy Wilts? . . . the Hardy Boys?



Ag 514 H - Care and Transplanting of Seedlings
Unit Test

True or false

____ 1. Seedlings should be planted after the development of true leaves.
____ 2. Seedlings should be handled by their stems.
____ 3. Media should be kept on the seedling's roots.
____ 4. Seedlings should only be inserted a quarter of an inch below the surface of the new media.
____ 5. Do not water seedlings once they are placed in the new media to prevent premature root rot.

Matching

____ 6.	Peat pot	A.	feeds the seedling until it is transplanted
____ 7.	Market packs	B.	one pot per seedling
____ 8.	Jiffy 7 peat moss pellet	C.	holds 6 to 12 plants

9. **List the five criteria in choosing container types.**

____ ____

____ ____

____

10. **Determine the best possible sequence for the following transplanting (seedling to pot) procedures.**

____ Hold transplant with the thumb and forefinger of your left hand at true leaves.

____ Gently press potting media around the plant and water at the media surface.

____ On a potting table, places seedlings and media on your left, and empty pots on your right.

____ Place seedling at planting depth.

____ Cover the drain with a coarse material for good drainage.

____ Fill the pot to the rim with potting media.

Multiple Choice

11. The accumulation of carbohydrates

    a. makes the plant more susceptible to disease.
    b. begins after the plant is a year old.
    c. makes the plant hardier.
    d. cannot occur in plants.

12. Hardening seedlings

    a. is a direct result of poor management.
    b. involves checking plant growth by reducing water and cooling growth condition air temperatures.
    c. is only feasible in summer annuals.
    d. requires continuous watering for 5 to 7 days.

13. Types of container material include

    a. Plastic
    b. Peat
    c. Wood fiber
    d. all of the above

Ag 514 H - Care and Transplanting of Seedlings
Unit Test
Answer Key

True or false

__**T**__ 1. Seedlings should be planted after the development of true leaves.
__**F**__ 2. Seedlings should be handled by their stems.
__**T**__ 3. Media should be kept on the seedling's roots.
__**F**__ 4. Seedlings should only be inserted a quarter of an inch below the surface of the new media.
__**F**__ 5. Do not water seedlings once they are placed in the new media to prevent premature root rot.

Matching

__**B**__ 6. Peat pot
__**A**__ 7. Market packs
__**C**__ 8. Jiffy 7 peat moss pellet

A. feeds the seedling until it is transplanted
B. one pot per seedling
C. holds 6 to 12 plants

9. List the five criteria in choosing container types.

_______________________ _______________________

_______________________ _______________________

____

Answer:
Economy
Consumer appeal
Ease of handling
Disease-free
Quality of plant growth

10. Determine the best possible sequence for the following transplanting (seedling to pot) procedures.

__3__ Hold transplant with the thumb and forefinger of your left hand at true leaves.
__6__ Gently press potting media around the plant and water at the media surface.
__1__ On a potting table, places seedlings and media on your left, and empty pots on your right.
__5__ Place seedling at planting depth.
__2__ Cover the drain with a coarse material for good drainage.
__4__ Fill the pot to the rim with potting media.

11. The accumulation of carbohydrates

    a. makes the plant more susceptible to disease.
    b. begins after the plant is a year old.
    c. **makes the plant hardier.**
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    a. Plastic
    b. Peat
    c. Wood fiber
    d. **all of the above**

Agricultural Science and Technology
Ag 514

Botany / Horticulture Plant Science

Ag 514 I - Environmental Factors of Plant Production

Unit Objectives

1. List five things plants need in order to grow.
2. Identify the most important requirement for plant growth and survival.
3. Identify the most important factor affecting the adaptation of plants to a particular region.
4. Identify a plant's macroenvironment.
5. Identify a plant's microenvironment.
6. Define the three areas of the plant environment.
7. Describe the components of the atmospheric environment.
8. Define four elements of weather.
9. State the effects of light, temperature, moisture, and wind on plants.
10. Discuss the factors which variate temperature.
11. Describe the components of the edaphic environment.
12. List the components of soil which influence plant growth.
13. Describe the influences of a soil's media on the growth of plants.
14. Define soil biomass.
15. Describe the negative and positive influences of the biotic environment on the growth of plants.
16. Indicate the components of the best strategy for plant culture.
17. List five elements of record-keeping in plant culture.

18. Relate plant culture record-keeping to the scientific method.

Information

1. List Five Things Plants Need in Order to Grow
📖
2. Identify the Most Important Requirement for Plant Growth and Survival
📖
3. Identify the Most Important Factor Affecting the Adaptation of Plants to a Particular Region
📖
4. Identify a Plant’s Macroenvironment
📖
5. Identify a Plant’s Microenvironment
📖
6. Define the Three Areas of the Plant Environment
📖
7. Describe the Components of the Atmospheric Environment
📖
8. Define Four Elements of Weather
📖
9. State the Effects of Light, Temperature, Moisture, and Wind on Plants
📖
10. Discuss the Factors Which Variate Temperature
📖
11. Describe the Components of the Edaphic Environment
📖
12. List the Components of Soil Which Influence Plant Growth
📖

13. Describe the Influences of a Soil's Media on the Growth of Plants

14. Define Soil Biomass

15. Describe the Negative and Positive Influences of the Biotic Environment on the Growth of Plants

16. Indicate the Components of the Best Strategy for Plant Culture

17. List Five Elements of Record-Keeping in Plant Culture

18. Relate Plant Culture Record-Keeping to the Scientific Method

Five Requirements for Plant Growth:

1. Sunlight
2. Temperature
3. Moisture
4. Air
5. Nutrients

Most Important Requirement for Plant Growth and Survival
= Water

Most Important Factor Affecting the Adaptation of Plants to a Region
= Temperature

Temperature varies with:
Latitude
Altitude
Topography.
Temperature is created by heat energy, in the form of solar radiation.

Plant adaptation to cold temperatures is known as a plant's **hardiness**.
Tender plants cannot tolerate extremes in cold temperatures.

Evaporation

Water changes from a liquid to a gaseous state.

Surface temperature / variating factors

Heat transfer from the surface as it warms from the morning sun to the atmosphere, as it cools at night.

Plant growth is greater at night, when temperatures cool.

Seasonal fluctuations in temperature influence growth by determining the optimum length of growing conditions for a plant species.

Higher altitudes and northern latitudes are associated with **colder** temperatures.

South- and south-western facing slopes receive more solar radiation.

The macroenvironment

The atmosphere surrounding a plant.

The microenvironment

The area at ground level immediately surrounding a plant.

Microenvironments can be manipulated to support plant growth.

The Three Areas of the Plant Environment

Atmospheric
Edaphic
Biotic

Atmospheric Environment

Includes the macroenvironment of the plant.

Can include simulated plant environment (e.g., greenhouse) or natural plant environment.

Atmospheric conditions include:

Temperature
Moisture
Light
Wind.

Weather systems tend to be regionally consistent, and play a large role in plant adaptation.

Pressure systems
Temperature
Topography (slope / face)
Wind

Cycles of day and night effect plant growth, exhibited by comparing plant growth at different latitudes.

Temperature is affected by latitudinal distance from the equator.

How much light and the type of light a plant receives affects its growth cycle.

Angular rays of morning promote cellular elongation.

Perpendicular rays of midday promote cellular stunting.

Plants receiving both types of rays exhibit normal growth.

Direct sun causes compact growth.

Shading creates longer, taller plants.

Water

Protoplasm in plant cells is primarily water.
Water uptake increases cell turgidity.
Water is essential to increase plant hardiness in hot weather.

Water vapor

Transpiration (absorption, transport, and release of water to the atmosphere) cools leaves.
Evapotranspiration (ET) is the rate of transpiration as affected by the rate of evaporation. The ET rate is used because it is difficult to distinguish where water vapour is coming from - soil evaporation or plant transpiration.

Moisture availability to plants

Precipitation (rain and snow)
Water vapor (relative humidity)
Dew (condensation - when air temperature is warmer than surfaces)

Wind / air movement

Velocity is the key factor.
Breezes cool a plant in hot weather.
Storms can damage or destroy plants.

Edaphic Environment

Soil environment surrounding the plant.

Soil horizons
Soil particle structure
Soil organic matter
Water movement through the soil

Percolation (from surface into soil structure)
Capillary (wicking action upward)
Gravitational (downward flow)

Aeration

Air into and through soil
Upward and out of soil

Temperature

Soil warmth is essential for seed germination.

pH

Soil acidity or alkalinity creates conditions for plant adaptation and growth.

Salinity

Soil salinity (salt in the soil) creates conditions for plant adaptation and growth. Plants vary in their tolerability to saline conditions.

Biomass

Source of organic matter in soil.
Living (standing crop matter and living organisms).

Non-living (decomposing and decomposed (humus) vegetative and animal matter).
A healthy soil has a diverse biomass for its source.
Competition for water, space, and light is balanced between plants.
Competition between organisms is balanced within the soil, allowing plant roots to receive essential nitrogen.

Biotic and Abiotic Environment

Biotic: living components of the biosphere.
Abiotic: non-living (physical and chemical) components of the biosphere.

Biotic factor: the influence of organisms upon other organisms (i.e., shading, competition, symbiosis, commensalism, parasitism).
Includes man's influence on plant life by cultural practices, or by creating damaging conditions for plants.

Negative influences:
Soil compaction compression of soil, reducing availability of water and air; limits root growth.
Wear Loss of vegetation due to excess traffic through an area (i.e., a worn path through a lawn).
Wasteful pesticide management
Over-fertilization
Wasteful irrigation practices.

Positive influences:
Selection of adaptive plant species for use in the landscape.
Limited cultural practices on plants (limited to the basics).

Best strategy is to incorporate best management practices in plant culture:
Selective pruning
Selective fertilization and irrigation
Composting
Mulching
Soil aeration
Integrated pest management
Controlled impact zones (minimize compaction and wear).

Record-keeping in plant culture - a best management practice.

Successful record-keeping includes:
Deciding **what data** needs to be recorded
The **most useful system** of recording the data
Easy access to the recorded information.

Crop records should include five basic elements of plant culture

In each batch:

1. Variety and propagation date (seeds or cuttings)
2. Number of seeds / cuttings sown
3. Number of transplants / date
4. Ready-for-plant date
5. Cultural procedures used for the particular plant variety, including containers used (germination, transplant, and sale containers, if different).

Records should correspond with container labels.

Good record keeping is essential to good science.
Recording allows the prediction of outcomes and the anticipation of possible problems (unexpected variables).
Good records lead to problem resolution based on facts (occurrences).
Facts are generalizable to similar situations, making their application useful to predict similar outcomes (increasing dependability of results).

References

1. Allaby, M. (ed.). (1992). *The Concise Oxford Dictionary of Botany*. Oxford, UK: Oxford University.
2. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
3. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
5. University of Wisconsin. (1995). *Exploring with Wisconsin Fast Plants*. Dubuque, IA: Kendall / Hunt.

Student Activities

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt:

- **Modifying the Atmosphere** (pp. 171-178)

From *The Growing Classroom*, Addison-Wesley:

- **The Station Creation** (pp. 289-291)
- **Keeping Track** (pp. 292-294)
- **I'm the Hottest** (pp. 298-300)
- **A Ravishing Radish Party** (pp. 301-304)
- **A Shoebox of Sunshine** (pp. 307-309)
- **A Journey to Different Lands** (pp. 312-314)

Internet Resources

2. Horticulture Environment
http://128.146.143.171/hvp/TMI/Hort210/HortScience/HortEnviron.html

Handout

- **Record Keeping**

Transparency

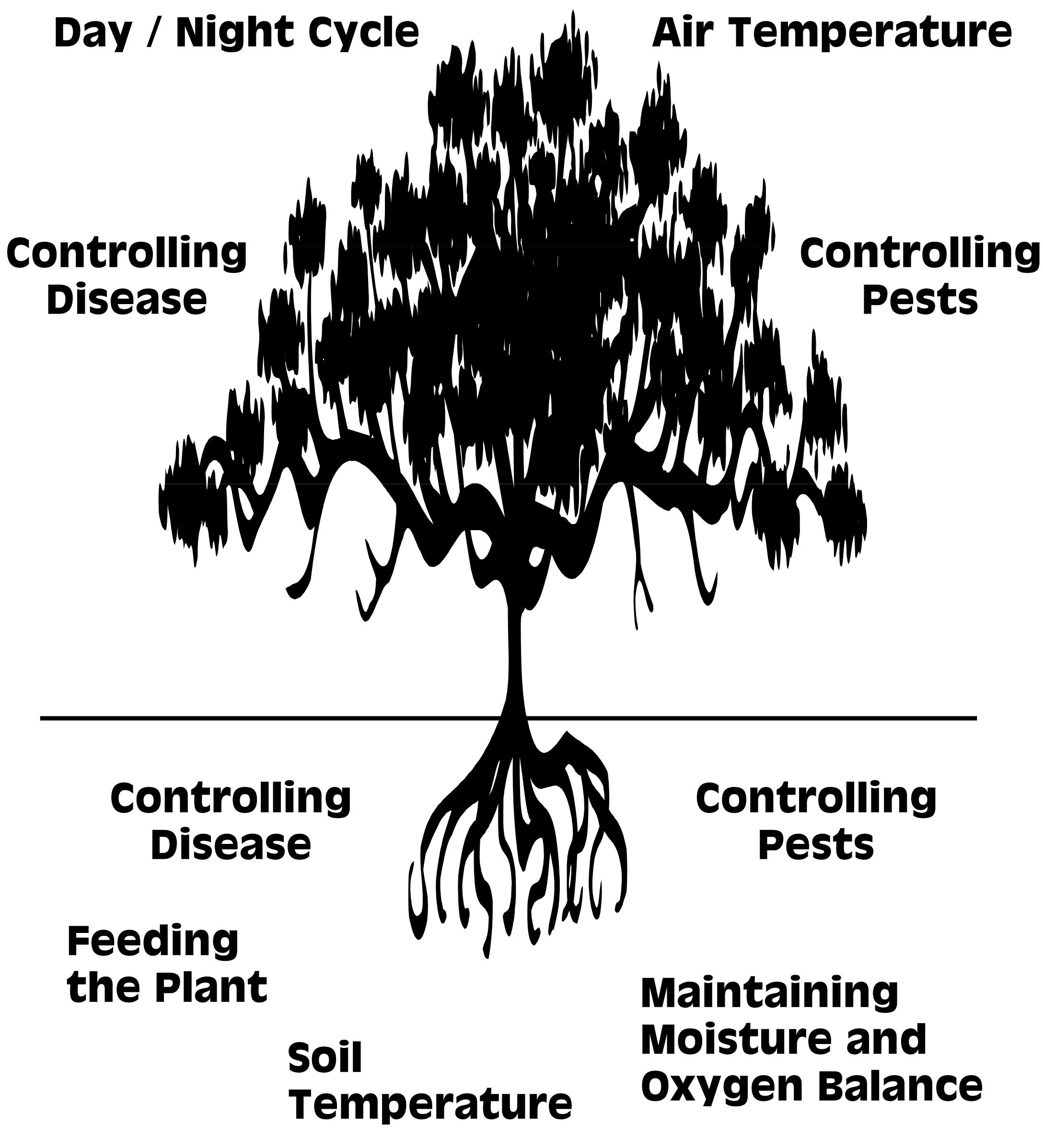
- **Optimizing the Biotic Environment**

Record Keeping

Records should correspond with container labels . . .

Variety and Propagation Date	Number of Seeds / Cuttings Sown (Indicate seed or cutting)	Container Type	Number of Transplants & Date	Container Type	Ready-for-Plant Date	Container (if different)
Culture:						

Optimizing the Biotic Environment



TM.514.I15-16

Ag 514 I - Environmental Factors of Plant Production
Unit Test

1. List the five requirements for plant growth.

____ ____

____ ____

____

2. The __________________ includes the living components of the biosphere while the ______________________ includes the non-living components.

Multiple Choice

3. The most important requirement for plant growth and survival is

   a. water.
   b. sunlight.
   c. the proper gestation of seeds.
   d. air.

4. The most important factor affecting the adaptation of plants to a region is

   a. soil biomass.
   b. temperature.
   c. the percentage of herbivores.
   d. variation in other plant species.

5. Water is essential to plant growth in that it

   a. increases the turgidity of a cell.
   b. transpires in order to cool leaves.
   c. is the primary component of plant cells.
   d. all of the above

6. Wind affects plant growth

   a. by ridding plants of potentially harmful insects.
   b. by clearing away dry soil.
   c. by cooling or damaging the plant.

d. in no significant way.

7. The edaphic environment is

a. the uncultivated area surrounding a cultivated segment of land.
b. the soil environment surrounding the plant.
c. significant only to the flowering part of a plant.
d. an environment not concerned with plant propagation.

8. The source of organic matter is soil is

a. aeration.
b. pH.
c. water movement.
d. biomass.

9. The influence of organisms upon other organisms is

a. the biotic factor.
b. the biotic environment.
c. almost always negative.
d. not a concern with plant growth.

10. One of the best management practices in plant culture is

a. making sure the soil is compacted.
b. using more than one fertilizer.
c. good record keeping.
d. avoiding the use of herbicides.

True or False

____ 11. A plants ability to adapt to cold temperatures is known as the plant's hardiness.
____ 12. Tender plants can tolerate cold temperature extremes.
____ 13. In evaporation, water changes from a solid to a liquid state.
____ 14. Plant growth is greater at night since the temperatures are cooler.
____ 15. Seasonal fluctuations in temperature do not effect plant growth.
____ 16. Higher altitudes and northern latitudes are associated with colder temperatures.
____ 17. South and south-western facing slopes receive more solar radiation.

Matching

____ 18. The areas of the plant environment
____ 19. Macroenvironment
____ 20. Atmospheric Environment
____ 21. Weather systems
____ 22. Microenvironment

A. conditions include temperature, moisture, light, and wind
B. the atmosphere surrounding the plant
C. the area at ground level immediately surrounding the plant which can be manipulated to support plant growth
D. atmospheric, edaphic, and biotic
E. regionally consistent; includes pressure systems, temperature, topography, and wind.

23. Plants which receive both ______________ and ______________ exhibit normal growth.

24. What are some of the best management strategies to incorporate in order to impact plant positively? (List at least five).

____

____

____

____

____

Ag 514 I - Environmental Factors of Plant Production
Unit Test
Answer Key

1. **List the five requirements for plant growth.**

_______________________________________ _______________________________________

_______________________________________ _______________________________________

____

Answers
Sunlight
Temperature
Moisture
Air
Nutrients

2. The _________________ includes the living components of the biosphere while the _____________________ includes the non-living components.

Answers: the biotic environment and the abiotic environment

Multiple Choice

3. The most important requirement for plant growth and survival is

    a. **water.**
    b. sunlight.
    c. the proper gestation of seeds.
    d. air.

4. The most important factor affecting the adaptation of plants to a region is

    a. soil biomass.
    b. **temperature.**
    c. the percentage of herbivores.
    d. variation in other plant species.

5. Water is essential to plant growth in that it

    a. increases the turgidity of a cell.
    b. transpires in order to cool leaves.
    c. is the primary component of plant cells.

d. **all of the above**

6. Wind affects plant growth

a. by ridding plants of potentially harmful insects.
b. by clearing away dry soil.
c. **by cooling or damaging the plant.**
d. in no significant way.

7. The edaphic environment is

a. the uncultivated area surrounding a cultivated segment of land.
b. **the soil environment surrounding the plant.**
c. significant only to the flowering part of a plant.
d. an environment not concerned with plant propagation.

8. The source of organic matter is soil is

a. aeration.
b. pH.
c. water movement.
d. **biomass.**

9. The influence of organisms upon other organisms is

a. **the biotic factor.**
b. the biotic environment.
c. almost always negative.
d. not a concern with plant growth.

10. One of the best management practices in plant culture is

a. making sure the soil is compacted.
b. using more than one fertilizer.
c. **good record keeping.**
d. avoiding the use of herbicides.

True or False

__T__ 11. A plants ability to adapt to cold temperatures is known as the plant's hardiness.
__F__ 12. Tender plants can tolerate cold temperature extremes.
__F__ 13. In evaporation, water changes from a solid to a liquid state.
__T__ 14. Plant growth is greater at night since the temperatures are cooler.
__F__ 15. Seasonal fluctuations in temperature do not effect plant growth.

__T__ 16. Higher altitudes and northern latitudes are associated with colder temperatures.
__T__ 17. South and south-western facing slopes receive more solar radiation.

Matching

__D__ 18. The areas of the plant environment
__B__ 19. Macroenvironment
__A__ 20. Atmospheric Environment
__E__ 21. Weather systems
__C__ 22. Microenvironment

A. conditions include temperature, moisture, light, and wind
B. the atmosphere surrounding the plant
C. the area at ground level immediately surrounding the plant which can be manipulated to support plant growth
D. atmospheric, edaphic, and biotic
E. regionally consistent; includes pressure systems, temperature, topography, and wind.

23. Plants which receive both ______________ and ______________ exhibit normal growth.
    Answer: angular rays and perpendicular rays

24. What are some of the best management strategies to incorporate in order to impact plant positively? (List at least five).

____

____

____

____

____

Answers can include:
Selective pruning
Selective fertilization and irrigation
Composting
Mulching
Soil aeration
Integrated pest management
Controlled impact zones

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 J - Introduction to Asexual Propagation

Unit Objectives

1. Match terms and definitions relating to asexual plant propagation.
2. List the methods of asexual plant propagation.
3. List the reasons for using asexual plant propagation.
4. Select cuttings that require leaves.
5. Select cuttings that do not require leaves.
6. List the main types of propagating by layering.
7. List the requirements for layering.
8. Describe propagation by division.
9. List the methods of propagating by budding.
10. List the methods of grafting.

Information

1. Match Terms and Definitions Relating to Asexual Plant Propagation

2. List the Methods of Asexual Plant Propagation

3. List the Reasons for Using Asexual Plant Propagation

4. Select Cuttings that Require Leaves

5. Select Cuttings that Do Not Require Leaves

6. List the Main Types of Propagating by Layering

7. List the Requirements for Layering

8. Describe Propagation by Division

9. List the Methods of Propagating by Budding

10.List the Methods of Grafting

Asexual plant propagation

Reproduction of new plants from the stem, leaf, or root of the parent plant.

Method of asexual plant propagation

- **Cuttings**
  - **Stem**
    - **Softwood**
    - **Hardwood**
    - **Semi-hardwood**
  - **Leaf**
  - **Leaf-bud**
  - **Root**

Placed in soil or soilless media.
Placed in test tubes containing nutrients in a liquid media.
Grafting
Budding
Layering
Separation
Division
Tissue Culture

Reasons for asexual plant propagation

Cloning

Reproduction by DNA replication retains all the genetic information of the parent plant.
Retains the unique characteristics of a plant.
Necessary to grow cultivars that do not produce viable seeds; i.e., bananas, figs, oranges, & grapes.
More economical for production of some species that do not reproduce well from seed.
Faster than slow-growth seedlings.
Used to avoid undesirable features of the juvenile stage; e.g., thorns.
Maintaining juvenile phase of a plant for cuttings in species where the juvenile plants root more readily than older plants.
Produce disease-free plants from parent plants (particular to tissue culture).

Cuttings that require leaves

Leaf cutting

Leaf blade
Leaf blade with attached petiole

Used when plant material is scarce.
Large numbers of new plants are needed.
Commonly used to produce foliage houseplants.

Leaf-bud cutting

Leaf, petiole, and a short piece of stem that includes a lateral bud

Used when woody plant material is scarce.
Large numbers of new plants are needed.
Buds should be well-developed for use in a cutting.

Cuttings that do not require leaves

Root cutting

From root pieces of young plants.

Grafting

Connecting two parts or plant parts together to grow as one plant.
Graft consists of scion and understock.

Scion short piece of stem with two or more buds
Understock (rootstock) lower portion which develops a root system.

Graft types:
Whip-and-tongue
Cleft
Bark.

Budding
Single-bud scion joined to an understock.
Budding types:
T-budding
Patch budding.

Layering
Roots are formed on a stem while attached to the parent plant.
Requirements for layering:
Continuous moisture
Good aeration
Moderate temperatures in the rooting zone.
Layering types:
Simple
Air.

Separation
Vegetative reproductive parts which are separated from the parent plant and planted.
Separation types:
Bulbs
Corms.

Division
Parts of plants are cut or divided into sections that will grow into new plants.
Division types:
Rhizomes
Tubers
Plant crowns.

Tissue culture
Also known as **micropropagation**.
Taking plant tissue or cells from a parent plant and growing them on or in a sterile, artificial medium to produce a plantlet with its own leaves, stems, and root system.
Tissue culture types:
Callus
Cell suspension
Embryo
Meristem
Anther.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T. & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
3. University of Wisconsin. (1995). *Exploring with Wisconsin Fast Plants.* Dubuque, IA: Kendall / Hunt.

Student Activities

- **Check It Out!**

From *Exploring with Wisconsin Fast Plants*, Kendall / Hunt:
- **Design a Plant** (p. 242)

Internet Resources

3. Horticulture Technology
http://128.146.143.171/hvp/TMI/Hort210/HortScience/HortTech.html

Asexual Propagation
http://hammock.ifas.ufl.edu/txt/fairs/11660

Hort 100 University of Illinois at Urbana-Champaign
Modified Stems and Roots
http://classes.aces.uiuc.edu/Hort100/contents.htm

T-Bud Grafting
http://classes.aces.uiuc.edu/Hort100/tbud/index.htm

Asexual propagation of wild and mutant strains of Arabidopsis in liquid and solid media
A. Corcos & R. Lewis
Michigan State University
http://genome-www.stanford.edu/Arabidopsis/ais/1972/corco-1972-aagwd.html

Plant Tissue Culture Information Exchange
http://aggie-horticulture.tamu.edu/tisscult/tcintro.html

Horticulture 201 H Plant Propagation
(See “Lecture Slides” & “Web Links”)
http://aggie-horticulture.tamu.edu/syllabi/cnotes96a/201H/lecoutlines/lecture22.html

Transparencies

See the slide set from *Propagation*, Texas A&M University:
Propag.ppt (need PowerPoint Viewer 4.2 or better) *or*

Propag.pdf at . . .
http://aggie-horticulture.tamu.edu/syllabi/cnotes96a/201H/lecoutlines/lecture22.html

Student Activity: Check It Out!

Purpose

- Understand the methods of asexual propagation.

Materials

- Notebook
- Hand-held tape recorder
- Camera (35mm / film for slides) or
- Videotape recorder

Procedure

Congratulations! You're the reporter for a story on plant propagation procedures. You plan to focus on *one* procedure of asexual propagation for a horticultural / gardening magazine or for a local TV broadcast on gardening.

Every good reporter needs prepared questions. Think about what you want to know about the "how-to" of asexual propagation. Consider how a good story is written:

> **Ask the questions** that will reveal the **who, what, when, where, how and why** for your story.

Prepare your questions and set up the interviews at a local greenhouse or at a local nursery.

Prepare for the interview! Remember your notebook, tape recorder, and camera (you may use a videotape recorder in substitute for the tape recorder and camera if you have that option).
The tape recorder is to back up your handwritten notes. Always take handwritten notes!

Record the procedures for asexual propagation at a local nursery and greenhouse. Interview the person doing the procedure. Record their name, the date, and the location of the interview. Take pictures of the steps of the procedures. Be sure to record the steps in your notebook along with where you're at on the film (you'll be glad you did later!).

Write your story!
Present a slide presentation of the procedure.

Or

Write your story, and present your broadcast videotape of the story.

Teacher Notes:

Each student should present one procedure. Depending on class size and access to equipment, students may write a story on the same procedure, but divide it according to a videotape for TV broadcast, a paste-up or computer-generated layout of a magazine article, and a slide presentation.

Ag 514 J - Introduction to Asexual Plant Propagation
Unit Test

1. The reproduction of new plants from the stem, leaf, or root of the parent plant is called

   ____.

2. Identify the seven methods of asexual propagation.

   _________________________________ _________________________________

   _________________________________ _________________________________

   _________________________________ _________________________________

   ____

3. List five reasons for asexual plant propagation.

   ____

   ____

   ____

   ____

   ____

4. When plant material is scarce, or large numbers of new plants are needed, use

   a. leaf cuttings with either a leaf blade or a leaf blade with attached petiole.
   b. a root cuttings.
   c. bulbs.
   d. none of the above.

5. In a leaf-bud cutting, buds should be

   a. carefully trimmed off the stem
   b. under-developed.
   c. well-developed.

d. along the same side of the short piece of stem.

6. Connecting two parts or plant parts together to grow as one plant is referred to as

a. rooting cutting.
b. grafting.
c. budding.
d. layering

7. Tissue culturing is known as

a. cell suspension.
b. patch budding.
c. micropropagation.
d. T-budding.

8. Rhizomes, tubers and plant crowns are types of

a. division cutting.
b. separation cutting.
c. layering.
d. budding.

Matching

____ 9. Root cutting
____ 10. Scion
____ 11. Understock (rootstock)
____ 12. Whip-and-tongue, cleft, and bark
____ 13. Budding
____ 14. Layering
____ 15. Separation
____ 16. Division
____ 17. Tissue culture

A. Graft types
B. Cut from root pieces of young plants
C. Vegetative reproductive parts which are separated from the parent plant and planted
D. Parent plant tissue grown on or in a sterile, artificial medium to produce a plantlet
E. Short piece of stem with two or more buds
F. Plant parts cut or divided into sections that will grow into new plants
G. Single-bud scion joined to an understock
H. Lower portion or grafted stem which develops a root system
I. Roots are formed on a stem while attached to the parent plant

Ag 514 J - Introduction to Asexual Plant Propagation
Unit Test
Answer Key

1. The reproduction of new plants from the stem, leaf, or root of the parent plant is called

   Answer: Asexual Reproduction

2. Identify the seven methods of asexual propagation.

   Answers:
   Cuttings
   Grafting
   Budding
   Layering
   Separation
   Division
   Tissue Culture

3. List five reasons for asexual plant propagation.

   Answers:
   Reproduction by DNA replication retains all the genetic information of the parent plant.
   Retains the unique characteristics of a plant.
   Necessary to grow cultivars that do not produce viable seeds.
   More economical for production of some species that do not produce well from seed.
   Faster than slow-growth seedlings.
   Used to avoid undesirable features of the juvenile stage.
   Maintaining juvenile plase of a plant for cuttings in species where the juvenile plants root more readily than older plants.
   Produce disease-free plants from parent plants (particular to tissue culture).

4. When plant material is scarce, or large numbers of new plants are needed, use

   a. **leaf cuttings with either a leaf blade or a leaf blade with attached petiole.**
   b. a root cuttings.
   c. bulbs.
   d. none of the above.

5. In a leaf-bud cutting, buds should be

a. carefully trimmed off the stem
b. under-developed.
c. **well-developed.**
d. along the same side of the short piece of stem.

6. Connecting two parts or plant parts together to grow as one plant is referred to as

a. rooting cutting.
b. **grafting.**
c. budding.
d. layering

7. Tissue culturing is known as

a. cell suspension.
b. patch budding.
c. **micropropagation**.
d. T-budding.

8. Rhizomes, tubers and plant crowns are types of

a. **division cutting.**
b. separation cutting.
c. layering.
d. budding.

Matching

__**B**__ 9. Root cutting

__**E**__ 10. Scion

__**H**__ 11. Understock (rootstock)

__**A**__ 12. Whip-and-tongue, cleft, bark

__**G**__ 13. Budding

__**I**__ 14. Layering

__**C**__ 15. Separation

__**F**__ 16. Division

__**D**__ 17. Tissue culture

A. Graft types
B. Cut from root pieces of young plants
C. Vegetative reproductive parts which are separated from the parent plant and planted
D. Parent plant tissue grown on or in a sterile, artificial medium to produce a plantlet
E. Short piece of stem with two or more buds
F. Plant parts cut or divided into sections that will grow into new plants
G. Single-bud scion joined to an understock
H. Lower portion or grafted stem which develops a root system

I. Roots are formed on a stem while attached to the parent plant

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 K - Propagation and Cuttings

Unit Objectives

1. Match terms and definitions associated with propagation by cuttings.
2. List treatments made to cuttings before placing them in rooting media.
3. List the basic kinds of plant wounding.
4. Explain the use of hormone treatment on cuttings.
5. Describe why storage and callusing are used with hardwood cuttings.
6. Demonstrate the ability to make various types of wounds on cuttings.
7. Demonstrate how to treat a cutting with hormone.
8. Describe how to store and calluse plant cuttings.
9. Demonstrate the propagation of a stem cutting.
10. Demonstrate a bud cutting.
11. Demonstrate a leaf cutting.
12. Demonstrate a root cutting.

Information

1. Match terms and definitions associated with propagation by cuttings
2. List treatments made to cuttings before placing them in rooting media
3. List the basic kinds of plant wounding
4. Explain the use of hormone treatment on cuttings
5. Describe why storage and callusing are used with hardwood cuttings
6. Demonstrate the ability to make various types of wounds on cuttings
7. Demonstrate how to treat a cutting with hormone
8. Describe how to store and callus plant cuttings
9. Demonstrate the propagation of a stem cutting
10. Demonstrate a bud cutting
11. Demonstrate a leaf cutting
12. Demonstrate a root cutting

Cuttings

Leaves, pieces of stems, or roots used for plant propagation.

Softwood cuttings

Taken from new spring growth of herbaceous or woody plants.

Materials:

Cuttings are 3-5 inches in length, including 2 or 3 nodes.

Procedure:

Cut at 45 degree angle ¼ inch below a node.
Remove 1/3 of the lower leaves to reduce loss through transpiration.
Cut large leaves in half to reduce wilting.
Remove all flower buds.
Place in growing medium.

Hardwood cuttings

Taken during the dormant season of deciduous plants or evergreens.

Materials:

Cuttings are 6-8 inches in length, taken from 1-year-old wood.

Procedure:

Place in growing medium.
Over the winter cuttings form callus tissue (tissue that forms over the cutting wounds) at base of the cuttings.
In the spring, new roots sprout from the callused tissue.

Leaf cutting

Materials:

Leaf blade, or leaf blade with petiole (leaf stem)

Procedure:

Leaf blades are cut across primary veins, laid top surface up, and pinned to the surface of a growing medium.
New plants form at the each cut.

With petiole:

Leaf blade with petiole attached is inserted in the growing medium.
New roots and shoots emerge from the base of the petiole.
The original leaf is pinched off, and the new plant is replanted.

Leaf-bud cuttings

Materials:

Leaf with petiole attached to part of stem with a lateral bud

Procedure:

Treat stem with rooting hormone
Insert in a growing medium with the lateral bud just below the surface
A new plant will develop from the lateral bud.

Root cuttings

Materials:

Root pieces of young plants taken during late winter or early spring.

Procedure:
Dig roots up, clean, and treat with fungicide.
Cut root pieces 2 to 6 inches in length.
Place either:
Horizontally 2 inches deep in growing medium *or*
Vertically in growing medium, pointing the root end that was originally close to the crown of the plant pointing up.
(Hint: to indicate correct placement, cut root closest to the main stem with a straight cut. Cut opposite to the main stem with a slant cut.)

Treatments
Rooting hormones are used to induce rooting from stem cuttings.
Fungicides are used to prevent root rot.
Hardwoods require a higher concentration of rooting hormone.
Not all herbaceous stems require rooting hormone (e.g., coleus; swedish ivy).
Maintain a mediate temperature range (about 70^0 to 80^0F).
Moisten the growing media.
Growing media used should be sterilized, hold moisture, provide aeration, and have good drainage.
Place cuttings in a plastic bag or on a misting bench to maintain humidity, preventing loss of water through transpiration.

Basal wounding
Stripping off the lower side of branches, making a vertical cut down each side of the cutting for 1 to 2 inches.
Promotes root production. Treat wound with rooting hormone, working directly into the wound.
Wounding allows:
- Increased water absorption
- Better absorption of a rooting hormone
- Better penetration of roots as they develop.

Hormone treatment:
- Increases the percentage of root-forming cuttings.
- Hastens the initiation of root formation.
- Increases the number of roots produced per cutting.
- Betters the quality of roots produced, particularly combined with wounding.
- Increases the uniformity of plants produced.

Storage and callusing hardwood cuttings
Hardwood cuttings are taken 6 to 8 weeks prior to planting.
During that time, they are treated with a rooting hormone, tied in a bundle, and stored.
Storage consists of:
- Bundling and placing cut ends in moist media (sawdust, sand, or other porous material).
  Cut ends will callus and begin to form new roots.

- Maintain a cool temperature of 50^0 to 55^0F during callus formation.
- After callus formation, lower the temperature to lower than 40^0F but not below freezing (32^0F).

Lining out cuttings

Planting woody plant (hardwood) cuttings outside in rows in the spring.
Site should have good drainage and full sunlight.
Soil should be workable (ready to plant).
Rows are prepared as narrow trenches that allow only the top bud to be above ground level.
Spacing varies according to how long the plant remains lined out and the plant's growth rate:
One year - 6 inches apart / rows one foot apart.
More than 1 year - 9 to 10 inches apart / rows 2 to 3 feet apart.
Soil surface is tamped down gently around the plants.
Soil is mulched around the plants to retain moisture and control weeds.
Watering should be as needed (do not let the soil dry out).
Cuttings will develop shoots and leaves first, and root by summer.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Ortho Books. (1995). *Easy Tips from Gardening Professionals*. San Ramon, CA: Author.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Taking Root: Propagating from Cuttings**

Internet Resources

Propagation of Landscape Plants Dewayne L. Ingram & Thomas H. Yeager
http://hammock.ifas.ufl.edu/txt/fairs/11658

Transparencies / Handouts

- **Hardwood Cuttings**
- **Leaf, Leaf-Bud, & Root Cuttings**
- **Softwood and Semi-Hardwood Cuttings**

Student Activity: Taking Root: Propagating from Cuttings

Purpose

- Demonstrate the ability to make plant cuttings and complete their propagation procedures.

Materials

Plant material
Rooting hormone
Planting media for leaf cuttings
Planting media for storage stem cuttings
Containers
Plastic bags / or access to misting bench

Plant Material / Procedural Groups:

African Violet (leaf with petiole)
Rex Begonia or Sansevieria (leaf)
Maple (leaf-bud)
Chrysanthemum (softwood)
Juniper (hardwood)

Procedure (In Two Parts)

Part One

- The class is divided according to procedural groups; i.e., types of cuttings taken.
- Within your plant group, follow the directions for completing the procedures for plant cuttings as instructed in your text, notes, and hand-outs.
- Each person will complete one entire procedure; however,
- You may work together as a group, helping each other with instructions on how to complete the procedure.
- Label your containers according to plant variety, date, and type of procedure; add your name.

Part Two

- Your group will instruct the other groups on how to accomplish your procedure.
- Each person within your group should choose a step or steps within your procedure to demonstrate to the rest of the class.
- Organize your demonstration according to the natural flow of the procedure.
- You may wish to demonstrate the procedure as a “poster session,” i.e., a demonstration to one group at a time in order to allow everyone to see the procedure and hear the instructions from close proximity.

Teacher Information

Assign the students to work in groups according to procedure type. This will allow them to instruct each other as well as learn the procedure. Each group will then instruct the other groups on the correct application of their particular procedure. Students within each group should divide the instruction of the procedure according to steps, so that each student participates in sharing the information.

f, Leaf-Bud, & Root Cuttings

e containers with rooting media.

f across primary veins.

f to surface of growing medium,
face up.

d:
af with petiole attached.

tem with rooting hormone.

n growing medium with lateral
ow surface.

ts up, clean, treat with fungicide.

t pieces 2 to 6 inches in length.

orizontally or vertically
-end up) in growing medium.

ll in plastic bag or under mist.

Hardwood Cuttings

Take wood from mature hardwood: current year's growt

Cut from ends of branches or from the base of the plant.

Cuts should be 6 to 8 inches in length.

Wound at cut vertically on both sides (about 1-2 inches).

Treat with hormone directly at wounding and base.

Tie in a bundle.

Store in rooting media at 50^{0} to 55^{0}F for 4 weeks.

Lower to 40^{0}F.

Line out plants in a sunny area when soil is workable.

Softwood and Semi-Hardwood Cuttings

Prepare the container with rooting media.

Take cuttings from new spring growth.

Cuttings should be 3-5 inches in length.

Cut at 45 degree angle 1/4 inch below node.

Remove lower leaves.
Cut large leaves in half.
Remove flower buds.

Apply rooting hormone directly to the cut (if required).

Insert the cutting into the rooting media.

Water the media.

Label the container.

Cover with plast
or place on a mi
bench.

Ag 514 K - Propagation by Cuttings
Unit Test

Fill in the blank.

1. Leaves, pieces of stems, or roots used for plant propagation are called ___________________________.

2. A cutting which utilizes the leaf blade or a leaf blade with a petiole is called a ____________ cutting.

3. The new plant develops from the ______________________ in leaf-bud cuttings.

4. ___________________________ are used to induce rooting from stem cuttings.

5. ___________________________ are take 6 to 8 weeks prior to planting.

Multiple Choice

6. In leaf cutting, leaf blades are cut across primary veins, laid top surface up, and then

   a. pinned to the surface of a growing medium.
   b. treated with a rooting hormone.
   c. cut at a 45° angle ¼ inch below a node.
   d. tied on a bundle and planted.

7. Once new roots and shoots emerge from the base of the petiole in a leaf cutting, the original leaf is

   a. treated with rooting hormone.
   b. grafted back on an adult plant.
   c. pinched off before the new plant is replanted.
   d. mulched into growing medium.

8. ___________ should be used in order to prevent root rot.

   a. Basal wounding
   b. Fungicides
   c. Callusing
   d. Misting benches

9. Basal wounding allows

   a. increased water absorption.

b. better absorption of a rooting hormone.
c. better penetration of roots as they develop.
d. all of the above.

10. Hormone treatment DOES NOT

a. increase the percentage of root-forming cuttings.
b. decrease the number of roots produced per cutting.
c. hasten the initiation of root formation.
d. better the quality of roots produced, particularly combined with wounding.

Place these Softwood and Hardwood cutting steps into their proper order.

Softwood and Semi-Hardwood Cuttings

____ Insert the cutting into the rooting media.

____ Cut in 3-5 inch lengths at a 45° angle (from new spring growth).

____ Cover with plastic, or place on a misting bench.

____ Prepare the container with rooting media.

____ Label the container.

____ Remove lover leaves, cut large leaves in half, and remove flower buds.

____ Water the media.

____ Apply rooting hormone directly to the cut (if required).

Hardwood Cuttings

____ Line out plants in a sunny area when soil is workable.

____ Cut in 6-8 inch lengths from the ends of mature hardwood branches (current year's growth).

____ After 4 weeks, lower temperature to 40°F.

____ Sore in rooting media at 50° to 55°F for 4 weeks.

____ Wound at cut vertically on both sides (about 1-2 inches).

____ Tie in a bundle.

____ Treat with hormone directly at wounding and base.

Ag 514 K - Propagation by Cuttings
Unit Test
Answer Key

Fill in the blank.

1. Leaves, pieces of stems, or roots used for plant propagation are called ___________________________
Answer: cuttings

2. A cutting which utilizes the leaf blade or a leaf blade with a petiole is called a ____________ cutting.
Answer: leaf

3. The new plant develops from the _______________________ in leaf-bud cuttings.
Answer: lateral bud

4. ____________________________ are used to induce rooting from stem cuttings.
Answer: rooting hormones

5. ____________________________ are take 6 to 8 weeks prior to planting.
Answer: hardwood cuttings

Multiple Choice

6. In leaf cutting, leaf blades are cut across primary veins, laid top surface up, and then

   a. **pinned to the surface of a growing medium.**
   b. treated with a rooting hormone.
   c. cut at a 45° angle ¼ inch below a node.
   d. tied on a bundle and planted.

7. Once new roots and shoots emerge from the base of the petiole in a leaf cutting, the original leaf is

   a. treated with rooting hormone.
   b. grafted back on an adult plant.
   c. **pinched off before the new plant is replanted.**
   d. mulched into growing medium.

8. ___________ should be used in order to prevent root rot.

   a. Basal wounding
   b. **Fungicides**
   c. Callusing
   d. Misting benches

9. Basal wounding allows

   a. increased water absorption.
   b. better absorption of a rooting hormone.
   c. better penetration of roots as they develop.
   d. **all of the above.**

10. Hormone treatment DOES NOT

    a. increase the percentage of root-forming cuttings.
    b. **decrease the number of roots produced per cutting.**
    c. hasten the initiation of root formation.
    d. better the quality of roots produced, particularly combined with wounding.

Place these Softwood and Hardwood cutting steps into their proper order.

Softwood and Semi-Hardwood Cuttings

__5__ Insert the cutting into the rooting media.

__2__ Cut in 3-5 inch lengths at a 45° angle (from new spring growth).

__8__ Cover with plastic, or place on a misting bench.

__1__ Prepare the container with rooting media.

__7__ Label the container.

__3__ Remove lover leaves, cut large leaves in half, and remove flower buds.

__6__ Water the media.

__4__ Apply rooting hormone directly to the cut (if required).

Hardwood Cuttings

__7__ Line out plants in a sunny area when soil is workable.

__1__ Cut in 6-8 inch lengths from the ends of mature hardwood branches (current year's growth).

__6__ After 4 weeks, lower temperature to 40°F.

__5__ Sore in rooting media at 50° to 55°F for 4 weeks.

__2__ Wound at cut vertically on both sides (about 1-2 inches).

__4__ Tie in a bundle.

__3__ Treat with hormone directly at wounding and base.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 L - Propagation by Layering

Unit Objectives

1. List the advantages and disadvantages of propagation by layering.
2. List the types of layering.
3. Identify the steps in transplanting layering plants.
4. Demonstrate how to propagate by tip, simple, and air layering.

Information

1. List the Advantages and Disadvantages of Propagation by Layering

2. List the Types of Layering

3. Identify the Steps in Transplanting Layering Plants

4. Demonstrate How to Propagate by Tip, Simple, and Air Layering

Advantages of Layering

- Ease and simplicity of process: the new plant receives water and nutrients from the parent plant, and the process of layering is very simple.
- Great degree of success with layering as a rooting technique.
- Larger new plants can be produced.
- Many plants root naturally by layering.

Disadvantages of Layering

- Only a few plants can be produced from each parent plant.
- Layering takes more time to complete the initial process and to produce plants.

Types of Layering

Tip (natural layering)
Simple
Air
Trench
Stool
Compound or serpentine

Tip

Natural reproduction method by cane or trailing plants such as blackberries and black raspberries.

Procedure:
Space plants 12 feet apart.
Cut plants down to 9 inches above the ground.
Pinch off 3 to 4 inches after a growth of about 18 to 30 inches.

Canes will begin to arch over.
Tips will assume a “rat-tail” appearance.
At that time, layer plants by placing tip in a hole with the shoot lying along the sloping side, with soil pressed firmly over it.
The tip will form roots and a vertical shoot.
Transplant:
When cutting the transplant from the parent plant, keep 6 to 8 inches of the original cane to serve as a handle to mark the plant, and to help remove the plant from the soil when you are ready to replant it.
Replant in the fall at the end of the season, or in early spring.

Simple

Use dormant, one-year-old shoots.
Layer in early spring or after current season’s growth is sufficient for layering (e.g. magnolia; rhododendron).
Procedure:
Bend the branch to the ground and cover the bend partially with soil or rooting medium.
Insert the bent part of the branch 3 to 6 inches into the soil.
Hold the bent section of the branch by placing a wooden peg over the branch (or a wire, or place a stone on top of the bent portion).
Additionally, you may twist the bend to loosen it, cut it, or notch it to induce rooting.
Notching the highest portion of the upside bend helps to loosen inflexible branches.
Leave the terminal end exposed as an upright shoot.
Insert a vertical stake next to the exposed shoot to hold it upright.
Remove in the fall or the following spring before growth starts.
Summer layered plants should not be harvested until the following spring or the end of that growing season.
Transplant:
Pot in a peat-sand mixture and keep cool and humid, held in a cold frame or shaded greenhouse.
Line out, reducing top to a size corresponding to the root system.

Air

Slitting stem of a plant at an upward angle, or girdling the stem to induce rooting.
Wound is covered in rooting medium and kept moist.
Use wood of previous season’s growth (spring), or late summer.
Procedure:
Girdle bark around stem 6 to 12 inches from the tip.
Remove the bark completely from the stem, in a band about ½ to 1 inch wide.
Scrape the exposed surface to remove the phloem and cambium, which retards wound healing.
Apply rooting hormone.
Pack wet sphagnum moss around the wound, completely covering the band.
Squeeze the moss until dry.
Snugly wrap the wound with the moss covering in polyethylene plastic film.

Secure both ends with electrician's tape, tight enough to make a waterproof seal (the branch may require support).
Transplant:
Observe the root formation through the plastic film.
If the transplant is a deciduous plant, wait until the plant is dormant (wait until the leaves fall from the plant).
If evergreen, remove the plant when no new active growth is apparent.
Cut below the rooted area.
Place in a container with media appropriate to the plant, and place in a cool, humid area.
Allow additional root development before hardening off the plant.
Harden off by exposure to a drier atmosphere.

Trench
Parent plant is bent to the ground and buried in a trench.
Shoots form from dormant buds.
Soil is filled in around the new shoots as they develop, protecting them from sunlight.
Roots develop from the base of the new shoots.
After dormancy, plants are removed from the original plant.
Used on fruit trees difficult to propagate by other means.

Stool (or mound)
Cut the parent plant to the ground during dormancy.
Mound soil around new shoots emerging in the spring to encourage rooting.
The established shoots are cut free in the autumn or following spring, lined out and planted.

Compound (serpentine)
Similar to simple layering.
Stem is girdled at more than one point along its length, and buried at those points (the stem is alternately exposed and buried).
At least one bud should be exposed to develop a new shoot.
Roots develop from the buried sections.
At the end of the growing season, the branch is cut into new sections containing the new shoot and root portions.
This method makes it possible to develop several plants from one branch.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Starting Plants by Layering**

Internet Resources

NebGuide
Propagating House Plants
http://ianrwww.unl.edu/IANR/PUBS/extnpubs/hort/g337.htm

Horticulture 201H Plant Propagation
http://aggie-horticulture.tamu.edu/syllabi/cnotes96a/201H/lecoutlines/lecture22.html

Table 1a. Propagation Methods for Landscape Plants
http://hammock.ifas.ufl.edu/txt/fairs/48087

Table 1b. Propagation Methods for Landscape Plants
http://hammock.ifas.ufl.edu/txt/fairs/48088

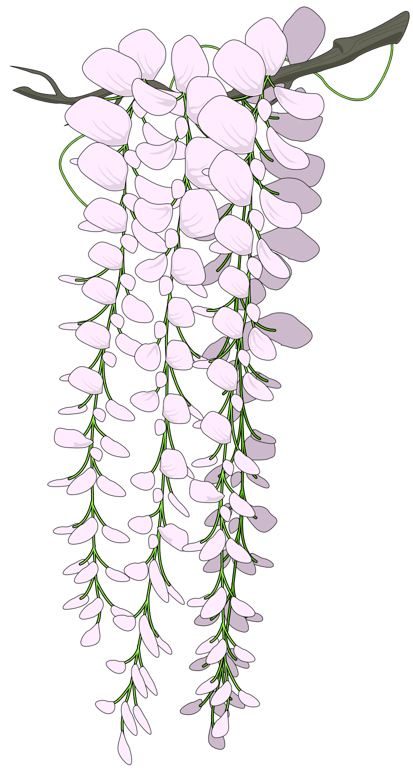
Layering
http:hammock.ifas.ufl.edu/txt/fairs/48084

H400 Layerage Lecture Images
http://www.cals.cornell.edu/dept/flori/hort400/layer.html

Transparencies / Hand-Outs

- **Air Layering**
- **Simple Layering**
- **Tip Layering**

Student Activity: Starting Plants by Layering



Purpose

- Demonstrate how to propagate by tip, simple, and air layering.

Materials

Plant material
Rooting media (appropriate to corresponding plant material)
Bedding containers (large, clear plastic square tubs about 7 to 10 inches deep).
Polyethylene plastic film wrap
Sphagnum moss
Electricians tape (waterproof)
Rooting hormone

Procedure

- Students will be divided into three groups according to tip, simple, and air layering.
- Each group will be assigned the demonstration of one method of layering.
- Each group participant will complete a layering propagation procedure.
- See hand-outs and notes on layering and follow the procedures.
- Each group will present the method of layering they completed to the other two groups in poster sessions.

A poster session consists of a display and talk, or display, demonstration, and talk on a subject that is presented to small numbers of people at a time who visit the poster display.

⇒ The group should work together in putting on their poster session: make individual assignments for creating the poster, the demonstration, and the presentations.

⇒ Individuals in the group are responsible for a group evaluation at the close of the group assignment.

Notes

Teacher Information

- You are the final evaluator for the student's procedural work on layering and the group's progress on completing and presenting their poster session.
- The students should evaluate each other's participation in the poster session. The group evaluation is a way to measure group function and participation, and to assess the student's view of their experience in learning by doing. See the form: "Group Evaluation" for use by the students.

Group Evaluation

The ability to work in groups is an important segment of real-world work experience. Please evaluate your participation and the participation of your fellow group members. Be honest and objective. Your instructor will discuss the evaluations with you.

Name:	
Group name:	
Group participants:	

Please indicate your participation according to the following:

(*Please check one*)

- ☐ I completed the layering procedure.
- ☐ I did not quite finish the layering procedure.
- ☐ I got halfway through the layering procedure.
- ☐ I tried the layering procedure.
- ☐ I did not attempt the layering procedure.

(*Please check one*)

- ☐ I completed my assignment for the poster session.
- ☐ I almost completed my assignment for the poster session.
- ☐ I co-completed an assignment for the poster session.
- ☐ I was not given an assignment for the poster session.
- ☐ I did not participate in the poster session.

Please describe your assignment for the poster session:

____

____

____

____

____

Please assess your group's participation according to the following:

(*Please check all that apply)*

- ☐ Our group had an organization meeting.
- ☐ Our group discussed the layering method assigned to our group.
- ☐ We offered and gave assistance when other group members requested it.
- ☐ Our group had a poster session planning meeting.
- ☐ We decided upon and received our poster session assignments at the planning meeting.
- ☐ Our group had follow-up meetings to prepare our poster session.
- ☐ Our group prepared a schedule with assignments for our poster session.

Our group divided the poster session according to the following activities:

Our group divided the poster session according to the following assignments:

On the following lines, please give your impression of the propagation by layering assignment.

____

____

____

____

____

On the following lines, please give your impression of the poster session assignment.

____

____

____

____

____

Air Layering

Slit stem of plant at an upward angle or girdle 1/2 to 1 inch wide, 6 to 12 inches from the tip removing the bark completely from the stem.

Scrape the exposed surface.

Apply rooting hormone.

Pack the wound in wet sphagnum moss, completely covering the wound surface.

Squeeze the moss until dry.

Snugly wrap the wound with clear plasti

Tightly secure both ends with electricia making a waterproof seal.

Support branch, if necessary.

Transplant when root has formed and pl dormant.

Allow transplant to harden off.

Simple Layering

Use the "pencil-size" measure to select
stem
that can be bent to soil level.

Make a cut or girdle
at point where stem
will be inserted into the soil.

Apply rooting hormone to cut.

Insert cut/bent part of stem into the s

Secure bend with a peg and replace so

Twist remaining portion of stem
to an upright position. Stake for suppo

Secure by placing a brick or stone on t
of the soil at bend.

Keep soil moist.

Rooting should be complete by the
following spring.

Cut layer free of the parent plant
and transplant, gradually hardening o
the new plant.

Tip Layering

Cut parent plant down to 9 inches above the ground.

Pinch off 3 to 4 inches of growth after the plant has grown 18 to 30 inches.

Canes will begin to arch over.

Bend plant over and insert tip into soil.

Firmly press soil over the tip.

The tip will form roots and a vertical shoot.

Cut transplant from the parent plant, keeping the plant in the soil.

Keep 6 to 8 inches of the original cane to mark the plant.

Remove the plant from the soil for immediate replant in the fall or early spring.

Ag 514 L - Propagation by Layering and Division
Unit Test

Indicate whether the follow statements are either advantages (A) or disadvantages (D) of layering.

____ 1. Larger new plants can be produced.

____ 2. Only a few plants can be produced from each parent plant.

____ 3. Layering takes more time.

____ 4. Many plants root naturally by layering.

Depending on how many advantages you identified in the first four questions, list the remaining advantages in no particular order. Use the space below.

List the 6 types of layering, and then match the technique with one of its defining characteristic listed below.

____ 5. ______________________________

____ 6. ______________________________

____ 7. ______________________________

____ 8. ______________________________

____ 9. ______________________________

____ 10. ______________________________

A. Uses dormant, one-year-old shoots.

B. The parent plant is bent to the ground and buried in a trench, and shoots develop from dormant buds.

C. The parent plant is cut to the ground during dormancy.

D. The stem is girdled at more than one point along its length, and buried at those points (the stem is alternately exposed and buried).

E. A natural reproduction method by cane or trailing plants such as blackberries and black raspberries.

F. The stem of a plant is slitted at an upward angle, covered in rooting medium, and kept moist.

514 L - Propagation by Layering - 2

Identify the following procedures using the 6 layering techniques you listed above. The first one as an example is done for you.

11. Pinch off 3 to 4 inches after a growth of about 18 to 30 inches.

12. Scrape the exposed surface to remove the phloem and cambium, which retards wound healing.

13. At the end of the growing season, the branch is cut into new sections containing the new shoot and root portions.

14. Bend the branch to the ground and cover the bend partially with soil or rooting medium.

15. After dormancy, plants are removed from the original plant.

16. Remove the bark completely from the stem, in a band aobut ½ to 1 inch wide.

17. Mound the soil around new shoots emerging in the spring to enourage rooting.

Ag 514 L - Propagation by Layering and Division
Unit Test
Answer Key

Indicate whether the follow statements are either advantages (A) or disadvantages (D) of layering.

__**A**__ 1. Larger new plants can be produced.

__**D**__ 2. Only a few plants can be produced from each parent plant.

__**D**__ 3. Layering takes more time.

__**A**__ 4. Many plants root naturally by layering.

Depending on how many advantages you identified in the first four questions, list the remaining advantages in no particular order. Use the space below.

Answers:
Ease and simplicity of process: the new plant receives water and nutrients from the prarent plant, and the process of layering is very simple.

There is a great degree of success with layering as a rooting technique.

List the 6 types of layering, and then match the technique with one of its defining characteristic listed below.

____ 5. ______________________________

____ 6. ______________________________

____ 7. ______________________________

____ 8. ______________________________

____ 9. ______________________________

____ 10. ______________________________

A. Uses dormant, one-year-old shoots.
B. The parent plant is bent to the ground and buried in a trench, and shoots develop from dormant buds.
C. The parent plant is cut to the ground during dormancy.
D. The stem is girdled at more than one point along its length, and buried at those points (the stem is alternately exposed and buried).
E. A natural reproduction method by cane or trailing plants such as blackberries and black raspberries.
F. The stem of a plant is slitted at an upward angle, covered in rooting medium, and kept moist.

Answers (in no particular order)
__E__ Tip
__A__ Simple
__F__ Air
__B__ Trench
__C__ Stool (or mound)
__D__ Compund (serpentine)

514 L - Propagation by Layering - 2

Identify the following procedures using the 6 layering techniques you listed above. The first one as an example is done for you.

11. Pinch off 3 to 4 inches after a growth of about 18 to 30 inches.

12. Scrape the exposed surface to remove the phloem and cambium, which retards wound healing.

13. At the end of the growing season, the branch is cut into new sections containing the new shoot and root portions.

14. Bend the branch to the ground and cover the bend partially with soil or rooting medium.

15. After dormancy, plants are removed from the original plant.

16. Remove the bark completely from the stem, in a band aobut ½ to 1 inch wide.

17. Mound the soil around new shoots emerging in the spring to enourage rooting.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 M - Propagation by Separation and Division

Unit Objectives

1. Describe the propagation method of plant separation.
2. Describe the separation process for bulbs.
3. Give four examples of bulbs which can be separated.
4. Describe the separation process for corms.
5. Give two examples of corms which can be separated.
6. Describe the propagation method of plant division.
7. Name the types of plants propagated by division.
8. List the steps in divisional propagation.
9. Demonstrate propagation by division of perennials.
10. Describe the division process for rhizomes and tubers.
11. Give two examples of rhizomes and tubers which can be divided.

Information

1. Describe the Propagation Method of Plant Separation
2. Describe the Separation Process for Bulbs
3. Give Four Examples of Bulbs Which Can Be Separated
4. Describe the Separation Process for Corms
5. Give Two Examples of Corms Which Can Be Separated
6. Describe the Propagation Method of Plant Division
7. Name the Types of Plants Propagated by Division
8. List the Steps in Divisional Propagation
9. Demonstrate Propagation by Division of Perennials
10. Describe the Division Process for Rhizomes and Tubers
11. Give Two Examples of Rhizomes and Tubers Which Can Be Divided

Separation

Natural structures produced by parent plants are removed and planted to become new plants.

Natural structures which can be **separated** are **bulbs or corms**.

Bulbs and corms are underground plant parts **responsible for food storage and propagation of the plant**.

Specialized nutrient-storing and propagative underground stem and root types:

1. Bulb and bulblet

2. Corm and cormel
3. Rhizome
4. Tuber
5. Tuberous roots.

True Bulbs

True bulbs are part of specialized underground stems which produce foliage leaves and bulb scales.

Bulbils are small bulbs that form in the axils of leaves, flowers, or stems of bulbous plants.

The bulb scales produce the small bulblets at their base which may be separated from the parent plant and planted.

The plants produced by the separated bulblets are termed offset bulbs.

Stages of bulblet growth:

Splits or slabs first separated from the parent plant.

Round bulb one-year-old slab or split capable of flowering the next season.

Double nose second year growth which produces a second flower bud. Can therefore produce *two* flower stalks; hence, the name "double nose."

Bulb outer scales

Laminate or tunicate

Tough, outer **dry** membraneous scales that protect them against drying or injury.

Nontunicate or scaly

Loosely scaled **wet** bulbs without a tough outer cover.

Separation process for bulbs

Parent bulbs are dug after the foliage has died back (the plant is in a dormant state) and new bulblets are separated from the parent plant.

Parent (established) bulbs are generally stored at 65^0 to 68^0F.

Plant bulbs at the appropriate time of year for the particular bulb.

Bulblets differ in growth time required before flowering (1 to 3 years).

Dry bulblets should be washed and treated for rot, then stored at 55^0 to 60^0F.

Wet bulblets (e.g., the lily) should be kept moist and stored in moist sphagnum moss, held at just below freezing for storage until planted.

Parent plants should be cut off when tops are brown to **allow bulbs to store food and acquire size before harvesting**.

Potted parent plants should be allowed to continue to grow for 6 to 8 months before inducing dormancy and harvesting bulblets.

Apply fertilizer after planting to encourage next year's flowering and formation of new bulbs.

Bulbs which can be separated:

Tulip
Amaryllis
Lilly

Daffodils
Narcissus
Hyacinth
Grape hyacinth
Allium

Corms

Short compact stem with nodes and internodes.
Dry covering prevents injury.
Used for plant food storage and reproduction.
New corms and cormels form from axillary bud of old corm.
New corms flower the following year.
Cormels flower in 2 to 3 years.

Separation process for corms

Plant corms from 2 to 3 inches deep.
Parent plant is allowed to die back after frost and the dug to harvest small corms and cormels, or allowed to grow for three months after blooming before harvesting to allow food storage and size development.
Small corms and cormels are separated from the parent plant, treated with fungicide, and stored at 40^0F.
Area should be well-ventilated and held at 80 percent humidity.
Plant in rows; fertilize.

Corms which can be separated:

Gladiolus
Crocus
Timothy

Perennial Division

Parts do not separate naturally from the parent plant.
Parts are cut into sections which grow into new plants.
Generally used for plants in crowded groupings.

Rhizomes

Thickened stem that grows partially or completely beneath the ground.
The eye serves as the growth bud, principally found at the tip, although other sections may form along the rhizome side.

Tubers

Swollen underground stem with no basal plate.
Roots grow from all sides.
Tubers have multiple eyes (growth points) over the upper surface.

Tuberous roots

Actual roots, not stems, which store nutrients.

Roots grow in a cluster.
Swollen tuberous roots radiate out in a cluster from the stem.
Eyes, or growth buds, are not on the tuberous roots, but at the base of the stem.

Rhizomes which can be divided:
Zantedeschia or Calla
Iris

Tubers which can be divided:
Begonia
Potato

Tuberous roots which can be divided:
Dahlia

Other perennials which can be divided:
Shasta daisy
Daylilies
Peonies
Sweet potato

Steps in plant division:

Rhizomes
Dig plants up by lifting out of the ground with a spading fork or shovel.
Wash all soil from the plant.
Cut the rhizome into sections, including at least one eye (bud) in each section.
Cut the top of the plant back to balance the remaining root section.
Treat each section with fungicide, then plant.

Tubers
Each cut section must contain an eye.
Although no storage is required, cut sections should dry before planting.

Tuberous roots
Dig the plant in the fall after frost when the plant has gone dormant.
Wash soil from roots and allow to dry.
Store in sawdust, peat, or other materials at 40^0 to 50^0F.
Before planting in early spring, divide the plant root crown.
Each division should contain roots and part of the stem's base with one or more buds.
Plant after last frost date.

Adventitious roots:
Tuberous root shoots from adventitious buds.
Pull off and plant as rooted shoots.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Ortho Books. (1990). *Greenhouse Plants*. San Ramon, CA: Author.
3. Ortho Books. (1995). *Easy Gardening: Tips from Garden Professionals*. San Ramon, CA: Author.
4. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
5. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
6. Sunset Books. (1995). *Sunset Western Garden Book* (6th ed.). Menlo Park, CA: Author.

Student Activity

- **Perennial Division - Making the Cut!**

Internet Resources

Modified Stems and Roots
http://classes.aces.uiuc.edu/Hort100/contents.htm

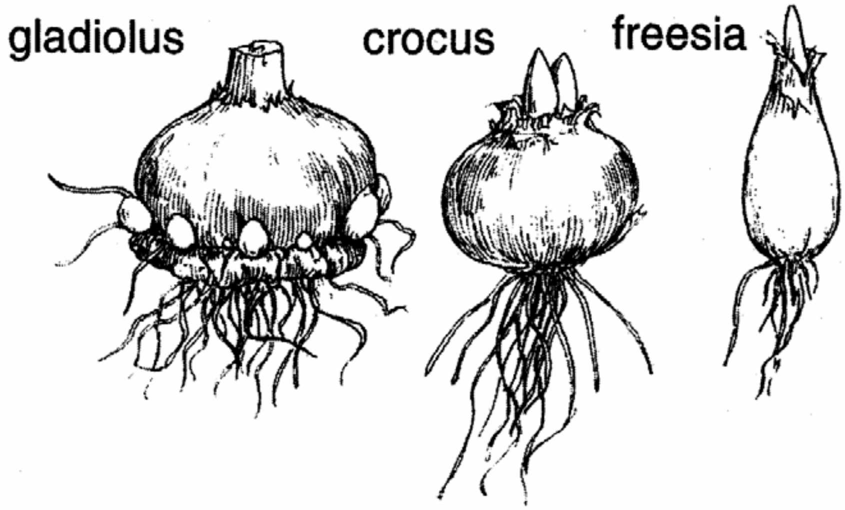
Transparencies / Hand-Outs

- **Bulbs and Corms**
- **Tubers, Tuberous Roots, and Rhizomes**

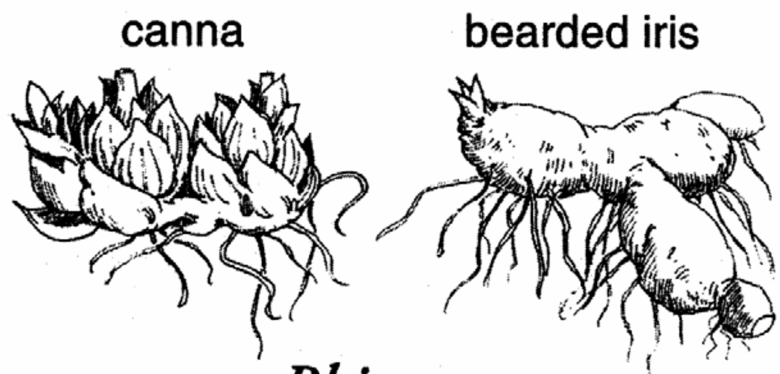
From *Agricultural Science and Technology, Botany / Science of Plant Growth and Development, 512 E - Vegetative Plant Parts*:

- **Below Ground Stem Modifications**

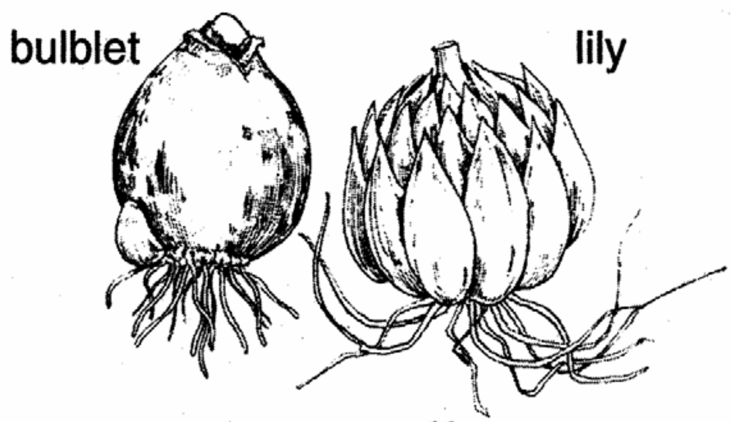
Bulb Types



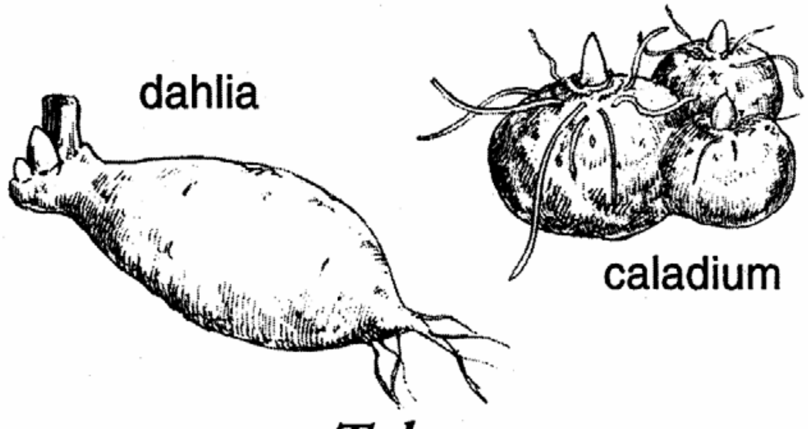
Corms



Rhizomes

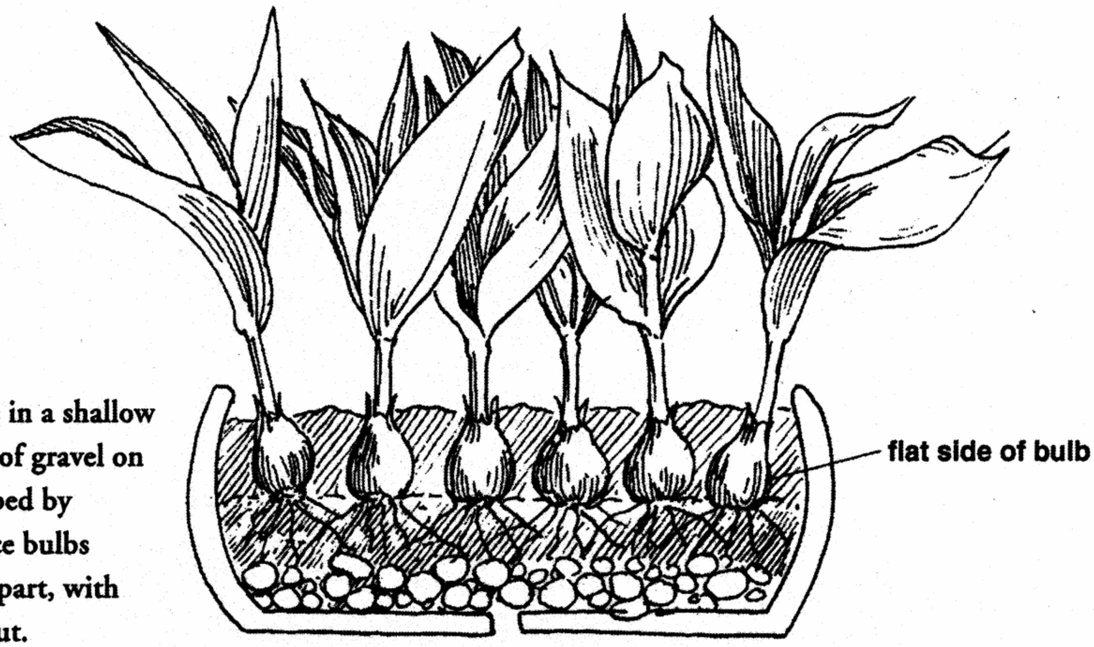


True Bulbs



Tubers

Bulbs in Soil



Plant tulip bulbs in a shallow pan with a layer of gravel on the bottom, topped by potting soil. Place bulbs about 1/2 inch apart, with flat side facing out.

Student Activity: Perennial Division - Making the Cut!

Purpose

- Demonstrate propagation by division of perennials.

Materials

Suggestions:
Shasta daisy
Peony
Sweet potato
Iris
Daylily
Calla
Begonia (tuberous)
Potato
Dahlia

Wear work / gardening gloves
Spading fork / shovel / knife
Newspaper or tarp for work area
Area for planting divisions, or containers with appropriate soil mix for the perennial type.
If planting outdoors, allow for storing at appropriate temperatures if storage is necessary for the plant type (e.g., tuberous roots).
Fungicide
Fertilizer
Water / watering can

Activity Information

Division is done when plants are dormant.
Fall is the best time for plants that bloom in spring or early summer.
Early spring is the best time for plants that bloom in later summer or autumn.
The exception: in cold zones, divide spring-blooming plants in early fall to allow root growth before the cold weather.

Procedure

- Each student should choose one plant each of a tuber, tuberous root, and rhizome type for division.
- Prune parent plant foliage back to 4 inches above the soil line.
- Remove dead leaves.
- Lift plant from soil.
- Gently rinse soil away from the roots, or swirl in a bucket of water.
- Follow dividing procedures for the particular below-ground stem type according to *Information, Steps in Plant Division*.

Container planting . . .

- Make sure soil mix is appropriate for the plant type (replant in same soil mix type as the parent plant).
- Treat divided stem area with fungicide.
- Fertilize if soil mix needs fertilization.
- Trim division above-ground foliage to 2 ½ inches.
- Set divisions at the same soil depth as parent plant, spread the roots, and water thoroughly.
- Fill in the empty container spaces around the parent plant with humus or compost, and smooth. Water the parent plant.

Follow-Up!

Track the health of your plants by maintaining good plant records.
Maintain a watering and feeding schedule for your plants, and note any changes or adjustments made.

Follow-up Activity:

- Track the growth of your plants by taking measurements every class session for 4 weeks.
- At the end of that time period, create a graph showing the growth of your plants. Make a graph for each plant.
- Graphs may be generated by hand or computer.
- Present your graphs in a binder with a short paper discussing the plant types, division dates, maintenance records, and growth records. Include a biographical sketch of each plant’s living history as an introduction to the paper. Reference your sources.

Ag 514 M - Botany/Horticulture Plant Science
Unit Test

Multiple Choice

1. In the propagation method of plant separation, natural structures produced by parent plants

    a. are removed and planted to become new plants.
    b. cannot be used in propagation by separation.
    c. are only present in conifers.
    d. none of the above.

2. Natural structures which can be separated are

    a. leaves.
    b. stems.
    c. bulbs or corms.
    d. buds.

3. Bulbs and corms are

    a. useless for plant propagation purposes.
    b. the underground parts of a plant responsible for food storage and propagation of the plant.
    c. the above ground parts of a plant responsible for food storage and propagation of the plant.
    d. only used when the adult plant is no longer viable.

4. Small bulbs that form in the axils of leaves, flowers, or stems of bulbous plants are called

    a. laminates.
    b. bulbils.
    c. daffodils.
    d. tubers.

5. Splits or stabs are

    a. called round bulbs after one year of growth.
    b. are capable of flowering after one season of growth.
    c. first separated from the parent plant.
    d. all of the above.

6. The tough, outer dry membranous scales that protect bulbs from drying or injury are called

    a. laminate or tunicate.
    b. nontunicate or scaly.
    c. double nose.
    d. bulblets.

7. In the separation process, parent bulbs

a. are stored at 35° to 38°F.
b. are not widely used.
c. have no laminate.
d. are dug after the foliage has died back.

8. The dry covering on corms

a. must be removed in order to assure plant survival.
b. contains a complex protein webbing.
c. prevents injury.
d. is the new plant.

9. In cuttings tubers, each section must contain

a. roots.
b. an eye.
c. part of the stem’s base.
d. bulblet

10. Adventitious roots must be

a. pulled off and planted as rooted shoots.
b. discarded.
c. stored at 75°F.
d. treated with rooting hormone.

Put these separation and division steps in their correct order.

11. Bulbs

____ New bulbets are separated from the parent plant.

____ Apply fertilizer after planting to encourage next year’s flowering and formation of new bulbs.

____ Parent bulbs are dug after the foliage has died back (the plant is in a dormant state).

____ Parent (established) bulbs are stored at 65° to 68°F.

12. Corms

____ Small corms and cormels are separated from the parent plant, treated with fungicide, and stored at 40°F.

____ Plant in rows; fertilize.

____ Ventilate area well at 80% humidity.

____ Parent plant is allowed to die back or grow for three months.

13. Rhizomes

____ Cut the rhizome into sections, including at least one eye(bud) in each section.

____ Dig plants up by lifting out of the ground with a spading fork or shovel.

____ Cut the top of each plant back to balance the remaining root section.

____ Wash all soil from the plant.

____ Treat each section with fungicide, then plant.

14. Tuberous roots

____ Plant after last frost date.

____ Store in sawdust, peat, or other materials at 40° to 50°F.

____ Wash soil from roots and allow to dry.

____ Dig the plants up by lifting out of the ground with a spading fork or shovel.

____ Before planting in early spring, divide the plant root crown.

15. Give four examples of bulbs which can be separated.

________________________________ ________________________________

________________________________ ________________________________

16. Give two examples of corms which can be separated.

________________________________ ________________________________

17. Name the two rhizomes and the two tubers which can be divided.

Rhizomes

________________________________ ________________________________

Tubers

________________________________ ________________________________

Ag 514 M - Botany/Horticulture Plant Science
Unit Test
Answer Key

Multiple Choice

1. In the propagation method of plant separation, natural structures produced by parent plants

    a. **are removed and planted to become new plants.**
    b. cannot be used in propagation by separation.
    c. are only present in conifers.
    d. none of the above.

2. Natural structures which can be separated are

    a. leaves.
    b. stems.
    c. **bulbs or corms.**
    d. buds.

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    a. useless for plant propagation purposes.
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4. Small bulbs that form in the axils of leaves, flowers, or stems of bulbous plants are called

    a. laminates.
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5. Splits or stabs are

    a. called round bulbs after one year of growth.
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    c. first separated from the parent plant.
    d. **all of the above.**

6. The tough, outer dry membranous scales that protect bulbs from drying or injury are called

    a. **laminate or tunicate.**
    b. nontunicate or scaly.
    c. double nose.
    d. bulblets.

7. In the separation process, parent bulbs

a. are stored at 35° to 38°F.
b. are not widely used.
c. have no laminate.
d. **are dug after the foliage has died back.**

8. The dry covering on corms

a. must be removed in order to assure plant survival.
b. contains a complex protein webbing.
c. **prevents injury.**
d. is the new plant.

9. In cuttings tubers, each section must contain

a. roots.
b. **an eye.**
c. part of the stem's base.
d. bublet

10. Adventitious roots must be

a. **pulled off and planted as rooted shoots.**
b. discarded.
c. stored at 75°F.
d. treated with rooting hormone.

Put these separation and division steps in their correct order.

11. Bulbs

__2__ New bulbets are separated from the parent plant.

__4__ Apply fertilizer after planting to encourage next year's flowering and formation of new bulbs.

__1__ Parent bulbs are dug after the foliage has died back (the plant is in a dormant state).

__3__ Parent (established) bulbs are stored at 65° to 68°F.

12. Corms

__1__ Small corms and cormels are separated from the parent plant, treated with fungicide, and stored at 40°F.

__4__ Plant in rows; fertilize.

__3__ Ventilate area well at 80% humidity.

__2__ Parent plant is allowed to die back or grow for three months.

13. Rhizomes

__3__ Cut the rhizome into sections, including at least one eye(bud) in each section.

__1__ Dig plants up by lifting out of the ground with a spading fork or shovel.

__4__ Cut the top of each plant back to balance the remaining root section.

__2__ Wash all soil from the plant.

__5__ Treat each section with fungicide, then plant.

14. Tuberous roots

__5__ Plant after last frost date.

__3__ Store in sawdust, peat, or other materials at 40° to 50°F.

__2__ Wash soil from roots and allow to dry.

__1__ Dig the plants up by lifting out of the ground with a spading fork or shovel.

__4__ Before planting in early spring, divide the plant root crown.

15. Give four examples of bulbs which can be separated.

______________________________ ______________________________

______________________________ ______________________________

Answers:
Tulip
Amaryllis
Lilly
Daffodils
Narcissus
Hyacinth
Grape hyacinth
Allium

16. Give two examples of corms which can be separated.

______________________________ ______________________________

Answers:
Gladiolus
Crocus
Timothy

17. Name the two rhizomes and the two tubers which can be divided.

Rhizomes

______________________ ______________________

Tubers

______________________ ______________________

Answers:

Rhizomes -	**Zantedeschia or Calla**
	Iris
Tubers -	**Begonia**
	Potato

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 N - Propagation by Tissue Culture

Unit Objectives

1. Describe the process of propagation by tissue culture.
2. Discuss the advantages of using tissue culture for propagation.
3. List five tissue culture methods used in research and commercial propagation.
4. Classify the steps of developing plants in tissue culture.
5. Define "agar."
6. Describe the use of agar in tissue culture.
7. Demonstrate a plant tissue culture.
8. List five plants commercially produced through tissue culture.

Information

1. Describe the Process of Propagation by Tissue Culture

2. Discuss the Advantages of Using Tissue Culture for Propagation

3. List Five Tissue Culture Methods Used in Research and Commercial Production

4. Classify the Steps of Developing Plants in Tissue Culture

5. Define "agar."

6. Describe the Use of Agar in Tissue Culture

7. Demonstrate a Plant Tissue Culture

8. List Five Plants Commercially Produced Through Tissue Culture

Tissue Culture (micropropagation / meristem culture)

Involves taking a small tissue sample, cell, or a group of cells from a parent plant and growing the sample in a sterilized media containing the nutrients the cells require. This method grows hundreds of new plants in a very short time.

Advantages of Tissue Culture

A large number of plants are produced from a very small amount of parent plant in a short period of time.

Allows propagation of virus-free plants.

Disadvantages of Tissue Culture

Parent plant can mutate and generations can become contaminated with the mutation before it is discovered.

Requires trained personnel and proper laboratory equipment.

Tissue Culture Methods Used in Research and Commercial Production:

Callus culture

Parenchyma (callus) tissue increases by continuous cell division, eventually growing large enough to be divided (subcultured) as explants to produce additional cultures, roots, and shoots.

The plantlets produced are not yet the size of seedlings.

Shoot tips can be used to produce callus used in this culture, or callus can be produced by single cell culture.

Single cell culture

Single cells are placed on top of a well-growing piece of callus tissue, separated by filter paper. These cells develop into small masses of callus tissue, nursed by materials absorbed through the filter paper from the underlying callus tissue.

Embryo culture

Developing plant embyos (embryoids), or endosperm (from germinating seeds) are used as starting points.

Single cell suspension culture

Cells and cell clumps are developed suspended in a rotated liquid medium and removed with a pipette to further develop in a petri dish or test tube in a liquid or agar medium.

Meristem culture

Tissue is derived from the parent plant's meristem, which is generally virus free.

Anther culture

Cultures started from pollen.

Steps for Developing Plants in Tissue Culture:

- Sterilize all equipment used with one part bleach to 10 parts media.
- Mix growth-regulating chemicals and nutrients into the growing media.
- Place media in sterilized test tube or jar.
- Place plant tissue in media.
- Seal to keep out disease organisms and mold.
- As growth progresses, pull off sprouts in media when large enough to tweeze.
- Place tweezed off sprouts in another container with growing media to grow roots or shoots.
- Open or uncover rooting / sprouting container gradually over days for about one week to harden off roots / shoots.
- Plants may be transplanted as seedlings after hardening off period.

Agar

Sugar-based (complex polysaccharide) gel derived from seaweed which substitutes for photosynthetic-produced plant sugars.

The agar gel or liquid is used in tissue culture as a sterile medium and a nutrient supply for developing plants.

Supplemented with nutrients, it supplies plant cells with the food energy needed to asexually propagate.

Plants Commercially Produced Through Tissue Culture (i.e.):

Orchids
Ferns
Chrysanthemums
Maples
Kiwi vine
Venus Flytrap
Blackberries
Carrots
Tobacco
Endive
Aspen
Citrus

References

1. Allaby, M. (Ed.). (1992). *The Concise Oxford Dictionary of Botany*. Oxford, UK: Oxford.
2. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Lab

Culturing Plants from Embryonic Plant Tissue
by Roger Herbert and Domenic J. Thompson
1993 Woodrow Wilson Biology Institute

Internet Resources

Culturing Plants from Embryonic Plant Tissue (see **Student Lab**)
http://www.gene.com/ae/AE/AEPC/WWC/1993/culturing.html

Cloning Plants by Tissue Culture
by Michael H. Renfroe James Madison University
http://www.jmu.edu/biology/biofrac/facfro/cloning/cloning.html

Poplar Tissue Culture National Centre for Biotechnology Education UK
1http://134.225.167.114/NCBE/PROTOCOLS/PRACBK/poplar.html

Transparency

From *Poplar Tissue Culture* NCBE

- **Poplar Tissue Culture**

Ag 514 N - Propagation by Tissue Culture
Unit Test

Decide the proper order for these tissue culture propagation steps.

1. ____ Place tweezed off sprouts in another container with growing media to grow roots or shoots.

2. ____ Place media in sterilized test tube or jar.

3. ____ Seal container to keep out disease organisms and mold.

4. ____ Plants may be transplanted as seedling after hardening off period.

5. ____ Sterilize all equipment used with one part bleach to 10 parts media.

6. ____ Open or uncover rooting/sprouting container gradually over days for about one week.

7. ____ Mix growth-regulating chemicals and nutrients into the growing media.

8. ____ Place plant tissue in media.

9. ____ As growth progresses, pull off sprouts in media when large enough to tweeze.

Classify the following statements as advantages (A) or disadvantages (D) of tissue culture propagation.

10. ____ A large number of plants are produced from a very small amount of parent plant in a short period of time.

11. ____ Parent plant can mutate and pass that mutation on to the next generation.

12. ____ Requires trained personnel and proper laboratory equipment.

13. ____ Allows propagation of virus-free plants.

14. Name the five tissue culture methods used in research and commercial production.

________________________________ ________________________________

________________________________ ________________________________

____

15. List five plants commercially produced through tissue cultures.

______________________________ ______________________________

______________________________ ______________________________

____

Multiple Choice

16. In a callus culture

    a. developing plant embryos are used as starting points.
    b. parenchyma tissue increases by continuous cell division.
    c. sugar-based gels are not used.
    d. young plants have a higher mortality rate.

17. Cultures started from pollen are called

    a. single cell cultures.
    b. not viable.
    c. anther culture.
    d. single cell suspension culture.

18. In an embryo culture, the sample includes developing plant embryos or

    a. endosperm.
    b. agar.
    c. the meristem.
    d. pollen.

19. The agar gel or liquid is

    a. derived from seaweed.
    b. used as a sterile medium and nutrient supply in tissue cultures.
    c. a supplier of food energy needed for asexual propagation in plants.
    d. all of the above.

20. Agar can also be described as a

    a. complex polysaccharide gel.
    b. disaccharide solution.
    c. complex carbohydrate gel.
    d. fructose supersaturated solution.

Ag 514 N - Propagation by Tissue Culture
Unit Test
Answer Key

Decide the proper order for these tissue culture propagation steps.

1. __7__ Place tweezed off sprouts in another container with growing media to grow roots or shoots.

2. __3__ Place media in sterilized test tube or jar.

3. __5__ Seal container to keep out disease organisms and mold.

4. __9__ Plants may be transplanted as seedling after hardening off period.

5. __1__ Sterilize all equipment used with one part bleach to 10 parts media.

6. __8__ Open or uncover rooting/sprouting container gradually over days for about one week.

7. __2__ Mix growth-regulating chemicals and nutrients into the growing media.

8. __4__ Place plant tissue in media.

9. __6__ As growth progresses, pull off sprouts in media when large enough to tweeze.

Classify the following statements as advantages (A) or disadvantages (D) of tissue culture propagation.

10. __A__ A large number of plants are produced from a very small amount of parent plant in a short period of time.

11. __**D**__ Parent plant can mutate and pass that mutation on to the next generation.

12. __D__ Requires trained personnel and proper laboratory equipment.

13. __A__ Allows propagation of virus-free plants.

14. Name the five tissue culture methods used in research and commercial production.

Answers: Callus culture
Single cell culture
Embryo culture
Single cell suspension culture
Meristem culture
Anther culture

15. List five plants commercially produced through tissue cultures.

Answers: Orchids	**Kiwi vine**	**Tobacco**
Ferns	**Venus fly trap**	**Endive**
Chrysanthemums	**Blackberries**	**Aspen**
Maples	**Carrots**	**Citrus**

Multiple Choice

16. In a callus culture

a. developing plant embryos are used as starting points.
b. parenchyma tissue increases by continuous cell division.
c. sugar-based gels are not used.
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c. a supplier of food energy needed for asexual propagation in plants.
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d. fructose supersaturated solution.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 O - Propagation by Budding

Unit Objectives

1. Match terms and definitions associated with propagation by budding.
2. List the types of budding.
3. List the techniques used when propagating by budding.
4. List the precautions used with T-budding.
5. Describe patch budding and list the variations of patch budding.
6. Demonstrate the ability to T-bud and patch bud.

Information

1. Match Terms and Definitions Associated with Propagation by Budding

2. List the Types of Budding

3. List the Techniques Used When Propagating by Budding

4. List the Precautions Used with T-Budding

5. Describe Patch Budding and List the Variations of Patch Budding

6. Demonstrate the Ability to T-Bud and Patch Bud

Propagation by Budding

Single bud attached to a small portion of bark or wood (**budwood**) is removed from one plant and joined with the understock of another plant (**rootstock**) to form a new plant.

Budwood

Small shoots or sticks of current season's growth.
Only vegetative buds are used (leaf buds).

Rootstock

Developed from seed for one year or more.
In active growth for T-budding process.
Should be at least pencil-size for budding.
Must be species-related to budwood.

Types of Budding

- **T-Bud**
  - **Inverted T-bud**
- **Patch Bud**
  - **Flute bud**

I-bud
Ring or annular bud
Chip bud

Techniques in Propagation by Budding

- Select the rootstock and budwood.
- Plant seeds for rootstock in the fall.
- Determine the correct date for budding by:
  - ⇒ Bud maturity
  - ⇒ Active growth of rootstock.
- Cut the budwood on the day you perform the budding process.
- Label the budwood according to variety and date cut.
- Protect the budwood from drying by wrapping in waterproof paper or place in plastic bags.
- Perform the selected budding process onto the rootstock.
- Determine if the budding process has taken on the rootstock.
- Cut the rootstock above the budding soon after leafing has taken place the following spring.

T-budding

Precaution: the knife used in grafting and budding is very sharp. Be very cautious. Cut "away from yourself" (toward the object being cut, not toward you).

Normally a two-person job: one to make the cuts, and one to bind the bud to the rootstock.

Cutting the T:

On the rootstock, make the cut 1 to 2 inches above the ground where the stem is smooth.
Choose the north side of the stem to protect the new bud against direct sun.
Make a 1-inch vertical cut (down) through the bark.
Make a 1-inch horizontal cut (across) the *tip* of the vertical cut to form a T.
Gently separate the bark from the wood with the tip of the knife, flaring out the vertical cut like a pocket.

Cutting the Bud:

Choose a vegetative bud in the middle of the bud stick.
Cut around the bud and leaf petiole in the form of a shield (the shape of the shield is reminiscent of an iron).
Start the cut ½ inch below the bud, cutting just deep enough to include a small amount of wood.
Cut under the bud and past it to ¼ inch above the bud.
Make a vertical cut across the top of the first cut (above the bud) to release it from the stem.

Inserting the Bud:

Insert the bud into the T cut, pushing the narrow end of the bud shield down and underneath the flared T cut. The top of the shield should be underneath the horizontal cut.

Tie the bud in place with a rubber band tie, wrapping the tie around the stem and shield, but not over the bud or the leaf petiole.

Checking the Bud:

In three weeks, check to see if:

The leaf petiole has fallen off

The bud is plumped up.

If so, the T-bud has taken.

Completing the T-Bud Process:

The following spring, make a slant cut topping the rootstock off just above the bud.

Pinch off any suckers or shoots apppearing below the bud.

Continue the pinching process, allowing only the bud to have new growth.

After one to two year's growth, transplant the seedling to a permanent site.

Note: Inverted T-budding is used with success in rainy areas to prevent collection of water in the T-bud pocket.

Patch budding

Used especially on thick-barked plants.

Special **double-bladed knives** are used for patch budding in order to make exact-sized horizontal cuts in both the rootstock and the bud stick.

As in T-budding, these knives are sharp. Exercise caution.

Patch budding is done in late summer or early fall when the bark slips easily.

Diameter of the rootstock and bud stick should be the same - about 1 inch in diameter, although the rootstock may be larger (but the healing process takes longer in older stock).

Cutting the Rootstock:

Cut the stock tree with a double-bladed knife, making two parallel cuts with the double-bladed knife about 1 inch wide.

Make two horizontal cuts on either side to complete the patch.

Cutting the Patch:

Choose a vegetative bud in the middle of the bud stick, making two parallel cuts with the double-bladed knife about 1 inch wide.

Make two horizontal cuts on either side to complete the patch.

The bud patch must contain a trace of wood attached to the back side of the bud in order for the patch to take.

To prevent the core of wood from breaking off the back side of the bud, *slide* the patch gently to one side to remove it from the bud stick. Do not lift the patch off.

Inserting the Patch:

Insert the patch immediately onto the rootstock, fitting the surfaces snugly together.

If it is not a snug fit, pare the *rootstock* down until the bark edges meet evenly.

Wrap the patch to the rootstock firmly covering all four sides, exposing only the bud.

Checking the Patch:

Tape is removed (or has deteriorated) after three weeks.
Patch should be healed in place.
Cut back the rootstock and follow the procedures as in T-budding to promote growth.
Relocate the seedling when

Note: budding rubber strip wrapping is preferred because they expand with growth and deteriorate naturally without girdling the stock. Tape should be monitored and cut to loosen after 10 days to prevent girdling.

Variations of patch budding include:

Flute budding

Patch cut from rootstock is almost complete in circumference except for a narrow strip, which helps keep the rootstock alive if the patch bud does not take.

Ring or annular budding

Complete ring is taken from both the rootstock and the budding stick. They must match exactly, and the rootstock may die if the patch does not take.

I-budding

Horizontal cuts are made with the double-bladed knife. One vertical cut is made from top to bottom between the cuts, forming an “I.” The patch is inserted between the two flared edges and bound to the rootstock.

Chip budding

Can be used when rootstock is not in active growth.

Cutting the chip out:

Cut is made in rootstock at a 45 degree angle, ¼ deep into the stem diameter.
Starting 1 ½ inches above the first cut, a second cut is made downward into the stem at the same depth, meeting the first cut.
The complete cut should form a u-shaped chip which can be lifted out of the rootstock.

Cutting the bud chip:

Cut the bud from the bud stick in the same procedure, making the first cut just below the bud, and the second cut just above the bud. Both cuts should be 1 ½ inches apart, matching the chip shape formed in the rootstock.

Placing the bud chip:

The bud chip is placed in the rootstock immediately, aligning the bud chip with the root stock on at least one side (making sure the two surfaces meet snugly).
Tie the chip in place with rubber bud tie. The bud should remain exposed.
Follow the same procedures for growth as the T-bud and patch bud.

References

1. Harman, H.T. & Kester, D.E. (1975). *Plant Propagation: Principles and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Demo the T-Bud and Patch Bud**

Internet Resources

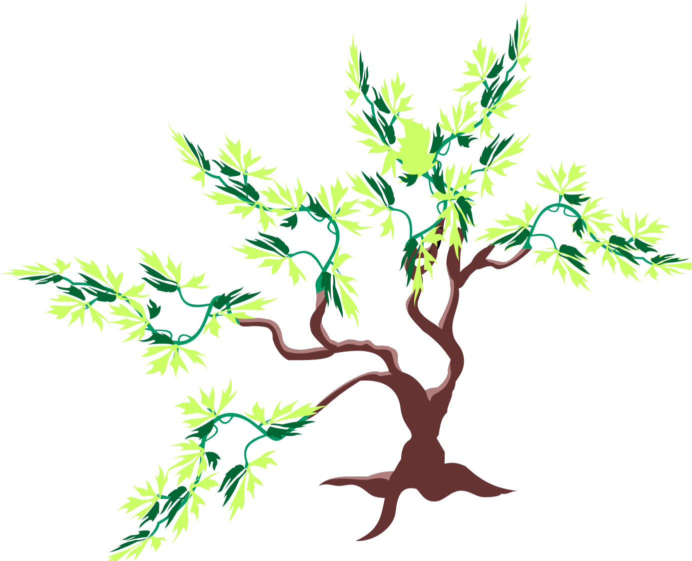
Budding
Ray R. Rothenberger & Christopher J. Starbuck
Dept. of Horticulture University of Missouri-Columbia
http://etcs.ext.misouri.edu:70/publications/xplor/agguides/hort/g06972.html

Four-flap Grafting of Pecans
Guide H-634 PH6-400
Esteban Herrera, Extension Horticulturist
New Mexico State University
http://rastro.nmsu.edu/cahe/redtops/_h/h-634.html

Transparencies

T-bud Grafting
Slide set and instructions
University of Illinois at Urbana-Champaign
http://classes.aces.uiuc.edu/Hort100/tbud/index.htm

Student Activity: Demo the T-Bud and Patch Bud



Purpose

- Demonstrate the ability to T-bud and patch bud.

Materials

Bud sticks
Rootstock
Single-bladed and double-bladed knife
Newspaper or tarp to work on
Notebook

Procedure

- Each student should have one set of materials for each procedure.
- Use the instructions given with **Information** for this section regarding *Techniques in Propagation by Budding*, *T-budding* and *Patch budding*.
- Conduct each procedure per instructions.
- Record the date of each T-bud and patch bud completed.
- Record dates and conditions of each budding upon:
  - ⇒ Checking if the budding has taken
  - ⇒ Checking or loosening the tape.

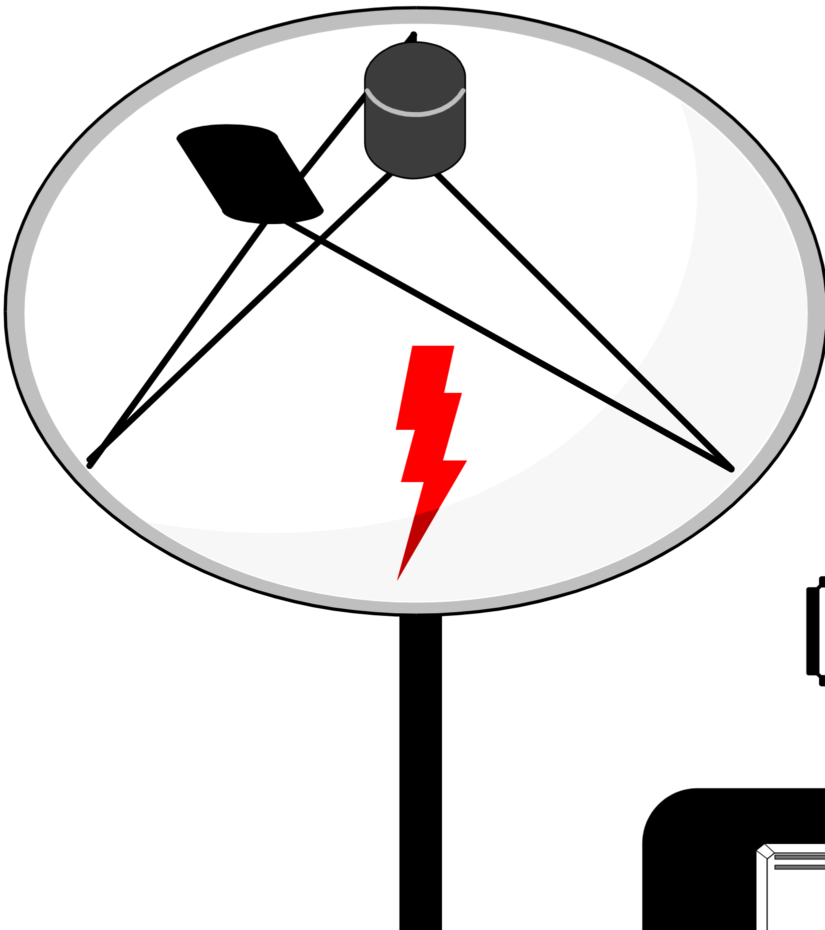
Follow-up Activity: Do an Internet Search:

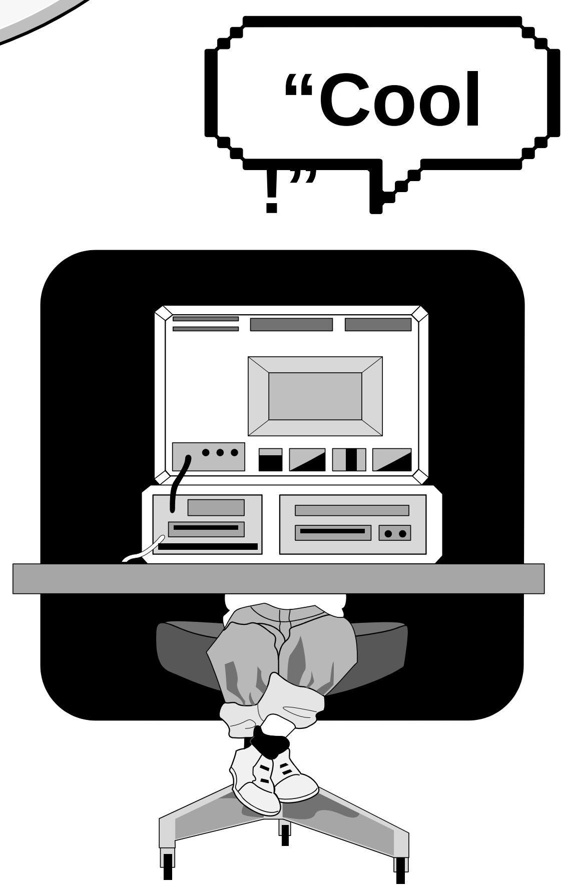
- On T-budding and patch budding procedures.
- Diagram your search procedure, starting with what search program you used, and key words entered.
- List at least six sources, including internet addresses.
- Pick three sources and write a review of each site.
- Use a questioning strategy for your review:
  - ⇒ Did the site feature helpful graphics?
  - ⇒ Were the procedures outlined step-by-step? If not, how?
  - ⇒ Was the site helpful? Elaborate (determine several reasons, not just one).

Do an Internet Project:

- If you designed a teaching site on T-budding and patch budding for use over the internet, what elements would it include?
- Do a storyboard of your internet site design.
- Share your design in group.
- Each group should choose the best design and share it with the class.
- The class should decide which group design is the best.

- Use that design to create an internet teaching site on T-budding and patch budding authored by your class. Get feedback from site visitors!
- Make your site interactive! For instance, making the cut: right way / wrong way; fitting the bud to the rootstock: right way / wrong way.





Teacher Information for the Internet Project:

- Completion of this project depends upon your classroom access to computers and the software necessary to create a web site.
- An excellent site on the internet to get you started and keep you going:
  The Global Schoolhouse sponsored by the Microsoft Corporation
  http://www.gsh.org/default.htm
- See the article: *Collaboration in the Classroom and Over the Internet* by Yvonne Marie Andres at:
  http://www.gsn.org/gsn/articles/article.collaboration.html

Ag 514 O – Propagation by Budding
Unit Test

1. List the three types of budding.

_______________________________________ _______________________________________

____

2. Small shoots or sticks of current season's growth are ______________________________.

3. In propagation by budding, the single bud attached to a small portion of bark or wood is joined with the _________________________ of another plant to form a new plant.

Multiple Choice

4. Seeds should be planted for rootstock in the

   a. spring.
   b. summer.
   c. fall.
   d. winter.

5. The correct date for budding is determined by

   a. bud maturity and active growth of rootstock.
   b. the FDA.
   c. average annual rainfall.
   d. the Farmer's Almanac.

6. The budwood should be cut

   a. the day before you perform the budding process.
   b. the day you perform the budding process.
   c. the day after you perform the budding process.
   d. none of the above.

7. The budwood should be labeled

   a. according to variety.
   b. according to the date it was cut.
   c. according to the site where it was cut.
   d. both a and b.

8. The budwood should be protected from drying

   a. by wrapping it in waterproof paper or placing in plastic bags.
   b. only if the budwood is to be used immediately after cutting.
   c. if it is taken from an immature parent tree.
   d. in the summer months before planting.

9. The rootstock should be cut above the budding

   a. by specialized agricultural engineers.
   b. during the fall harvest.
   c. soon after leafing has taken place the following spring.
   d. once the budwood has been replaced.

10. In T-budding, the general procedure is as follows:

   a. Cut the bud; Cut the T; Check the bud in three months.
   b. Cut the T; Cut the bud; Check the bud in three weeks.
   c. Cut the rootstock; Cut the patch; Insert the patch; Check the patch in three weeks.
   d. Cut the patch; Insert the patch; Cut the rootstock; Check the patch in three weeks.

11. A variation of patch budding is

   a. I - budding.
   b. T - budding.
   c. Flute budding.
   d. both a and c.

12. Chip budding can be used when

   a. the rootstock is not in active growth.
   b. the rootstock is in active growth.
   c. when the budwood is not in active growth.
   d. when the budwood is in active growth.

13. Patch budding is done

   a. in the late fall and early winter when the ground has hardened.
   b. in late summer or early fall when the bark slips easily.
   c. in the late spring or early summer when the petioles have first formed.
   d. during the winter in a greenhouse.

14. Determine the proper order for these T-budding procedures.

____ Cut underneath the bud and paste it ¼ inch above the bud.

____ Make a 1 inch vertical cut (down) through the bark.

____ Gently separate the bark from the wood with the tip of the knife, flaring out the vertical cut like a pocket

____ Insert the bud into the T cut and tie the bud in place with a rubber band tie.

____ Make a vertical cut across the top of the first cut (above the bud) to release it from the stem.

____ Make a 1 inch vertical cut (down) through the bark.

____ Choose a vegetative bud in the middle of the bud stick.

____ Choosing the north side of the stem, make a cut 1 to 2 inches above the ground on the stem.

____ Cut around the bud and petiole, starting ½ inch below the bud.

____ Gently separate the bark from the wood.

____ Check the bud in three weeks to see that the leaf petiole has fallen off and the bud is plumbed up.

15. Determine the proper order for these patch budding procedures.

____ Choosing a vegetative bud in the middle of the bud stick, make two parallel cuts and two horizontal cuts, about 1 inch wide.

____ Cut back the rootstock and follow the procedures as in T-budding to promote growth.

____ Slide the patch gently to one side to remove it from the bud stick.

____ Cut the stock tree with two parallel cuts about 1 inch wide.

____ Insert the patch immediately onto the rootstock, fitting the surfaces snugly.

____ Make two horizontal cuts on either side to complete the patch.

____ Remove tape after three weeks.

Ag 514 O – Propagation by Budding
Unit Test
Answer Key

1. List the three types of budding.

Answers:
T-Bud
Patch Bud
Chip Bud

2. Small shoots or sticks of current season's growth are ______________________________.

Answer:
Budwood

3. In propagation by budding, the single bud attached to a small portion of bark or wood is joined with the _________________________ of another plant to form a new plant.

Answer:
Rootskock

Multiple Choice

4. Seeds should be planted for rootstock in the
   a. spring.
   b. summer.
   c. **fall.**
   d. winter.

5. The correct date for budding is determined by
   a. **bud maturity and active growth of rootstock.**
   b. the FDA.
   c. average annual rainfall.
   d. the Farmer's Almanac.

6. The budwood should be cut
   a. the day before you perform the budding process.
   b. **the day you perform the budding process.**
   c. the day after you perform the budding process.
   d. none of the above.

7. The budwood should be labeled

   a. according to variety.
   b. according to the date it was cut.
   c. according to the site where it was cut.
   d. **both a and b.**

8. The budwood should be protected from drying

   a. **by wrapping it in waterproof paper or placing in plastic bags.**
   b. only if the budwood is to be used immediately after cutting.
   c. if it is taken from an immature parent tree.
   d. in the summer months before planting.

9. The rootstock should be cut above the budding
   a. by specialized agricultural engineers.
   b. during the fall harvest.
   c. **soon after leafing has taken place the following spring.**
   d. once the budwood has been replaced.

10. In T-budding, the general procedure is as follows:
    a. Cut the bud; Cut the T; Check the bud in three months.
    b. **Cut the T; Cut the bud; Check the bud in three weeks.**
    c. Cut the rootstock; Cut the patch; Insert the patch; Check the patch in three weeks.
    d. Cut the patch; Insert the patch; Cut the rootstock; Check the patch in three weeks.

11. A variation of patch budding is

    a. I - budding.
    b. T - budding.
    c. Flute budding.
    d. **both a and c.**

12. Chip budding can be used when

    a. **the rootstock is not in active growth.**
    b. the rootstock is in active growth.
    c. when the budwood is not in active growth.
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    a. in the late fall and early winter when the ground has hardened.
    b. **in late summer or early fall when the bark slips easily.**
    c. in the late spring or early summer when the petioles have first formed.

d. during the winter in a greenhouse.

14. **Determine the proper order for these T-budding procedures.**

__7__ Cut underneath the bud and paste it ¼ inch above the bud.

__3__ Make a 1 inch vertical cut (down) through the bark.

__4__ Gently separate the bark from the wood with the tip of the knife, flaring out the vertical cut like a pocket

__9__ Insert the bud into the T cut and tie the bud in place with a rubber band tie.

__8__ Make a vertical cut across the top of the first cut (above the bud) to release it from the stem.

__2__ Make a 1 inch vertical cut (down) through the bark.

__5__ Choose a vegetative bud in the middle of the bud stick.

__1__ Choosing the north side of the stem, make a cut 1 to 2 inches above the ground on the stem.

__6__ Cut around the bud and petiole, starting ½ inch below the bud.

__4__ Gently separate the bark from the wood.

__10__ Check the bud in three weeks to see that the leaf petiole has fallen off and the bud is plumbed up.

15. **Determine the proper order for these patch budding procedures.**

__3__ Choosing a vegetative bud in the middle of the bud stick, make two parallel cuts and two horizontal cuts, about 1 inch wide.

__7__ Cut back the rootstock and follow the procedures as in T-budding to promote growth.

__4__ Slide the patch gently to one side to remove it from the bud stick.

__1__ Cut the stock tree with two parallel cuts about 1 inch wide.

__5__ Insert the patch immediately onto the rootstock, fitting the surfaces snugly.

__2__ Make two horizontal cuts on either side to complete the patch.

__6__ Remove tape after three weeks.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 P - Propagation by Grafting

Unit Objectives

1. Match terms and definitions associated with propagation by grafting.
2. List the reasons for using grafting.
3. Discuss the limitations of using grafting.
4. List the sequence of making a union graft.
5. List the functions of the callus tissue.
6. List the types of grafting used when the diameter of the rootstock and scion are similar.
7. List the types of grafting used when the diameter of the rootstock is greater than the scion.
8. Describe the qualities of a grafting seal.
9. List the basic functions of grafting seals.
10. List the basic kinds of grafting wax.
11. Demonstrate the ability to perform the basic types of plant grafts.


Information

1. **Match Terms and Definitions Associated with Propagation by Grafting**
2. **List the Reasons for Using Grafting**
3. **Discuss the Limitations of Using Grafting**
4. **List the Sequence of Making a Union Graft**
5. **List the Functions of the Callus Tissue**
6. **List the Types of Grafting Used when the Diameter of the Rootstock and Scion are Similar**
7. **List the Types of Grafting Used when the Diameter of the Rootstock is Greater than the Scion**
8. **Describe the Qualities of a Grafting Seal**
9. **List the Basic Functions of Grafting Seals**
10. **List the Basic Kinds of Grafting Wax**
11. **Demonstrate the Ability to Perform the Basic Types of Plant Grafts**

Grafting

Connecting two plants to grow as one by attaching the scion to the rootstock.
The union of plant tissue allows movement of the sap back and forth from one portion of the plant to the other.

Scion

Shoot, or short piece of stem with two or more buds used as the top portion of the plant, grafted to the rootstock.

Rootstock

Scion is grafted onto the rootstock, the bottom half of the plant which provides the root system for the entire plant.

Reasons for grafting:

Increasing the number of a desirable species.
Increase the root strength and disease resistance of a plant.
Topwork a tree by grafting a different variety or many varieties to many limbs of a tree.
Propagate a plant asexually due to difficulty of propagation by other methods.
Cross-pollinate by grafting different varieties onto the same tree.

Limitations of grafting:

May reduce the vigor of the new plant.
May reduce the size of the new plant.
A complicated process which requires practice.
Grafting between species is only successful in some families, and may not be reciprocal (e.g., species used as rootstocks may not be successful in the reverse, used as scions).
Incompatibility may not be apparent until the development of abnormal growth patterns.

Successful grafts

- Scion and rootstock must be compatible (i.e., apple to apple).
- Both scion and rootstock should be at least one year old and disease free.
- Preferably both the scion and rootstock are dormant, but at least the scion should be dormant (which depends on the type of graft used).
- The scion and rootstock should be held in close contact for the graft to take place.
- The graft must be waterproofed with grafting wax.

Sequence of the graft union

🡇 Fresh scion is brought into contact with rootstock tissue.
🡇 Exposed layers of cells on both the scion and the rootstock produce parenchyma cells which intermingle, forming callus tissue.
🡇 Cells within callus differentiate into new cambium cells.
🡇 New cambium cells produce xylem and phloem, establishing a new vascular pathway between the scion and the rootstock.

Functions of callus tissue

Callus is the mass of parenchyma cells that develops from wounded plant tissues.
Callus occurs from both the scion and the rootstock.
When the parenchyma unite, it initiates mitosis, and allows the process of the successful graft union to take place.

Types of Grafts

Whip and Tongue (see below)

Cleft (see below)

Saw-Kerf or Notch

Three cuts are made into but not through the rootstock. These cuts are made to place the scions into the rootstock as in Cleft grafting.

Side

Scion is inserted into the side of the rootstock

Bark

Scion is inserted between the bark and wood of the stock, then nailed in place.

Splice

Scion and rootstock are cut at the same angle and spliced, or placed together cambium to cambium, and tied together as in the whip graft.

Approach

Two plants are grafted together, usually two container plants that can sit side-by-side until the union heals.

Inarching

The roots of an established tree are assisted by grafting a new rootstock plant by approach graft onto the trunk of the existing tree to provide a new root system.

Whip and Tongue Grafting

Useful for grafting small material equal in diameter (about ¼ to ½ inches).

The cuts in both the scion and rootstock form sections that fit together much like tongue and groove in woodworking.

Preparation

The scion should contain three buds.

The rootstock should be 4 to 8 inches long and the same diameter as the scion.

Procedure

Cut the scion off below a bud at a clean angle = ⇲

Cut the rootstock top off at a matching angle = ⇲

Make an insertion cut on the bottom of the scion about 1/3 of the way across the diameter of the scion, 1 ½ inches into the cut surface = ⇱

Make an insertion cut on the top of the rootstock about 2/3 of the way across the diameter of the rootstock, 1 ½ inches down into the cut surface = ⇲

Cuts made on both pieces should be exactly the same slope and length.

This creates a “tongue and groove” effect that should allow the scion and rootstock to be joined by inserting one into the other.

Waxing

After joining, the two pieces are tied together with rubber banding tie, then sealed with grafting wax to prevent drying.

Cleft Grafting

Used in joining small scion parts to large rootstocks.

Especially useful for grafting to the trunk of a small tree or in the scaffold branches of a larger tree.

Preparation

Species used should have straight-grained wood which will split evenly.
Stock branches, or budsticks used as scions should be 1 to 4 inches in diameter, from dormant, one year-old wood.
Best done in spring before active growth but after buds have begun to swell.
Collect the scion wood in early spring and use immediately, or hold under refrigeration until use.

Procedure

Saw off the rootstock straight across, leaving the surface level and smooth-grained.
Split the rootstock all the way across, using a saw or mallet and butcher knife.
Split down several inches with a clean cut.
Hold the split open by inserting a wedge.
Make two scions from a budsticks containing two or three buds, 3 to 4 inches long.
Cut the inserting ends of the scions into smooth wedge shapes for about 2 inches.
The budsticks used as scions are inserted right-side-up - cut the wedge at the *basal* end of the scion.
Important: you are trimming the scions to expose the cambium layer, in a shape that will match the notch made in the rootstock for insertion. The two cambium surfaces must make contact for a successful graft.
Place the scions into the rootstock, one on each side. Remove the wedge.
Set them in past the bark, assuring contact between the wedge sections and the cambium of the rootstock.
Buds should be above the surface, wedge-cut edges below.

Waxing

Cover the entire top surface with grafting wax.
Permit the wax to work into the notch.
Cover the sides of the rootstock to include the entire split.
Cover the cut, top surfaces of the scions, but do not cover over the entire scion or the buds.
Check the waxing after a few days to rewax any openings.

If both scions grow, the most vigorous is kept and the other removed after the first season of growth.

Grafting seals:

- Seal over the graft union to prevent moisture loss and death of the parenchyma cells which produce the callus and healing of the graft union.
- Prevent decay and wood rot.

A good grafting wax should:

- Adhere well to plant surfaces

- Resist moisture and wash-off
- Be pliable to allow for plant growth yet resist the effects of heat and cold.

Types of grafting wax:

Hot wax

Must be preheated for application.
Should be hot enough to flow but not bubble.
Applied with a brush.

Hand wax

Does not require heating.
Sticky, soft and pliable, warms by hand application.
Applied by pressing in and around the graft.

Cold wax

Water soluble.
Water within the compound evaporates a few days after the application.
Effected by freezing temperatures - warm storage required.
Will not withstand application during rainy weather. Conditions must be dry long enough for the wax to set up.

Hot wax application by brush and hand waxing are the most commonly used forms of grafting wax.
Grafting seals are may be covered initially with plastic bags and tied off to assist resistance to weathering.

References

1. Hartman, H.T. & Kester, D.E. (1975). *Plant Propagation: Priniciples and Practices* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
4. Sunset Books. (1995). *Sunset Western Garden Book* (6th ed.). Menlo Park, CA: Author.

Student Activity

- **Demonstrating the Whip and Tongue and the Cleft Grafts**

Internet Resources

Grafting Agricultural publication G06971 - Reviewed October 1, 1993
Ray R. Rothenberger and Christopher J. Starbuck
Department of Horticulture, University of Missouri-Columbia
http://etcs.ext.missouri.edu:70/publications/xplor/agguides/hort/g06971.html

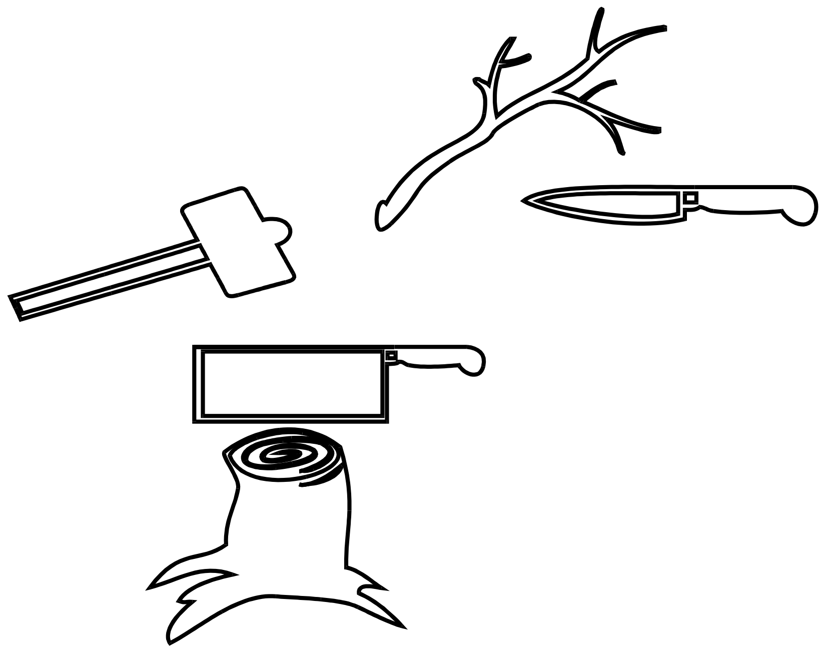
Plant Propagation Cleft Grafting
http://aggie-horticulture.tamu.edu/propagation/cleftgrafting/cleftgrafting.html

Transparencies

- **Whip and Tongue Graft**
- **Cleft Graf**

Student activity: Demonstrating the Whip and Tongue and the Cleft Grafts

Purpose
Demonstrate the ability to perform the basic types of plant grafts.



Materials
Rootstock and scion wood
Propagation knife
Mallet
Wedge
Waterproof tie
Hand grafting wax
Plant labels / waterproof marking pen

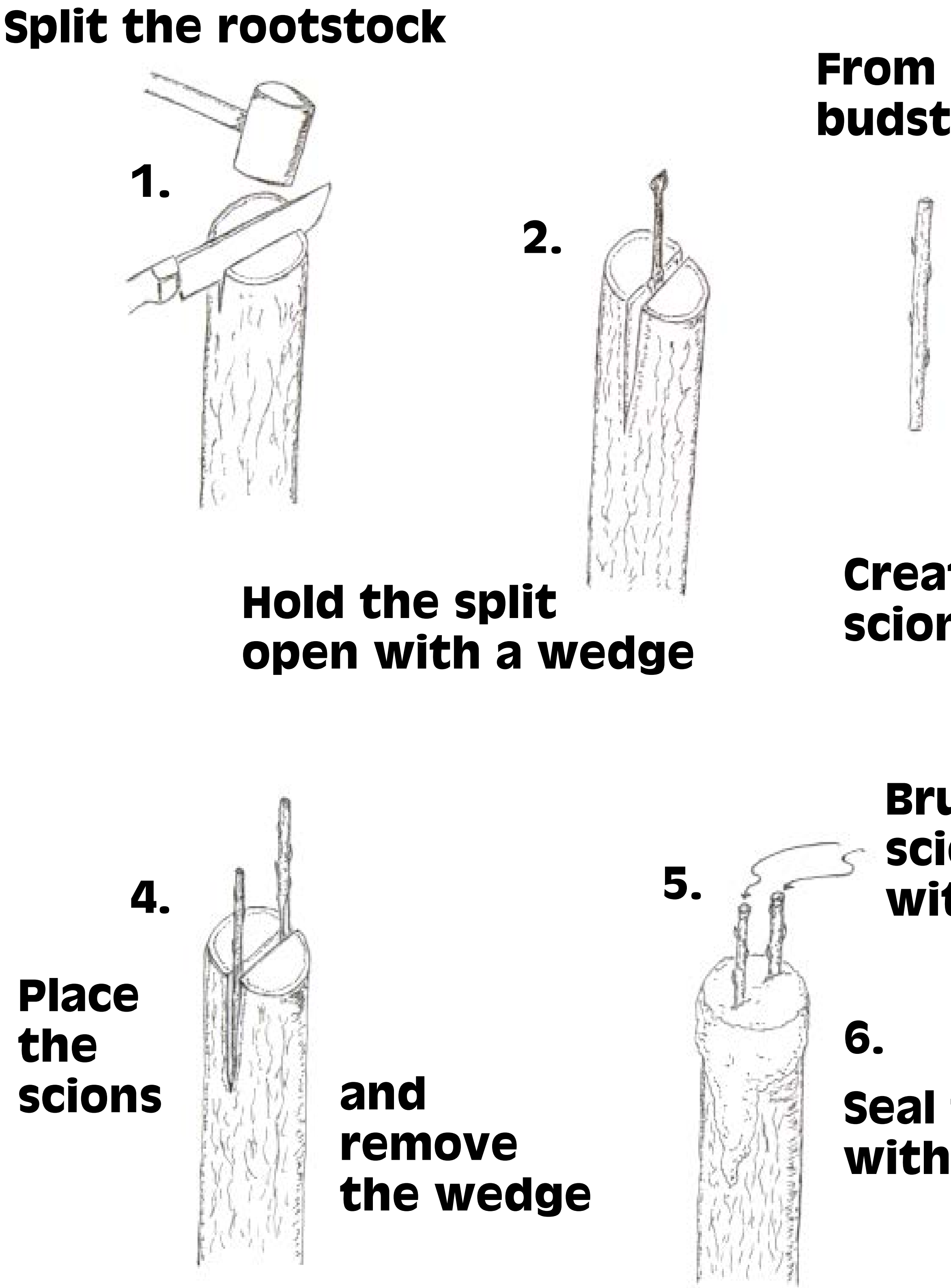
Procedure
Caution: *cut away from yourself or others when using cutting instruments.*
Each student should follow the procedures as outlined in the **Information** sheet for this section on *Whip and Tongue Grafting* and *Cleft Grafting*.
Each student should perform one whip and tongue graft and one cleft graft.
Label the plant according to variety of scion and rootstock, and date grafted.

Demonstration
Each student should choose one part of one of the grafting procedures to demonstrate to the class.
Prepare a hand-out for your section of the procedure with an illustration. Give your instructor a copy of your hand-out.
Distribute the hand-outs before your demonstration.
Demonstrate your section of the procedure to the class.
Make certain everyone can view the procedure.
Open the floor to a question and answer / discussion period following the demonstration of your section of the procedure.

Your Procedure

Teacher Note
A large class can be divided into groups, allowing each group member to demonstrate a portion of the whip and tongue or cleft grafting procedures to the other members of the group.

Cleft Graft



Split the rootstock
1.
From
budst
2.
Hold the split
open with a wedge
Creat
scion
4.
Place
the
scions
and
remove
the wedge
5.
Bru
sci
wit
6.
Seal
with

Whip and Tongue Graft

1.

Cut the scion

Cut the rootstock

2.

3.

Join the scion and the root-stock

Seal the graft with wax

5.

to retain moisture

Ag 514P Propagation by Grafting
Unit Test

Fill in the Blank

1. ____________________ is connecting two plants to grow as one by attaching the scion to the rootstock.

2. The union of _________________ allows movement of the sap back and forth from one portion of the plant to the other.

3. A shoot or short piece of stem with two or more buds, which is used as the top portion of the plant, is the ________________.

4. The _______________ is the mass of parenchyma cells that develop from wounded plant tissues.

True or False

____ 5. Grafting increases the population of desirable species.

____ 6. Grafting does not reduce the vigor or size of a new plant.

____ 7. Grafting between species is possible with every plant family.

____ 8. Grafting incompatibility may not be immediately apparent.

____ 9. Grafting does not increase the root strength or the plant's immunity to disease.

____ 10. Plants, which are difficult to propagate by other methods, can be asexually propagated through
grafting.

Essay

11. What are the basic functions of grafting seals? List them including in your definition at least one quality of a good grafting seal and an example.

Matching

Ag 514 P - Propagation by Grafting - 1

____	12. Bark	A.	useful for grafting small material (¼ to ½ inches) equal in diameter
____	13. Hot Wax	B.	used in joining small scion parts to large rootstocks
____	14. Whip and Tongue	C.	three cuts are made into but not through the rootstock
____	15. Side	D.	scion is inserted into the side of the rootstock
____	16. Hand Wax	E.	scion is inserted between the bark and wood of the stock and nailed in place
____	17. Cleft	F.	scion and rootstock are cut at the same angle and placed together
____	18. Splice	G.	two plants, usually side-by-side container plants, are grafted together
____	19. Cold Wax	H.	roots of an established tree are assisted by grafting a new rootstock
____	20. Inarching	I.	must be preheated for application and applied with a brush
____	21. Approach	J.	sticky, soft and pliable; applied by pressing in and around graft
____	22. Saw-Kerf or Notch	K.	water within the compound evaporates a few days after application

Ag 514P - Propagation by Grafting
Unit Test
Answer Key

Fill in the Blank

1. ____________________ is connecting two plants to grow as one by attaching the scion to the rootstock.
   Answer: Grafting

2. The union of _________________ allows movement of the sap back and forth from one portion of the plant to the other.
   Answer: plant tissue

3. A shoot or short piece of stem with two or more buds, which is used as the top portion of the plant, is the ________________.
   Answer: scion

4. The _______________ is the mass of parenchyma cells that develop from wounded plant tissues.
   Answer: callus

True or False

__T__ 5. Grafting increases the population of desirable species.

__F__ 6. Grafting does not reduce the vigor or size of a new plant.

__F__ 7. Grafting between species is possible with every plant family.

__T__ 8. Grafting incompatibility may not be immediately apparent.

__F__ 9. Grafting does not increase the root strength or the plant's immunity to disease.

__T__ 10. Plants, which are difficult to propagate by other methods, can be asexually propagated through
grafting.

Essay

11. What are the basic functions of grafting seals? List them including in your definition at least one quality of a good grafting seal and an example.

Matching

__**E**__ 12. Bark

__**I**__ 13. Hot Wax

__**A**__ 14. Whip and Tongue

__**D**__ 15. Side

__**J**__ 16. Hand Wax

__**B**__ 17. Cleft

__**F**__ 18. Splice

__**K**__ 19. Cold Wax

__**H**__ 20. Inarching

__**G**__ 21. Approach

__**C**__ 22. Saw-Kerf or Notch

A. useful for grafting small material (¼ to ½ inches) equal in diameter
B. used in joining small scion parts to large rootstocks
C. three cuts are made into but not through the rootstock
D. scion is inserted into the side of the rootstock
E. scion is inserted between the bark and wood of the stock and nailed in place
F. scion and rootstock are cut at the same angle and placed together
G. two plants, usually side-by-side container plants, are grafted together
H. roots of an established tree are assisted by grafting a new rootstock
I. must be preheated for application and applied with a brush
J. sticky, soft and pliable; applied by pressing in and around graft
K. water within the compound evaporates a few days after application

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 Q - Plant Identification

Unit Objectives

1. Discuss the system of plant classification.
2. Identify the parts of simple and compound leaves.
3. Name the types of leaf arrangement, venation, and margins.
4. Identify the types of leaf attachment to stems.
5. Identify the parts of a stem.
6. Match stem modifications with their correct description.
7. Identify the parts of a perfect flower.
8. Identify the types of inflorescence.
9. Identify the common plants of economic impact to the horticulture industry of Idaho.

Information

From *Agricultural Science and Technology, Botany / Plant Growth and Development, Ag 512 A - The Organisms*:

1. Discuss the System of Plant Classification

From *Agricultural Science and Technology, Botany / Plant Growth and Development, Ag 512 E - Vegetative Plant Parts*:

2. Identify the Parts of Simple and Compound Leaves

3. Name the Types of Leaf Arrangement, Venation, and Margins

4. Identify the Types of Leaf Attachment to Stems

5. Identify the Parts of a Stem

6. Match Stem Modifications with Their Correct Description

Also see Agricultural Science and Technology, Botany / Plant Growth and Development, Ag 512 F - Reproductive Plant Parts:

7. Identify the Parts of a Perfect Flower

Also see Agricultural Science and Technology, Introduction to the Agricultural Plant Industry, Ag 150 J - Crop and Weed Identification:

8. Identify the Types of Inflorescence

9. Identify Common Plants of Economic Impact to the Horticulture Industry of Idaho

The perfect flower

Contains both stamens and pistils.

The imperfect flower

Either stamens or pistils are missing.

The incomplete flower

Lacking one or more of stamens, pistils, petals, or sepals.

The complete flower
Has stamens, pistils, petals, and sepals attached to a receptacle.

Inflorescence
Mode of development and arrangement of flowers on their axis.

Indeterminate
Sequential flowering from the lateral or basal buds to the central or uppermost buds.
Main stem continues to elongate indefinitely without being limited by terminal inflorescence.

Determinate
Sequential flowering from the central or uppermost bud outward to the lateral or basal bud.
Main stem ends in a florescence and stops growing.
Branches from the main stem grow in a similar manner.

Axis
Plant stem.

Apex
Uppermost part of the stem.

Pedicel
Emerging from the apex; supports the fruiting or spore-bearing part of the plant.

Peduncle
Single stalk bearing the flower or flower cluster.

Racemose
Growing in the form of a raceme.

Sessile
Flower is attached directly to the stem by the base (without peduncle).

Simple
A single carpel.

Compound
Having two or more flowers within a single flower head.

Types of inflorescence

Raceme

Simple inflorescence.

Flowers borne on short stalks of equal length, located at equal distances along an elongated axis, open in succession toward the apex.

Corymb

Flat-topped inflorescence

Stalks ascend at different levels on the main axis, reaching about the same height. Outer flowers open first; inflorescence is *indeterminate*.

Umbel

Pedicels seem to emerge from the same point at the apex to form a flat or rounded flower cluster.

Compound umbel

Having two or more umbels emerging from the apex.

Capitulum

A rounded or flattened cluster of sessile flowers.

Spike

Racemose elongated inflorescence. Flowers are sessile on the main axis.

Compound spike

Having more than one flower on a common axis, emerging from main axis. Flowers are sessile on their common axis.

Panicle

A pyramidal loosely branched compound flower cluster.

Cyme

A *determinate* inflorescence containing several flowers.

The central flower opens first; subsequent flowers open from lateral buds.

Common plants of economic impact to horticulture in Idaho, including the floral, greenhouse, and nursery industries:

Sweet cherries
Apples
Prunes and plums, fresh
Grapes and wine production
Vegetables; specialized, organic, hydroponic
Fruits and nuts
Christmas trees

References

1. Merriam-Webster. (1996). *Merriam-Webster's Collegiate Dictionary* (10th ed.). Springfield, MA: Author.
2. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
3. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

4. Idaho Nursery Association
   N. Woodruff
   Idaho Falls, Idaho 83401
   INA-GROW or (208) 522-7307

Student Activity

- **In Search of Inflorescence**

Teacher Information / Optional Activity

- **Idaho Certified Nurseryman Examination Plant Material Identification List**

(See *Learning Objectives* for possible writing activity)

Internet Resources

Micro-Unit 901: Classification Schemes
From *Scope, Sequence, and Coordination*
The National Science Teachers Association
http://www.gsh.org/nsta_scripts/mu_record.idc

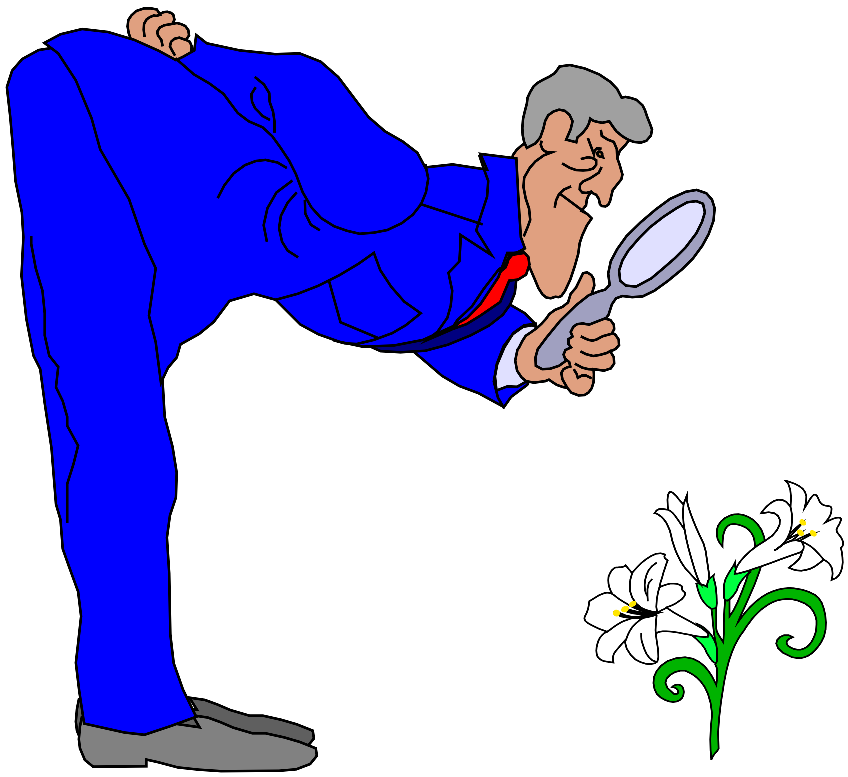
Transparencies

- **Inflorescence Types**

From *Agricultural Science and Technology, Introduction to the Agricultural Plant Industry, 150 J - Crop and Weed Identification*:

- **Types of Inflorescence**
- **Types of Inflorescence (continued)**

Student Activity: In Search of Inflorescence



Purpose

- Identify the types of inflorescence.
- Understand the basic scheme for identifying plants.

Materials

- Field guide to wildflowers (i.e., Peterson's; Golden)
- *Weeds of the West* - Western Society of Weed Science
- *Sunset Western Garden Book* - Sunset Books
- 35 mm camera
- At least one roll of 24 or 36 color print film, ASA 200 to 400
- Photo binder with plastic "see-through" sleeves
- Notebook

Procedure

- Find one example each of each type of inflorescence. You may use wildflowers, ornamental plants, or a combination of each as your examples.
- Use a field guide and/or the Sunset Western Garden Book to help you find plant types which meet the criteria for examples of each inflorescence.
- Document your finds with a color photograph of each.
- Make notes as your search progresses.
    - ⇒ Describe the habitat where you found your flower type, and which guide you referenced to help you identify it. This includes a natural habitat or the conditions in which you found the ornamental plant.
    - ⇒ Note the date and the time of day the photo was taken. You may also wish to note the film type you used and the conditions of the shoot; e.g., the weather, the lighting, etc.

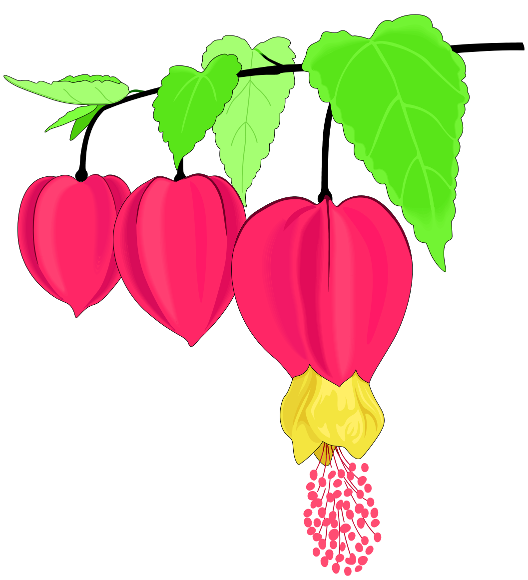
<u>Photo Notes</u>

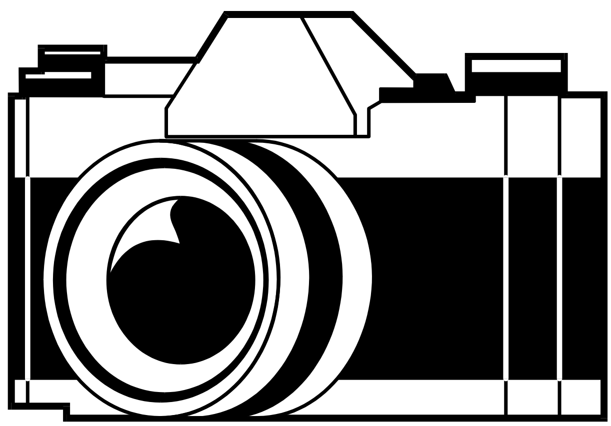
The camera can become an important research document. Take good shots!

- Compose your pictures. Be sure you get the important aspects of the plant that indicate what type of plant it is: leaves and their arrangement on the stem; flower-head types and their arrangement on the stem; number of petals, nectar guides, and depth of color.

- Screen out extraneous information. Get close enough to visually "crop" the picture down to just the information you want in the frame of the photo.
- Keep a steady hand! Rest your camera on a small tripod or anything that is immobile to take your shot.
- You may have to take more than one picture of the same flower to get all the information you need. Be sure to document each photograph *in sequence in your notebook*. Number each roll and note accordingly; e.g., roll #1 - photo #4 - name of wildflower - photo description.
- Use natural light, if possible. Unless your camera has a flash you can "bounce" to light the subject indirectly, your photo flash will "white out" some of the important plant aspects you are trying to photograph.
- Place your pictures and an explanation of each in your photo binder.
  - ⇒ Your photos need the common and scientific name of the plant and the type of inflorescence it represents.
  - ⇒ A brief explanation beside each plant picture(s) should come from your notebook notes: where you found the plant and the conditions of its habitat. If it was an ornamental, explain the type of environment the plant was placed in: light, humidity, etc.

Peer Review: your work will be reviewed by your classmates. See "Plant ID Evaluation" sheet. Your research will serve you well. You'll have a permanent plant record for your reference and you can add records to your binder in the future.





Compose your shots!

Plant ID Project Evaluation

Binder # _____

Evaluator ____________________

Instructions

To the evaluator: On the line provided above, indicate which binder # you are evaluating with this sheet. Please use a field guide or other reference book to check the work you are evaluating.

1. Does the binder feature each type of inflorescence?
   ☐ Yes
   ☐ No
   (*check one*)

2. Does each photo caption include the common and scientific name of the plant?
   ☐ Yes
   ☐ No
   (*check one*)

3. Does each photo caption indicate the type of inflorescence the photo represents?
   ☐ Yes
   ☐ No
   (*check one*)

4. Are the captions correct?
   ☐ Yes
   ☐ No
   (*check one*)

If not correct, what is wrong? (*please indicate on the following lines . . .*)

____

____

____

5. Does a habitat description accompany each photograph?
   ☐ Yes
   ☐ No
   (*check one*)

6. How complete was the work?
   ☐ Complete
   ☐ Incomplete
   (*check one*)

If incomplete, please describe: ______________________________

____

____

7. How would you rate this binder overall? Excellent Good Average Below Average Poor
   (*circle one*)

Thank you for your comments!

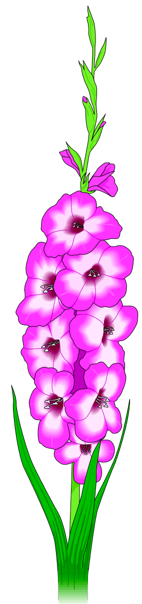
Teacher Information

To the instructor: each binder should be numbered for the purposes of the evaluation. Do not allow students to attach a name to their binders until the evaluations are finished.

The evaluations are also meant to reinforce the knowledge of the evaluator. Please make sure the students use reference guides to help them evaluate the work of the other students.

For the sake of time management, reduce the number of evaluations done by each student to 1 to 3 binders.

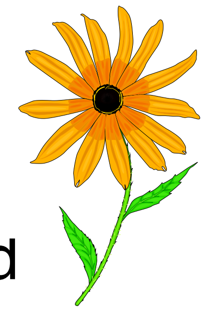
Inflorescence Types

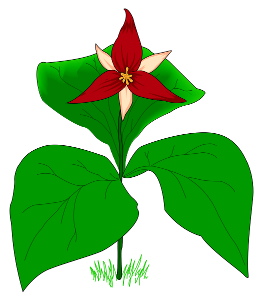


Spike

Raceme

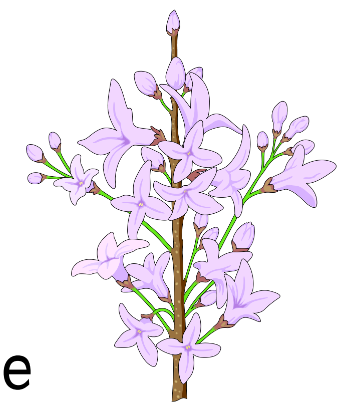
Compound



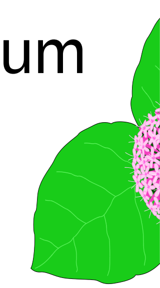


Solitary

Panicle



Capitulum



Umbel

Ag 514 Q – Plant Identification
Unit Test

____ 1. The imperfect flower

____ 2. Determinate

____ 3. Umbel

____ 4. Inflorescence

____ 5. Apex

____ 6. Capitulum

____ 7. The perfect flower

____ 8. The incomplete flower

____ 9. Simple

____ 10. Axis

____ 11. Raceme

____ 12. Compound

____ 13. Peduncle

____ 14. Compound umbel

____ 15. Sessile

____ 16. Compound spike

____ 17. Cyme

____ 18. The complete flower

____ 19. Racemose

____ 20. Spike

____ 21. Indeterminate

____ 22. Panicle

____ 23. Pedicel

____ 24. Corymb

A. contains both stamens and pistils
B. either stamens or pistils are missing
C. lacking one or more of stamens, pistils, petals, or sepals
D. has stamens, pistils, petals, and sepals attached to a receptacle
E. mode of development and arrangement of flowers on their axis
F. sequential flowering from the lateral or basal buds to the central or uppermost buds
G. main stem ends in a florescence and stops growing
H. plant stem
I. uppermost part of the stem
J. supports the fruiting or spore-bearing part of the plant
K. single stalk bearing the flower or flower cluster
L. growing in the form of a raceme
M. flower is attached directly to the stem by the base
N. a single carpel
O. having two or more flowers within a single flower head
P. flowers born on short stalks of equal length
Q. flat-topped inflorescence
R. pedicels seem to emerge from the same point at the apex forming a flat or rounded flower cluster
S. having two or more umbels emerging from the apex
T. a rounded or flattened cluster of sessile flowers
U. flowers are sessile on the main axis
V. flowers are sessile on their common axis
W. a pyramidal loosely branched compound flower
X. a determinate inflorescence containing several flowers

25. List five of the seven common plants of economic impact to horticulture in Idaho.

Ag 514 Q – Plant Identification
Unit Test
Answer Key

__B__ 1. The imperfect flower

__G__ 2. Determinate

__R__ 3. Umbel

__E__ 4. Inflorescence

__I__ 5. Apex

__T__ 6. Capitulum

__A__ 7. The perfect flower

__C__ 8. The incomplete flower

__N__ 9. Simple

__H__ 10. Axis

__P__11. Raceme

__O__ 12. Compound

__K__ 13. Peduncle

__S__14. Compound umbel

__M__15. Sessile

__V__ 16. Compound spike

__X__ 17. Cyme

__D__ 18. The complete flower

__L__ 19. Racemose

__U__ 20. Spike

__F__21. Indeterminate

__W__ 22. Panicle

__J__ 23. Pedicel

__Q__ 24. Corymb

Y. contains both stamens and pistils
Z. either stamens or pistils are missing
AA. lacking one or more of stamens, pistils, petals, or sepals
BB. has stamens, pistils, petals, and sepals attached to a receptacle
CC. mode of development and arrangement of flowers on their axis
DD. sequential flowering from the lateral or basal buds to the central or uppermost buds
EE. main stem ends in a florescence and stops growing
FF. plant stem
GG. uppermost part of the stem
HH. supports the fruiting or spore-bearing part of the plant
II. single stalk bearing the flower or flower cluster
JJ. growing in the form of a raceme
KK. flower is attached directly to the stem by the base
LL. a single carpel
MM. having two or more flowers within a single flower head
NN. flowers born on short stalks of equal length
OO. flat-topped inflorescence
PP. pedicels seem to emerge from the same point at the apex forming a flat or rounded flower cluster
QQ. having two or more umbels emerging from the apex
RR. a rounded or flattened cluster of sessile flowers
SS. flowers are sessile on the main axis
TT. flowers are sessile on their common axis
UU. a pyramidal loosely branched compound flower
VV. a determinate inflorescence containing several flowers

25. List five of the seven common plants of economic impact to horticulture in Idaho.

Answer:
Sweet Cherries
Apples
Prunes and plums, fresh
Grapes and wine production
Vegetables; specialized, organic, hydroponic
Fruits and nuts

Christmas Trees

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 R - Plant Pests and Their Control

Unit Objectives

1. Identify the five major categories of plant pests.
2. Describe the relationship between plant pest and plant host.
3. Determine the indications of plant pest problems.
4. Describe the ramifications of plant damage on plant production and distribution.
5. Describe the types of plant damage inflicted by small animals.
6. Describe the types of plant damage inflicted by large animals.
7. Discuss the prevention and control of animal pests.

Information

1. Identify the Five Major Categories of Plant Pests

2. Describe the Relationship Between Plant Pest and Plant Host

3. Determine the Indications of Plant Pest Problems

4. Describe the Ramifications of Plant Damage on Plant Production and Distribution

5. Describe the Types of Plant Damage Inflicted by Small Animals

6. Describe the Types of Plant Damage Inflicted by Large Animals

7. Discuss the Prevention and Control of Animal Pests

Five major categories of plant pests:

1. **Insects**
   - Animals with three distinct body parts
   - Three pairs of legs (six total)
   - No wings; one, or two pairs of wings
2. **Nematodes**
   - Appendageless, nonsegmented invertebrates.
   - Worm-like, largely transparent at 1/75 to 1/10 inches
3. **Weeds**
   - Plant growing out of place
   - Unwanted plant (invasive species)
4. **Diseases**
   - Fungi
   - Bacteria
   - Viruses
5. **Animals**

Small
- Birds
- Mice / rodents generally
- Rabbits

Large
- Deer
- Bear
- Farm animals

Pest

Anything that causes damage or loss to a plant.
Usually a living organism.

Pests effect plant damage by:

Affecting their reproduction capability
Destroying them.

Host

Provides a pest with food.

Indications of plant pest problems

Insects
- Birds feeding on grubs and caterpillars.
- Holes and lacey effect of leaf deterioration (only veinage is left) (chewing insects).
- Twisted plant tips / rolled leaves (sucking insects).
- Sap eminating from trunk / stems.

Nematode invasion
- Roots have knots or bumps.
- Certain weeds are present.
- May mimic other problems (low fertility, frost damage, root-rot fungi, etc.)
- Indicated best by nematode type count in soil (tested at a laboratory) = the nematode action threshold.

Weeds
- Certain species of long-standing weeds evidence of unsuitable conditions.
  - Low moisture
  - Poor soil
  - Low nitrogen
  - Hosting nematodes

Diseases
- Foliage damage
- Root damage
- Abnormal appearance
  - Weakened stems
  - Rolled leaves
  - Brown / yellow / red spots; depigmentation

Animals

Small

Eaten foliage and stems
Eaten fruit / vegetables and roots
Gnawed bark
Holes and mounds (soil surface damage)
Equipment damage (trying to navigate fields with holes and mounds)
Fire ants attack people and animals

Large

Eaten twig tips and fruit
Rubs (bark damage)
Trampling (soil surface and plant damage)

Ramifications of plant damage on production and distribution:

Loss of income

Production costs increase (re-planting)
Quantity produced decreased (unable to re-plant)
(fruit and vegetable production reduced)
Reduced quality
Control costs of:

Insecticides
Herbicides
Fungicides.

Equipment and inventory costs:

To re-plant
To apply pesticides.

Labor costs

Prevention and control of animal pests:

Fencing
Screening / wrapping (seedlings and young saplings)
Root collars
Bulb screens
Removing pest habitat.
Trapping / removal
Pesticides
Repellants
Providing more desirable habitat / food away from the growing area.
Providing habitat / favorable conditions for natural predators.

Nematode Control

Nematodes are plant parasites which move from plant to plant in soil water, feeding on plant roots. Some nematode types live in plant leaves.

Control measures to reduce nematode populations:

Fumigants (by contact)
Systemic (for leaf-feeding nematodes)
Resistant varieties
Crop rotation
Leaving planting areas fallow in the summer.

References

1. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
2. Project WILD. (1992). *Project WILD Activity Guide* (2nd ed.). Boulder, CO: Author.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activities

- **The Best Offense is a Good Defense**

From *Project WILD Activity Guide*, Project WILD:
- **"Oh Deer!"** (pp. 146-149)
- **"Birds of Prey"** (pp. 150-151)

Internet Resources

Keeping Wildlife at a Safe Distance
http://cc.usu.edu/~rschmidt/welcome.html

University of California
Sustainable Agriculture Research and Education Program
http://www.sarep.ucdavis.edu/

Transparency

- **Encouraging Wildlife Predators**

Student Activity: The Best Offense Is a Good Defense

Purpose
- Discuss the prevention and control of animal pests.

Materials
- Notebook
- Presentation binder with plastic sleeves
- Other presentation materials as needed per *Procedure*

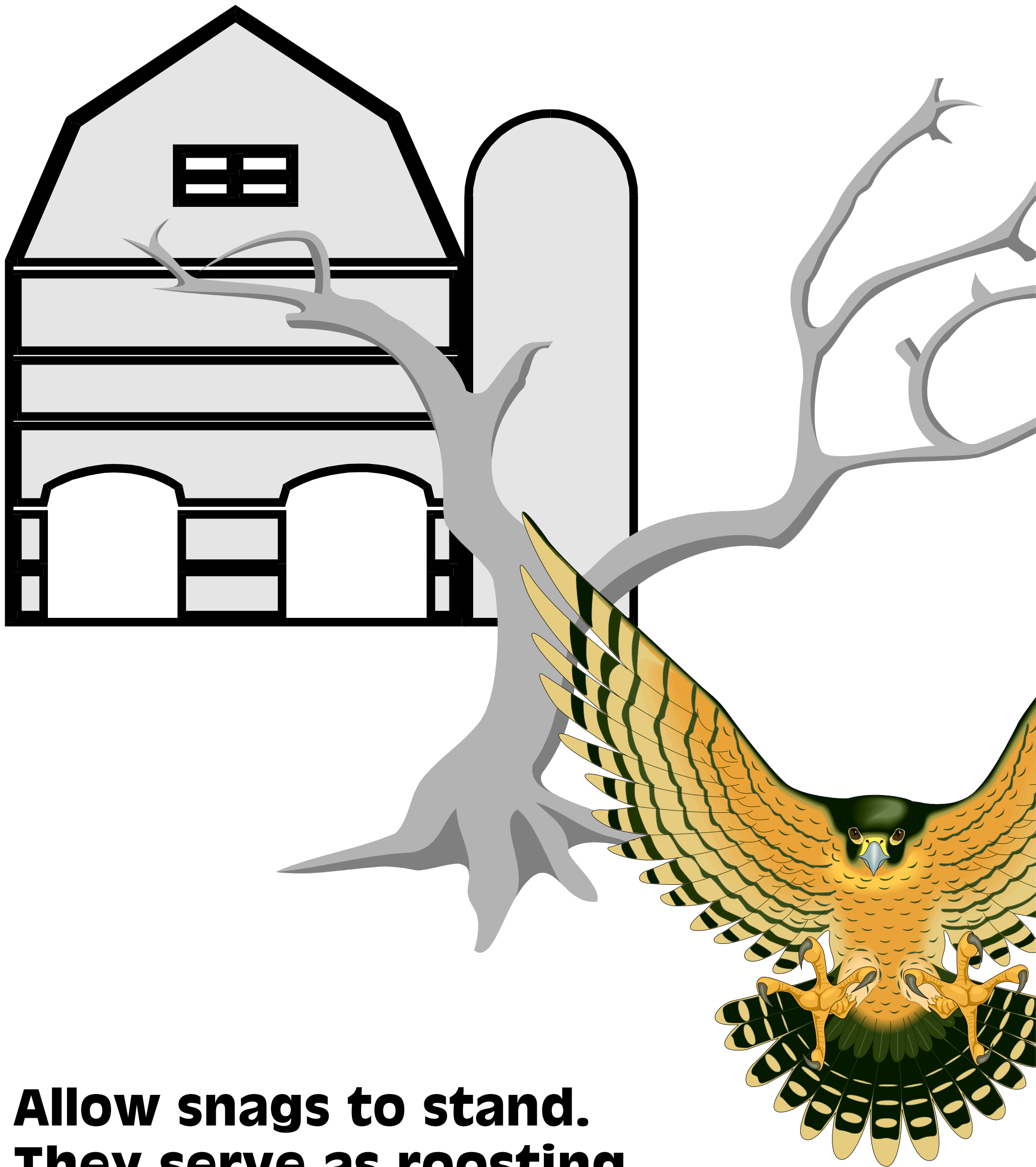
Discussion
Natural pest control is based on using the dynamics of a natural system to control populations of unwanted pests. This calls for manipulation of a predator/prey relationship. By understanding the limiting factors of both the predator and the prey, you can enhance an area for a predator by establishing or promoting the conservation of its habitat; limit an area to a pest by destroying its habitat (and risk limiting a beneficial animal's habitat with it), or create conditions that foster biodiversity.

Nature reaches biodynamically balanced or *steady* states within ecosystems. These systems are considered healthy states because their populations fluctuate and recover, or are suitably replaced within the niche, maintaining a type of balance that fosters diversity within a system rather than the dominance of one form of life over another, which could ultimately deplete the diversity necessary to sustain the food web - the heart of an ecosystem. For instance, when a disruption of a food web occurs within a system, it creates a limiting factor for one or more members of a food chain within the web. If a food source disappears, the populations which survived on that source of food must either migrate to another source of food, suffer a population die-off due to lack of food, or discover a new source of food within the web.

Procedure
This activity involves finding a predator/prey relationship that will serve as an effective control for an animal pest (as opposed to a weed, insect, nematode, or disease pest). Use your notebook to log your research.
Each student should:
- Identify an animal pest and describe the type of damage it does to an agricultural plant or situation.
- Research the animal's life history. What does the animal need to survive, including food, water, shelter, and space?
- How does the agricultural environment meet the animal's needs?
- Research the limiting factors of the animal:
    - food resources
    - natural predators
    - population / territorial controls
    - habitat restrictions

- Research the limiting factors of the animal's natural predator(s). Choose one predator as the most desirable for controlling the pest population and describe what the animal needs to survive, including food, water, shelter, and space.
- Identify the best methods for controlling the pest animal.
- Write the description of the control methods as if you were instructing a farmer or rancher.
- Write a paper on your pest control method which includes the instructions and any use of graphics which are helpful in supporting your points. Use your research to support your suggested methods of control.
- Do a presentation on your "best defense." Create graphics to accompany your presentation. Post your graphics as a poster presentation, or create a slide presentation or computer-generated slide show. Create hand-outs on the important points of your presentation for your audience.

Encouraging Wildlife Predators: Natural Pest Control



Allow snags to stand. They serve as roosting and nesting sites for raptors (falcons, hawks, and owls) - natural predators of rodents.

Ag 514 R -Plant Pest and Their Control
Unit Test

Identify the five major categories of plant pests and give at least one example or a description for each.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Multiple Choice

6. A pest is anything that

   a. causes damage or loss to a plant.
   b. does not cause damage to a plant.
   c. is a living organism.
   d. is not a living organism.

7. Pests damage plants by

   a. affecting their reproductive capability.
   b. destroying them.
   c. both a and b.
   d. none of the above

8. An organism which provides a pest with food is called a

   a. weed.
   b. host.
   c. beneficial organism.
   d. nematode.

8. The ramifications of plant damage on production and distribution are

a. production cost increase, as well as reduced plant quality and quantity.
b. loss of income only.
c. production cost increase only.
d. reduced plant quality and quantity only.

9. Besides control costs and extra labor costs, plant damage by pests requires

a. additional costs to re-plant and apply pesticides, herbicides, or fungicides.
b. no additional cost.
c. additional equipment and inventory costs.
d. both a and c.

10. One way in which to reduce nematode populations is

a. root collars.
b. crop rotation.
c. fencing.
d. bulb screens.

List at least five measures taken in the prevention and control of animal pests.

11. ____

12. ____

13. ____

14. ____

Determine whether the plant damage described was inflicted by large animals, small animals, disease, weeds, nematodes, or insects.

15. Holes and mounds (soil surface damage) ______________________________

16. Twisted plant tips ______________________________

17. Brown/yellow/red spots; depigmentation ______________________________

18. Trampling (soil surface and plant damage) ______________________________

19. Evidence of unsuitable conditions ______________________________

20. Roots have knots or bumps ______________________________

Ag 514 R -Plant Pest and Their Control
Unit Test
Answer Key

Identify the five major categories of plant pests and give at least one example or a description for each.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Answer:
Insects: animals with three distinct body parts, three pairs of legs, with or without wings
Nematodes: appendageless, nonsegmented invertebrates; worm-like, largely transparent at 1/75 to 1/10 inches
Weeds: plant growing out of place; unwanted plant (invasive species)
Diseases: Fungi, bacteria, viruses
Animals: birds, rodents, rabbits, deer, bear, farm animals

Multiple Choice

6. A pest is anything that

   a. **causes damage or loss to a plant.**
   b. does not cause damage to a plant.
   c. is a living organism.
   d. is not a living organism.

7. Pests damage plants by

   a. affecting their reproductive capability.
   b. destroying them.
   c. **both a and b.**
   d. none of the above

8. An organism which provides a pest with food is called a

a. weed.
b. **host.**
c. beneficial organism.
d. nematode.

8. The ramifications of plant damage on production and distribution are

a. **production cost increase, as well as reduced plant quality and quantity.**
b. loss of income only.
c. production cost increase only.
d. reduced plant quality and quantity only.

9. Besides control costs and extra labor costs, plant damage by pests requires

a. additional costs to re-plant and apply pesticides, herbicides, or fungicides.
b. no additional cost.
c. additional equipment and inventory costs.
d. **both a and c.**

10. One way in which to reduce nematode populations is

a. root collars.
b. **crop rotation.**
c. fencing.
d. bulb screens.

List at least five measures taken in the prevention and control of animal pests.

11. ____

12. ____

13. ____

14. ____

Answers:
Fencing
Screening/wrapping (seedlings and young saplings)
Root collars
Bulb screens
Removing pest habitat
Trapping/removal

Pesticides
Repellents
Providing more desirable habitat/food away from the growing area
Providing habitat/favorable conditions for natural predators

Determine whether the plant damage described was inflicted by large animals, small animals, disease, weeds, nematodes, or insects.

15. Holes and mounds (soil surface damage) ______________________________________
Answer: small animal

16. Twisted plant tips ______________________________________
Answer: insects

17. Brown/yellow/red spots; depigmentation ______________________________________
Answer: disease

18. Trampling (soil surface and plant damage) ______________________________________
Answer: large animals

19. Evidence of unsuitable conditions ______________________________________
Answer: weeds

20. Roots have knots or bumps ______________________________________
Answer: nematodes

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 S - Weeds and Their Control

Unit Objectives

1. Discuss weed competition and crop plant loss caused by weeds.
2. Discuss how weeds spread.
3. List the basic methods of weed control.
4. Discuss methods of cultural, mechanical, chemical, and biological weed control.
5. Identify the factors of a weed control program.
6. Determine when to apply selective and non-selective herbicide compounds.
7. Determine when to apply preplanting, pre-emergence, and post-emergence weed control treatments.

Information

1. Discuss Weed Competition and Crop Plant Loss Caused by Weeds

2. Discuss How Weeds Spread

3. List the Basic Methods of Weed Control

4. Discuss Methods of Cultural, Mechanical, Chemical, and Biological Weed Control

5. Identify the Factors of a Weed Control Program

6. Determine When to Apply Selective and Non-selective Herbicide Compounds

7. Determine When to Apply Preplanting, Pre-emergence, and Post-emergence Weed Control Treatments

Weed

Any plant growing where it is not wanted.
Invasive species.

Weed classifications

Grassy monocots
Broadleaf dicots
Sedges
Wild onion
Wild garlic
Moss
Algae

Factors of a weed control program to consider:

1. **Weed stages of development**
   - ⇒ Vegetative
   - ⇒ Reproductive
   - ⇒ Dormancy
   - ⇒ Senescence
2. **Weed growth cycles:**
   - ⇒ Annual
   - ⇒ Biennial - growing vegetatively the first year and reproducing the second year.
   - ⇒ Perennial - reseeding or vegetatively reproducing, as in creeping perennials.
3. **Weed germination season (fall or spring)**
4. **Accurate identification of the weed**
5. **Selecting control measures specific to the weed.**

Weed competition:

- Detracts from colors and textures of desired plants in an area.
- Reduces the number of desired plants in an area.
- Causes loss of vigor in plants by competing with desired plants for light, water, nutrients, and space.
- Invasive in natural areas, out-competing indigenous plants for light, water, nutrients, and space - sometimes changing or eradicating the ecosystem (i.e., cheat grass, brown knapweed, kudzu, garlic mustard).
- Serve as hosts to insects and diseases.
- May be hazardous to livestock.
- Can reduce the quality of milk, wool, or crops.
- Can create allergens.

Weeds indicate type of soil, pH, and amount of water availability to plants.

Weeds spread by:

- Prolifically producing seeds.
- Reproducing both sexually and asexually.
- Efficient seed dispersal:
  - ⇒ Wind-borne (i.e., dandelion).
  - ⇒ Seeds have hooks that catch on animal fur or clothing and "travel."
  - ⇒ Seeds can remain on farm machinery and travel from field to field.
  - ⇒ Float on water (particularly a problem with canal irrigation).
  - ⇒ Ingested by animals and remain viable after passing through the animal.
- Seeds remain dormant and viable over long periods of time.
- Rapid growth.

Some of the worst weeds were imported or established with good intent: kudzu, Johnsongrass, multiflora rose.

Methods of controlling weeds:

Cultural

- Maintaining clean equipment to prevent seed or rhizome spreading.
- Crop rotation - alternative plantings disrupt weed cycles.
- Mulch preserves moisture and blocks weed growth

  Examples:

  Straw
  Sawdust
  Black plastic (almost total weed control).

Mechanical

- Pulling weeds
- Hoeing around crops
- Plowing between rows
- **Cultivators** destroy the maximum amount of weeds with minimum damage to crops.

  Disadvantages of cultivators:

  ⇒ Root damage
  ⇒ Expensive equipment to purchase, maintain, and operate
  ⇒ Erosion by wind and water
  ⇒ Moisture loss.

Chemical

Herbicides can:

- Interfere with photosynthesis
- Inhibit amino acids and protein formation
- Block cell division
- Block carotenoid formation, disrupting photosynthesis
- Supply too much auxin to plant for uncontrolled growth; block tissues supplying food and water to plant.

Biological

Use of animals, insects, and disease organisms to control weed growth.

Animals

Goats eat coarse plants to make room for forage grasses.
Geese eat grass to make room for crop plants.
Fish used in aquaculture to control aquatic weeds.

Insects

Species eating certain weeds but not crop plants (i.e., tansy ragwort eaten by cinnabar moth).

Disease organisms

Bacteria, fungi, and viruses which are specific pathogens to specific plants.
Advantage is they can be isolated to affect only the weed species.

Disadvantages to biological control:

⇒ Slow results
⇒ Expensive
⇒ Potential that the controls may become pests.

Integrated Pest Management

The use of cultural, mechanical, herbicidal, and biological controls in combination for effective, efficient, environmentally sensitive pest control.

Application of selective and non-selective herbicides:

Selective herbicides

Chemicals which kill select weeds, but not the crop.
E.g., 2,4-D
Apply to kill weeds interspersed with a crop.

Non-selective herbicides

Chemicals which kill any plant to which they are applied.
Used where plant growth is undesirable, such as fence lines, driveways, sidewalks, and parking areas.
E.g., Roundup, Atrazine, Atratol
Low concentrations of some in the slightly toxic range can still be used to kill young weeds without damaging the crop.

Application of preplanting, preemergence and postemergence weed control treatments:

Preplanting

Mixed into or sprayed onto soil or seed beds.

Preemergence

Made before appearance of plant growth or after crop emerges, but before weeds appear.
Effective on germinating weed seeds.

Postemergence

Selective herbicide used after crop has appeared.

Variables in herbicide application:

Correct herbicide selection for the weed

Requires accurate identification of the weed to be controlled.

Proper herbicide types and application considerations for:

- The correct time of year to arrest germination, vegetative reproduction, or reseeding.
- Plant maturity with direct application.
- Amount of rainfall - too much can wash away the chemical.
- Soil type and amount of organic matter in the growing media - application varies according to rate of percolation, holding by clay particles, and absorption by humus.
- Even spreading of the herbicide.
- Preplanting herbicide - must be flushed into the soil by water.
- Postemergents - must be sprayed onto the plant or its roots for absorption by the plant.
- Correct amounts over a specified area (water application of the treatment area as pre-test for proper tank mix amounts).

  Sprayers must be calibrated for proper application rate to avoid:

  ⇒ Too high a rate, which kills the crop as well as the weeds
  ⇒ Too low a rate, which has poor weed killing results.

References

1. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
2. Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
3. Project WILD. (1992). *Project WILD Activity Guide* (2nd ed.). Boulder, CO: Author.
4. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
5. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Travelin' Plants**

From *The Growing Classroom: Garden-Based Science*, Addison-Wesley:
- **"Adapt-a-Seed"** (p. 118)

From *Project WILD Activity Guide*, Project WILD:
- **"Who Fits Here?"** (pp. 160-161)

Internet Resources

Idaho Farm and Ranch Resource Center (Idaho One Plan)
http://www.idwr.state.id.us/oneplan/
Site Map
http://www.idwr.state.id.us/oneplan/sitemap.htm

WeedFacts
Joseph C. Neal & Andrew F. Senesac
Cornell Cooperative Extension
Cornell University
http://www.cals.cornell.edu/cals/dept/flori/wdfct

Revised Weed Management Guide Documents
Florida Cooperative Extension Service
University of Florida
FAIRS - Florida Agricultural Information Retrieval System
http://hammock.ifas.ufl.edu/rev_wg.html

Additional Resource

Idaho's Noxious Weeds
Series No. SP9 @ $3
Agricultural Publications
University of Idaho

Moscow, ID 83844-2240
(208) 885-7982

Transparency

- **Indicator Weeds**

Student Activity: Travelin' Plants

Purpose

- Discuss how weeds spread.
- Identify common weeds for your area.
- Determine the growing conditions weeds indicate for the areas in which they are found.

Materials

Plant field guides for your area (Peterson's "Rocky Mountain Wildflowers," Golden Guide to Wildflowers, Weeds of the West, etc.)
Soil type key
Notebook
Plastic baggies
Labels
Permanent waterproof marker
Foam core display board

Procedure

Before gathering any wild plants, you must be certain you are in an area where gathering is permitted. Roadside and waste areas are usually not a problem, but when on private or public land (parks, etc.) you must seek permission to gather plants. Do not proceed without permission!

- With permission, gather five (5) examples of plants representative of weeds in your area.
- Gather one live specimen, one dried specimen (last year's plant), if available, and an example of the plant's seed type. Include a pod or fruiting body if representative.
- Place each plant specimen in a baggie and label it according to plant and site gathered.
- Take a small soil sample at the same site, place it in a baggie and label it according to the plant and site gathered.
- **When labeling the baggies establish a KEY** which will help you keep the specimens together; i.e., #1 - "live specimen / plant name;" #1 - "dried specimen / plant name;" #1 "plant seed," #1 - soil sample for "plant name."
- Record in your notebook:
  - ⇒ Plant name
  - ⇒ Plant seed type
  - ⇒ Observations on plant seed dissemination, or your predictions, based on the seeds observed.
  - ⇒ Where you found the plant.
  - ⇒ Key # and corresponding baggie labels.
  - ⇒ Soil types which corresponded with the plants gathered.
  - ⇒ Indications for plant growth which you observed in the area at the time you gathered your plant specimens.
- Create a poster display of your examples using the foam core board. Hint: pin your baggies to the board, labeling the plants, soil, and the growing conditions they represent.

- Write a summary paper of your research and include it with your display. Include an introductory abstract, the intent of your study, your prediction of what you would find, a description of your observations and findings, and interpret your results, directly relating them to: weeds found / soil indicating what growing conditions / seed dispersal type / how adaptations of seeds relate to soil type and accomplish dispersal.

References

Whitson, T.D. (Ed.), (1991). *Weeds of the West*. Jackson, WY: Western Society of Weed Science.

Hitchcock and Cronquist, *Flora of the Pacific Northwest: An Illustrated Manual* (5 vols; advanced reference), University of Washington Press. (This is **the reference** for positive identification, if you need it. It is usually found in college / university libraries, but check your local library.)

Pacific Northwest Field Guides
http://chemwww.chem.washington.edu/native/fieldguides.html#Jump27

Indicator Weeds

Compacted Areas	Knotweed
High Moisture Conditions	Sedges Mosses Rushes Annual bluegrass
Low Moisture Conditions	Prostrate spurge Poorjoe Annual lespedeza Prostrate knotweed
Low pH	Red sorrel Broomsedge
Low Nitrogen	Clovers Legumes Mosses
High Phosphorus	Annual bluegrass
High nitrogen	Common chickweed
Compacted Soils	Annual bluegrass Goosegrass Prostrate knotweed Annual lespedeza
Nematode Indicators	Prostrate spurge Florida pusley Prostrate knotweed

Ag 514 S - Weeds and Their Control
Unit Test

Multiple Choice

1. Among other things, weed competition

   a. reduces the number of desired plants in the area.
   b. increases the number of desired plants in the area.
   c. adds to colors and textures of desired plants.
   d. causes increase of vigor in plants.

2. Weeds compete with indigenous plants

   a. in deserts and forests only.
   b. for light, water, nutrients, and space.
   c. for nutrients and space.
   d. for light and water.

3. Weeds serve as hosts to

   a. nematodes.
   b. insects.
   c. diseases.
   d. both b and c.

4. Weeds can reduce the quality of

   a. the soil.
   b. milk, wool, or crops.
   c. all of the above.
   d. none of the above.

5. Weeds indicate the type of soil, pH and

   a. amount of water availability to plants.
   b. the species of plant found in the area.
   c. the types of insects that can be identified.
   d. when harvesting should begin.

List the five methods in which weeds disperse their seeds.

6. ____

7. ____

8. ____

9. ____

10. ____

11. **Name at least one other way in which weeds spread their seeds.**

____
_

Matching

____ 12. Biological

____ 13. Postemergence

____ 14. Cultural

____ 15. Integrated Pest Management

____ 16. Preemergence

____ 17. Mechanical

____ 18. Selective herbicides

____ 19. Chemical

____ 20. Preplanting

____ 21. Non-selective herbicides

A. Maintaining clean equipment to prevent seed or rhizome spreading.
B. Pulling weeds, hoeing around crops, and plowing between rows.
C. Herbicides: may interfere with photosynthesis among other things
D. Use of animals, insects, and disease organisms to control weed growth.
E. The use of a combination of weed control methods.
F. Chemicals which kill weeds, but not the crop.
G. Chemicals which kill any plant to which they are applied.
H. Weed control treatment mixed into or sprayed onto soil or seed beds.
I. Treatment effective on germinating weed seeds.

J. Selective herbicide used after crop has appeared.

Ag 514 S - Weeds and Their Control
Unit Test
Answer Key

Multiple Choice

1. Among other things, weed competition

    a. **reduces the number of desired plants in the area.**
    b. increases the number of desired plants in the area.
    c. adds to colors and textures of desired plants.
    d. causes increase of vigor in plants.

2. Weeds compete with indigenous plants

    a. in deserts and forests only.
    b. **for light, water, nutrients, and space.**
    c. for nutrients and space.
    d. for light and water.

3. Weeds serve as hosts to

    a. nematodes.
    b. insects.
    c. diseases.
    d. **both b and c.**

4. Weeds can reduce the quality of

    a. the soil.
    b. **milk, wool, or crops.**
    c. all of the above.
    d. none of the above.

5. Weeds indicate the type of soil, pH and

    a. **amount of water availability to plants.**
    b. the species of plant found in the area.
    c. the types of insects that can be identified.
    d. when harvesting should begin.

List the five methods in which weeds disperse their seeds.

6. ____________________

7. ____________________

8. ____________________

9. ____________________

10. ____________________

Answers:
wind-borne
seed hooks that attach to animal fur or clothing
can remain on farm machinery and travel from field to field
by float on water
ingested by and passed though animals

11. **Name at least one other way in which weeds spread their seeds.**

____

Answers: (one of the following)
prolifically producing seeds
reproducing both sexually and asexually
by remaining dormant and viable over long periods of time
rapid growth

Matching

__**D**__ 12. Biological

__**J**__ 13. Postemergence

__**A**__ 14. Cultural

__**E**__ 15. Integrated Pest Management

__**I**__ 16. Preemergence

__**B**__ 17. Mechanical

__**F**__ 18. Selective herbicides

__**C**__ 19. Chemical

__**H**__ 20. Preplanting

__**G**__ 21. Non-selective herbicides

A. Maintaining clean equipment to prevent seed or rhizome spreading.
B. Pulling weeds, hoeing around crops, and plowing between rows.
C. Herbicides: may interfere with photosynthesis among other things
D. Use of animals, insects, and disease organisms to control weed growth.
E. The use of a combination of weed control methods.
F. Chemicals which kill weeds, but not the crop.
G. Chemicals which kill any plant to which they are applied.
H. Weed control treatment mixed into or sprayed onto soil or seed beds.
I. Treatment effective on germinating weed seeds.
J. Selective herbicide used after crop has appeared.

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 T - Beneficial and Non-Beneficial Insects

Unit Objectives

1. List ways that insects cause losses in plants.
2. List the beneficial effects of insects.
3. Identify the three parts of an insect's body.
4. Match the types of insect mouth parts with their feeding habits.
5. Identify the three types of life cycles for insects.
6. Diagnose the symptoms of insect damage to plants.
7. Describe the three classifications of insect control.
8. Identify the insects having an economic impact on the horticulture industry of Idaho.
9. Define "Integrated Pest Management."
10. Classify the phases of Integrated Pest Management.
11. Define "Best Management Practices."
12. List six examples of Best Management Practices in Horticulture.
13. Classify the six basic elements of an Integrated Pest Management program.
14. Select appropriate cultural / mechanical, biological, and chemical control practices for identified insect pests.

Information

1. List Ways that Insects Cause Losses in Plants

2. List the Beneficial Effects of Insects

3. Identify the Three Parts of an Insect's Body

4. Match the Types of Insect Mouth Parts with Their Feeding Habits

5. Identify the Three Types of Life Cycles for Insects

6. Diagnose the Symptoms of Insect Damage to Plants

7. Describe the Three Classifications of Insect Control

8. Identify the Insects Having an Economic Impact on the Horticulture Industry of Idaho

Insect Losses in Plants

- **Monetary loss**
  - Averages $5 billion dollars annually.
- **Physical damage**
  - Phytophagous - feed on plants
  - Feed on roots, stems, leaves
  - Fruit damage
    - Less saleable, particularly peaches, apples, pears, and grapes
    - Less desirable for consumers
  - Grain damage
    - During plant storage.

Insects can also cause damage by:

- **Spread of diseases** from insect bites, affecting humans and other animals.

Parasitism in livestock egg of an insect deposited within livestock that weakens animals through loss of blood from the insect feeding as it grows, creating susceptibility to disease.

Beneficial Effects of Insects

Pollination

Bees

Butterflies

Moths

Other predatory insects which move from flower to flower searching for prey or hosts to lay their eggs; e.g., wasps, ants.

Predation on non-beneficial insects

Beneficial insects such as ichneumons, praying mantis, ladybird beetles (lady bugs), lacewings, and damsel flies are predators, with larvae eating only other insects which are plant eaters, and thus destructive to crops.

Predatory insects can destroy pest insects by:

Ovipositing their eggs in adult insects or larvae (females using their ovipositors - their “stingers” to lay their eggs in the host insects).

Eating adult insects or larvae.

Eating insect eggs.

Three Parts of an Insect’s Body:

Head

Compound eyes

Sensory appendages or antennae

Mouth parts

Thorax

Three segments: three pairs of legs (six legs all together)

In some species: wings, attached to the last two segments of the thorax

Abdomen

Contains the insect’s digestive system.

Insect Mouth Parts

Insects are grouped by their mouth parts, relating to how they feed on plants or other animals.

Categories:

Rasping / sucking

Feed on cells scraped from the plant surface; e.g. thrips.

Piercing / sucking

Proboscis extension which pierces a hole into plant stems, sucking plant sap; e.g., scale insects and aphids.

Sponging

Absorb liquids with a sponge-like mouth extension; e.g., house flies.

Siphoning

Proboscis extension which enables the insect to suck up nectar, like a straw; e.g., moths and butterflies.

Chewing

Mandibles (jaws) that bite off plant parts and grind them as they chew, e.g., beetles and grasshoppers.

Chewing / lapping

Lap up liquids with long, hair-covered tongue-like projections which enable them to reach into flower nectar tubes and lap up nectar; e.g., bumblebees and honeybees.

Insect Life Cycles: Metamorphosis

Changes in an insect's shape, structure, and habits between its embryonic and adult stages.

These changes take place over a series of molts, with each stage between each molt termed an "instar."

Molts are the shedding of exoskeletons, because the exoskeleton is hard, and does not permit extended growth.

The number of molts needed is generally four to eight, but can be up to 20 in some species, until the larval insect reaches the final molt before becoming an adult (the penultimate molt).

Bristletail insects continue to molt after becoming an adult, which is rare.

Complete

Egg

Larva (feeding / non-sexual)

Pupa (non-feeding / non-sexual but actively undergoing metamorphosis from the larval stage [instar] to the adult form [imago] while within a chysalis, cocoon, or puparium)

Adult (sexual / egg-laying / may or may not feed [many short-lived adult insects will not feed])

Incomplete (water-born insects)

Egg

Naiad e.g., mayfly, dragonfly, damselfly, or stonefly / water-born / living in water;

or early nymph e.g., grasshopper or true bug / land-born (without wings) (feeding / non-sexual)

Late nymph (incompletely developed wings and genitalia / feeding / non-sexual / metamorphically changing to adult structure) (water-born insects are still in water until their final molt)

Adult (sexual / may or may not feed / living out of water)

Gradual or Simple

Egg

Nymph stages:

Gradual growth

Shedding exoskeleton to grow (non-sexual and feeding)

Adult (sexual / egg laying stage and may or may not feed)

Symptoms of Insect Damage to Plants

Chewing insects

Holes in leaves; missing pieces of bark; holes in bark with sap backfill; leaf and stem galls.

Sucking insects

Twisted plant tips; rolled leaves.

Classifications of Insect Control

Cultural/Mechanical

Planting insect resistant varieties.

Monitoring crops for pesticide use only when needed.

Pulling, mowing, mulching, and plowing to remove weeds and reduce havens for insects.

Biological

Using living organisms for pest control.

Encouraging birds, bats, toads, frogs, and pest insect predators.*

*Do not use insecticides when insect predators are the primary pest control method.

Introduction of diseases to insect populations; e.g., *Bacillus thuringinensis*.

Use of pheromones to attract male insects to traps.

Release of sterile males (females mate with them but no offspring are produced and eventually the insect pest population is greatly reduced or eradicated).

Chemical

Insecticides: dusts, granules, powders, and solutions.

Classified by how they penetrate the insect's body:

Stomach poison

Used as a spray or dust.

Eaten by chewing insects:

Caterpillars, grasshoppers, and beetles.

Contact poison

Absorbed by any type of insect but commonly used on sucking insects.

Aphids, mites, leaf hoppers, scale, and whiteflies.

Oil sprays are the most common form.

Systemic poison

Applied to be taken into the plant that the pest insect feeds on, to poison the insect.

Food plants must not be harvested until the chemical has broken down.

Used on chewing or sucking insects.

Successful on insects underground or under leaves who avoid contact poisons.

Fumigant

Gas poisonous to insects are injected into the air in a greenhouse or at the soil level and covered to infuse the soil. (Fumigants should be used only in enclosed areas, away from people and other animals.)

Used to control soil-borne insects, who ingest it through their breathing pores.

Insects take in the gas through their respiratory systems.

Repellants

Drive insects away from the plant.

Plant repellants: mint, onion, garlic, chives, leeks, marigolds, nasturtiums, sage, horseradish.

Attractants

Pheromone bait traps lure the male insect to the trap, where they are unable to get out.

Successful on Japanese beetles and gypsy moths.

Poisonous bait traps kill the pests who eat the poison.

Successful on slugs, snails, cutworms, grasshoppers, and weevils.

⇒ Insecticide application requires the applicator to wear protective clothing and a mask.

Chemical Insecticide Types:

Inorganic

Of mineral origin, usually in the form of a stomach poison.

Organic

Derived from plants; used in the forms of stomach poisons or contact poisons.

Synthetic

Not found naturally; produced in laboratories.

Also toxic to human beings.

Three groups:

Chlorinated hydrocarbons

Long-lasting residual control; destructive to animals by build-up in the food chain.

E.g., DDT

Organophosphates

Break down quickly in the environment and do not build up in the food chain.

E.g., parathion: extremely toxic to humans and other animals.

E.g., malathion: relatively safe and effective.

Carbamates

Safer than organophosphates; break down quickly and leave no residue in the environment.

Sevin: slightly toxic to humans and other animals.

Chemical sterilants

Gamma radiation treatments to sterilize male insects for biological control. Females will mate with sterile males but the resulting eggs will not be fertilized.

Insecticide Application Timing is extremely important!

Insects must be killed at a stage in their growth when they are actively feeding or mating.

References

1. Borror, D.J. & White, R.E. (1970). *A Field Guide to Insects: America North of Mexico*. Boston, MA: Houghton-Mifflin.
2. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Insect-Watching**

Student Lab

From *Access Excellence Activities Exchange*:
- **Pesticides and Eggshell Thinning** by David Tucker

Internet Resources

The Entomological Society of America
http://www.entsoc.org/ns3.htm

Pesticides and Eggshell Thinning
by David Tucker
Access Excellence Activities Exchange
http://www.gene.com/ae/AE/AEC/AEF/1996/tucker_eggshell.html

Additional References:
Beneficial Organisms Associated with Pacific Northwest Crops
Cooperative Extension publication: PNW 343 @ $1
Agricultural Publications
University of Idaho
Moscow, ID 83844-2240

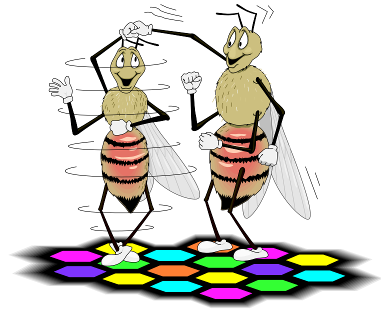
(208) 885-7982
(208) 885-7982 (fax)
E-mail: publinv@uidaho.edu

Pacific Northwest 1997 Insect Control Handbook
Cooperative Extension publication
Order from:
Publication Orders
Agricultural Communications
Oregon State University
Administrative Services A422
Corvallis, Oregon 97331-2119
(503) 737-2513

Transparencies

- **Insect Classification** (set of #3 transparencies)
- **Beneficial Insects**

Student Activity: Insect-Watching



Purpose

Discover various aspects of insects: habitat, feeding and mating habits, and identification of the insect within its life cycle.

Materials (recommended)

For insect identification:

Hand lens

If capture is necessary:

"Bug box" (available at most nature shops or museum stores)

Clear glass jar with mesh netting or several small holes in lid

For pond or streamside viewing:

Underwater viewing box such as "Aquavue" or water-scope apparatus available at museum stores, nature shops, or by catalog (see your instructor for catalog information).

You can also make a viewing box by doing the following:

Use a clear, hard plastic container and place the bottom surface in the water. It won't magnify your viewing, but it will allow you to see under the water surface minus the ripples.

For observation records:

Notebook

Procedure

- Choose four insects from four different orders for field observation.
- Keep a record of your observations in your notebook.
- Record the following observations:
  - ⇒ Habitat where insect is seen
  - ⇒ Feeding activities (food type and how they eat it)
  - ⇒ General observations about ground, water, or flight movements / purpose of movement
  - ⇒ Territorial and mating activities
  - ⇒ Egg-laying activity
  - ⇒ Life cycle stages seen
- Write a summary report on your observations. Use your notes as reference.
- Document your observations with photos when possible.
- Create a display of your insect observations. Include a graphic of the entire life cycle of your insects, and illustrate which stage or stages in which you found your insects.
- Be creative! How can you make your display interactive?

Display for a Day!

Put your displays up for viewing by the entire class or classes for at least a day. Include comment sheets with each display and allow viewers to comment on your work. An example is included with this activity.

Information

9. Define “Integrated Pest Management”

10. Classify the Phases of Integrated Pest Management

11. Define “Best Management Practices”

12. List Six Examples of Best Management Practices in Horticulture

13. Classify the Six Basic Elements of an Integrated Pest Management Program

14. Select Appropriate Cultural/Mechanical, Biological, and Chemical Control Practices for Identified Insect Pests.

Integrated Pest Management

Combination pest management strategy

Uses best management practices in combination with chemical, cultural/mechanical, and biological controls to reduce pest damage with the least amount of disruption to the environment.

Why integrated pest management?

Single control measures do not work with consistency over long periods of time.

Pests develop resistance to the chemicals in pesticides.

IPM provides better protection to the environment, reducing the toxicity level input necessary to control pests.

Goals of IPM

Keep pest populations at a control level

The point at which plant losses are equal to the cost of control.

Maintain a balance

Strive for the least risk of destroying helpful organisms as well as harmless organisms.

IPM Methodology

A strategy of choice options according to the severity of the problem:

Do nothing, giving nature a chance to restore the balance of predator/prey relationships and population control.

Mechanical and cultural controls:

Plant washing

Soaps or water sprays.

Repelling

Use of barriers and traps; i.e., stem collars, diatomaceous earth, strategically placed buckets of soapy water, and dishes of beer.

Cover soil

Row covers destroy weeds and pests.

Remove plant debris

Serves as habitat.

Physically destroy pests

Mechanical controls: plowing, cultivating, and hoeing.

Select plants

Adapted to the climate zone and disease-resistant varieties.

Plant for control

Adjust planting times to avoid prime emergence of pests to the more vulnerable young plant.

Maintain water and nutrient levels

Increase plant hardiness.

Sterilize by heating the soil

Use the hottest weather periods to heat the soil and reduce / eliminate soil dwelling pests. Till and remove weeds to allow the surface to heat; water the soil thoroughly, then cover with plastic mulch (sheets) for 4 to 6 weeks.

Biological controls:

Predatory insects

I.e., wasps, ladybird beetles, lacewings, predator mites, and mantids.

Semio-chemicals

Pheromones; hormones

Pheromones affect communication between insects.

Used to confuse, lure, or trap insects.

Parasitic nematodes

Eat grubs, weevils, sod webworms, and carpenter worms.

Bacillus thuringiensis (BT): bacteria applied as different strains and application strengths which kill caterpillars, mosquitoes, Colorado potato beetles, and the elm-leaf beetle.

Chemical controls:

- **Botanical insecticides**
  - Toxic to animals / birds / beneficial insects
  - Non-toxic to animals
  - Non-toxic to beneficial insects
- **Contact dusts**
  - Scrape / destroy pest exteriors; hazardous as inhalants to humans
- **Broad-spectrum insecticides**
  - Non-discriminatory toxicity to insects
- **Specific to insects**
  - Toxic with uptake in certain plants
  - Non-toxic to animals
- **Specific to slugs and snails**
  - Toxic to animals
- **Systemics**
  - Toxic to sucking insects; toxic to humans with uptake in edible plants.
- **Smothering oils**
  - Smother insects and insect eggs.
- **Soaps**
  - Low toxicity to humans; injure some plants; safe on edible plants.
- **Sulfur dust**
  - Not advised for use at temperatures over 90^0F.

Best Management Practices for Horticulture

Practices that combine scientific research with practical knowledge.

Optimization of yields, plant quality, and environmental integrity.

Management of:

- **Surface and subsurface water**
- **Soil erosion**
- **Irrigation**
- **Pests**
  - *Methods*:
  - **Cultural / Mechanical**
  - **Biological**
  - **Chemical**
    - Selection
    - Use
- **Soil nutrient value**
- **Fertilization**
  - Timing
  - Placement
  - Controlled release

Phases of Integrated Pest Management:

1. Predetermination
2. Evaluation
3. Implementation
4. Monitoring
5. Re-evaluation

Predetermine

Potential for pest problems
Threshold for pest damage
Pest identification
Best Management Practices to control pests

Evaluate

If damage threshold has been exceeded
Select a treatment option or combination of options

Implement

Control treatment(s)
BMPs

Monitor

Monitor pest levels after treatment(s)
Monitor for damage from controls used

Re-evaluation

Determine effectiveness of treatment(s)
Determine effectiveness of management strategies

Basic Elements of an Integrated Pest Management Program

1. System and pest control managers
2. Knowledge and information
3. Ecosystem management
4. Pest level management
5. Techniques for pest population controls
6. Pest control treatments (agents and materials)

References

1. Reiley, H.E., & Shry, C.L., Jr. (1991). Introductory Horticulture (4th ed.). Albany, NY: Delmar.
2. Schroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., and Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.
3. Sunset Books and Magazine. (1995). *Sunset Western Garden Book*. Menlo Park, CA: Author.

Student Activity

- **One-Two Pest Punch**

Internet Resources

Idaho Farm and Ranch Resource Center (Idaho One Plan)
http://www.idwr.state.id.us/oneplan/
Site Map
http://www.idwr.state.id.us/oneplan/sitemap.htm

IPM Integrated Pest Management Florida
http://www.ifas.ufl.edu/~FAIRSWEB/IPM/IPMFL/ipmfl.htm

National IPM Network University of Florida
http://www.ifas.ufl.edu/~FAIRSWEB/IPM/index.htm

IPM Integrated Pest Management Cooperative State Research, Education, and Extension (CSREES)
http://www.reusda.gov/ipm/

UC Statewide Integrated Pest Management Project
http://axp.ipm.ucdavis.edu/default.html
UC Pest Management Guidelines
http://www.ipm.ucdavis.edu/PMG/selectnewpest.home.html

Additional Resources

Beneficial Organisms Associated with Pacific Northwest Crops
Series No. PNW 343
Agricultural Publications
University of Idaho
Moscow, ID 83843-2240
(208) 885-7982

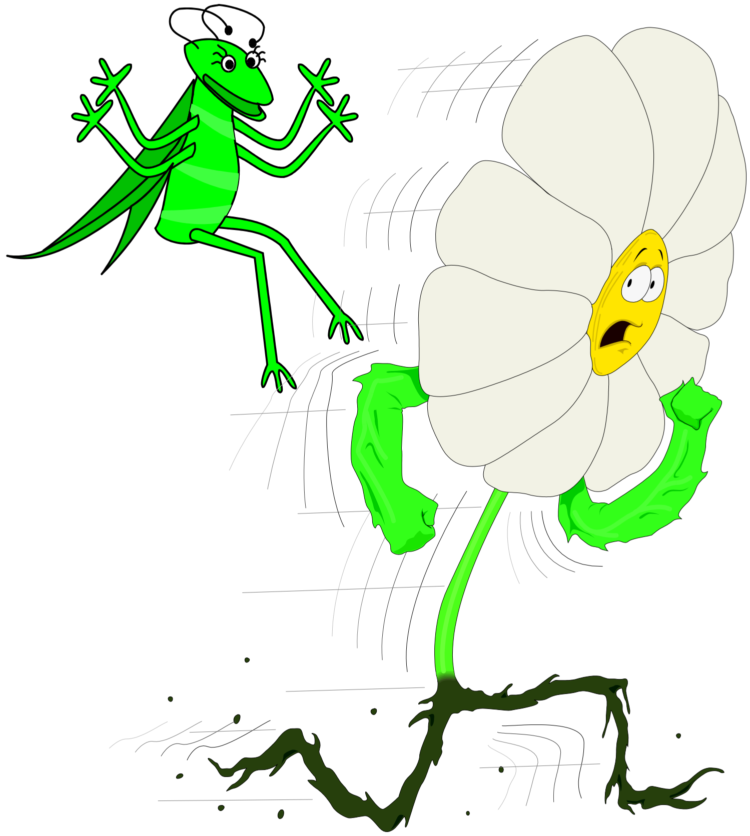
Transparency

- **Integrated Pest Management**

Student Activity: One-Two Pest Punch

Purpose

- Select appropriate cultural / mechanical, biological, and chemical control practices for identified insect pests.



Materials

- Insect Field Guide (Peterson Field Guide series or other)
- Plant Field Guide or other guide to assist in ornamental or wild plant identification
- Notebook
- Small plastic bags (staple or twist-tie)
- Empty plant container for potting a field example
- Trowel for digging a field example

Procedure

Using your notebook to record:

- Identify four examples of insect damage.
- Collect evidence of the insect damage, placing in small plastic bags.*

For each:

- Identify the insects responsible for the damage.
- Determine the stage of the pest insect's development.
- Describe the type and amount of damage done to the entire plant.

Following the procedures for decision-making in determining appropriate integrated pest management responses, indicate for each:

- Evaluate all possible control options and record them in your notebook for each pest-infested plant found. Include all possible cultural / mechanical, biological, and chemical responses.
- Choose one plant of the infestation examples found and dig it up, placing it in a pot with a plastic bag secured over the plant with a twist tie.* Poke pinholes in the plastic bag to assure the insects and the plant receive air.
- Bring in the plant the same or very next day with the other examples of infestations.
- For the potted plant, choose one method of control to try to rid the infested plant of the pest.

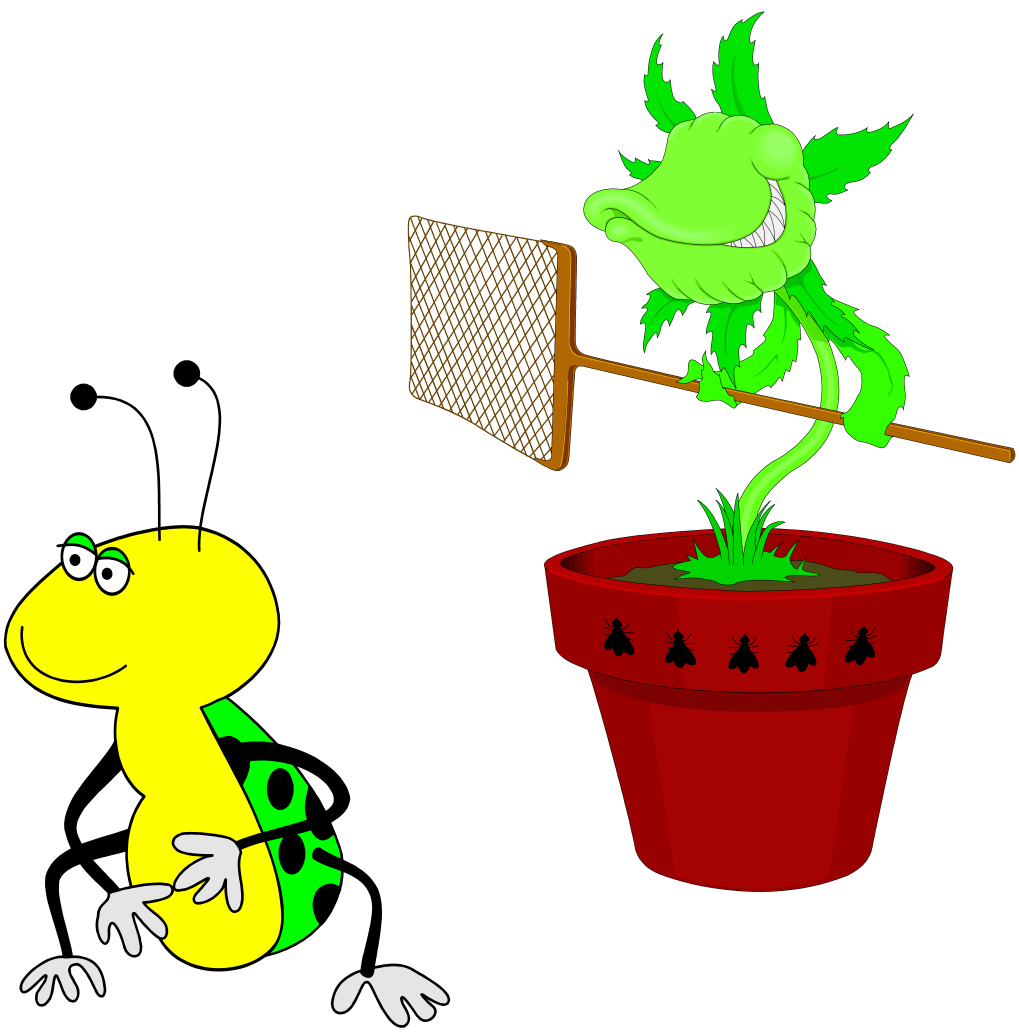
Record your methodology:

- Indicate the type of control used (cultural / mechanical, biological, or chemical) and the specific method.
- Indicate the type of plant, type of pest, amount of damage to the plant, and the date the control method was implemented.
- Predict the amount of time it will take to eradicate the pest with your method of control.

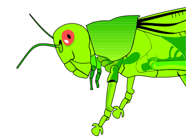
Record the results:

- Indicate the number of applications of the control method and the amount of time it took to eradicate the pest, or if the results were not successful.
- Report your results: make a poster display of your plant damage examples. Label your work. Include your potted plant on a table with your poster. Write an abstract summary of your research and make enough copies for classmates.

*Before collecting, **always get permission** from private or public landowners; nursery or greenhouse operations. It is illegal to collect plants from most public lands.



Insect Classification - #1

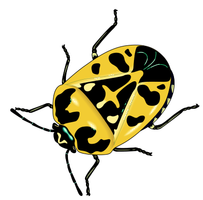


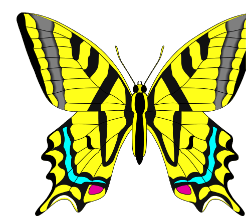
Orthoptera

Grasshoppers, Katydids, Crickets, M
Walkingsticks, and Cockroaches

Hemiptera

Bugs





Lepidoptera

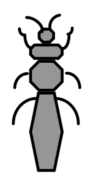
Butterflies and Moths

Homoptera

Aphids, Hoppers, Cicadas, Whitefli
and Scale

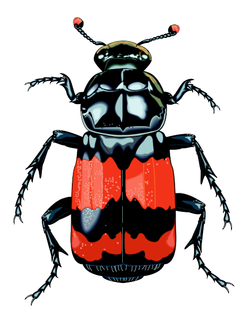
Thysanoptera

Thrips



Coleoptera

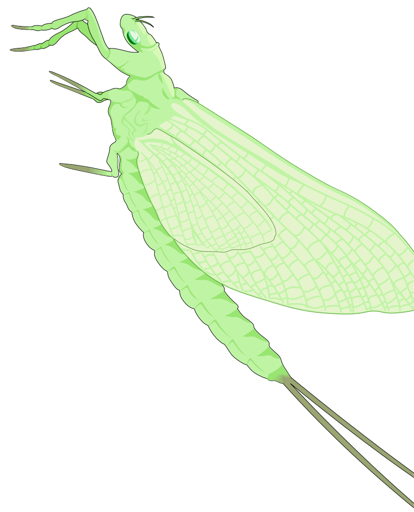
Beetles



Insect Classification - #2

Protura
Proturans

Thysanura
Bristletails

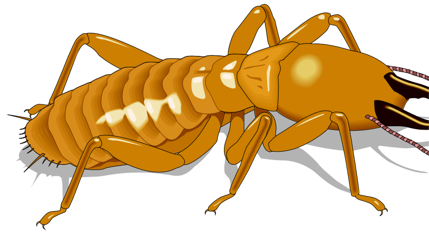


Collembola
Springtails

Ephemeroptera
Mayflies

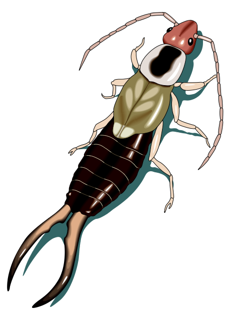
Odonata
Dragonflies and Damselflies

Isoptera
Termites



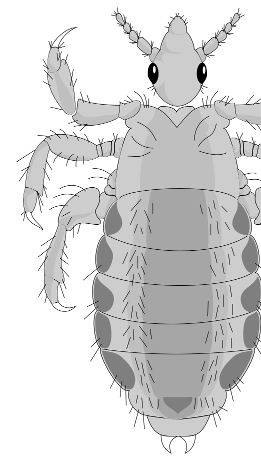
Plecoptera
Stoneflies

Dermaptera
Earwigs



Insect Classification - #3

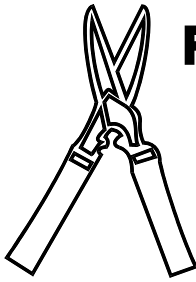
Embioptera
Webspinners
Zoraptera
Zorapterans
Psocoptera
Booklice and Barklice
Mallophaga
Chewing lice
Anoplura
Sucking lice



Neuroptera
Fishflies, Snakeflies, Lacewings, A
Strepsiptera
Twisted-winged parasites
Mecoptera
Scorpionflies
Trichoptera
Caddisflies
Diptera
Flies
Siphonaptera
Fleas

Hymenoptera
Sawflies, Ichneumons, Chalcids, A
Wasps, and Bees

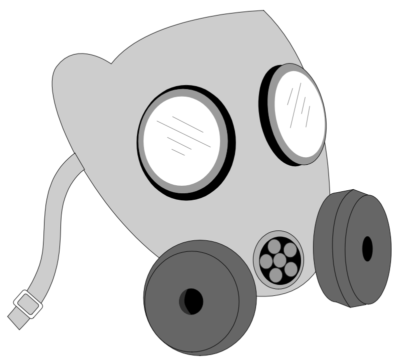
Integrated Pest Manageme



First Control
- **Non-chemical**
  - **Hand-collecting**
  - **Pruning**

Second Control
- **Biological**
  - **Natural diseases**
  - **Natural predators**

Third Control
- **Chemical**
  - **Insecticides**
    - **Body contac**
    - **Swallowing**
  - **Miticides**
    - **Body contac**
    - **Biological or**
  - **Fungicides**
    - **Contact**
  - **Herbicides**
    - **Nonselective**
    - **Selective**
  - **Rodenticides**
    - **Swallowing**
  - **Nematocides**
    - **Fumigant**
  - **Molluscicides**
    - **Swallowing**



Ag 514 T - Beneficial and Non-Beneficial Insects
Unit Test

Fill in the blank

1. Insects cause losses in plants through ____________________________ and ________________________.

2. Insects can also cause damage by _______________________________ and ________________________.

3. The beneficial effects of insects are _____________________________ and ________________________.

4. Name the three parts of an insect's body.

   a. _____________________________

   b. _____________________________

   c. _____________________________

6. Identify the five phases of Integrated Pest Management.

   1. _____________________________

   2. _____________________________

   3. _____________________________

   4. _____________________________

   5. _____________________________

7. Integrated Pest Management is ____

____

____

8. What are the six basic elements of an Integrated Pest Management Program?

1. ____

2. ____

3. ____

4. ____

5. ____

6. ____

Matching

__**G**__ 9. Attractants

__**E**__ 10. Fumigant

__**C**__ 11. Chewing/lapping

__**H**__ 12. Organic

__**B**__ 13. Sponging

__**A**__ 14. Piercing/sucking

__**H**__ 15. Organic

__**K**__ 16. Botanical insecticides

__**D**__ 17. Sucking insects

__**J**__ 18. Predatory insects

__**F**__ 19. Repellents

__**I**__ 20. Repelling

A. Proboscis extension which pierces a hole into plant stems, sucking plant sap.
B. Absorb liquids with a sponge-like mouth extension
C. Lap up liquids with long, hair-covered tongue-like projections
D. Cause twisted plant tips and rolled leaves
E. Insects take in gas through their respiratory systems
F. Drive insects away from the plant
G. Male insect trapped with pheromone bait
H. Derived from plants; used in forms of stomach poisons or contact poisons
I. Use of barriers and traps
J. Wasps, ladybird beetles, lacewings, predator mires and mantids
K. Toxic to animals/birds/beneficial insects

Ag 514 T - Beneficial and Non-Beneficial Insects
Unit Test
Answer Key

Fill in the blank

1. Insects cause losses in plants through ___________________________ and ______________________.

Answers: monetary loss and physical damage

2. Insects can also cause damage by ______________________________ and ______________________.

Answers: spreading disease (through insect bites) and parasitism in livestock

3. The beneficial effects of insects are ____________________________ and ______________________.

Answers: pollination and predation of non-beneficial insects

4. Name the three parts of an insect's body.

   a. ____________________________

   b. ____________________________

   c. ____________________________

   Answers: Head, Thorax, and Abdomen

6. Identify the five phases of Integrated Pest Management.

   1. ____________________________
   2. ____________________________
   3. ____________________________
   4. ____________________________
   5. ____________________________

   Answers:

   1. **Predetermination**
   2. **Evaluation**
   3. **Implementation**
   4. **Monitoring**
   5. **Re-evaluation**

7. Integrated Pest Management is ____

____

____

Answer: A pest management strategy which uses the best management practices in combinations with chemical, cultural/mechanical, and biological controls to reduce pest damage with the least amount of disruption to the enviroment.

8. What are the six basic elements of an Integrated Pest Management Program?

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____

Answers:

1. **System and pest control managers**
2. **Knowledge and information**
3. **Ecosystem management**
4. **Pest Level management**
5. **Techniques for pest population controls**
6. **Pest control treatments**

Matching

__G__ 9. Attractants

__E__ 10. Fumigant

__C__ 11. Chewing/lapping

__H__ 12. Organic

__B__ 13. Sponging

__A__ 14. Piercing/sucking

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J. Wasps, ladybird beetles, lacewings, predator mires and mantids
K. Toxic to animals/birds/beneficial insects

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Ag 514 U - Plant Disease Identification and Control

Unit Objectives

1. Describe the life cycles of plant diseases.

2. Describe the ways and means diseases are spread.

3. Describe growing conditions and cultural practices favorable to common diseases.

4. Diagnose the symptoms of common plant diseases.

5. Describe preventative measures for disease.

6. Describe cultural and chemical control measures for diseases.

7. Identify by name, symptom, and causal agent the diseases that have an economic impact on Idaho crops.

Information

1. Describe the Life Cycles of Plant Diseases

2. Describe the Ways and Means Diseases are Spread

3. Describe Growing Conditions and Cultural Practices Favorable to Common Diseases

4. Diagnose the Symptoms of Common Plant Diseases

5. Describe Preventative Measures for Diseases

6. Describe Cultural and Chemical Control Measures for Diseases

7. Identify by Name, Symptom, and Causal Agent the Diseases that Have an Economic Impact on Idaho Crops

Plant Disease Types

- **Environmental / Abiotic**
  - Nutrient deficiencies or oversupply of nutrients
  - Damaged plant parts
  - Chemical burns
  - Pollution, inhibiting oxygenation and photosynthesis
  - Weather
  - Genetic mutations or irregularities
- **Parasitic / Biotic**
  - **Bacteria**; e.g.,
    - Fireblight
    - Fruit rot
  - **Viruses**; e.g.,
    - Cucumber mosaic
    - Citrus tristeza
    - Tomato ring spot

Fungi; e.g.,

Spotting or rotting
Mildew
Rusts
Smuts

Soil fungi and bacteria cause seed decay, blights, root rots, wilt and damping-off of seedlings.

Three factors which must be present for disease occurrence:

1. Susceptible host plant
2. Causal agent; e.g., fungi
3. Favorable environment; e.g., days of warm, rainy weather.

Three methods of control:

1. Increasing host plant's resistance
2. Altering the host plant's environment; e.g., mixing sand with soil to increase drainage.
3. Keeping the disease-producing organism from the host plant; e.g., destroy the fungal growth area.

Organisms that cause diseases

Fungi

One-celled, filamentous (hyphae), spore-bearing organisms
Causal agent for plant mildew, rusts, smuts; i.e., fruit rot, Dutch Elm disease
Spread by water, wind, insects, and other contact.
Beneficial and non-beneficial

Bacteria

One-celled organisms with a primitive nucleus
Pathogens enter plants through stomata, flower parts, cuts, or breaks in the plant.
Insects may transmit disease organisms.

Viruses

Do not have organized nuclei.
Rely on strands of host cell's nucleic acid to replicate; therefore, cause disease by using up cell material needed to live and function.
Become a part of the host cell by interacting with the host cell's DNA.
May rupture cells during viral reproduction.

Plant Disease Life Cycles and Movement

Fungi

Spores land on leaves or other plant surfaces.
Spores send hyphae (tubes) into the leaf or plant, weaving throughout the plant tissue to extract nutrients.
As nutrients are lost to the plant, the leaf wilts and plant cells die.
Hyphae send out spore-bearing branches from the plant to the outside.
Spores are carried by the wind to begin the cycle again on another host plant.

Bacteria

As pathogens, invade plant surface to feed on cells. Some secrete toxins to destroy cells.

Attack different plant systems; e.g., root, leaves, flowers, stems.

Roots

Plant cannot take in water or other nutrients

Leaves

Impair photosynthesis; plant cannot manufacture food

Flowers

Plant cannot reproduce or fruit

Stems

Water and nutrients cannot translocate throughout the plant.

Bacteria travel by contact, and continue to move, breed, and feed from one plant to another unless they are completely destroyed on site.

Viruses

Viruses spread by contact.

As pathogens, use up material in a cell host to live and reproduce.

Breeding causes cell rupture where bacteria may invade the plant.

Secondary infection from feeding bacteria causes death.

Virus life cycle depends upon reproduction.

Virus cycle of reproduction must be stopped in order to arrest the progress of the virus.

Only plant resistance and non-contact with other diseased plants can stop a virus.

Symptoms of Plant Diseases:

Wilt

Rotting plant parts

Brown spots on leaves, fruits (plus softness at brown areas), or other plant parts

Appearance of powdery white substances

Discolored or multicolored appearance for lack of chlorophyll

Stunted growth

Leaf buds, floral parts, or fruit not developing or falling off

Twisted stems or leaves

Hallucinogenic if ingested; e.g., ergot infestation of wheat.

Floral parts are weakly colored.

Plant Disease Natural Defense Systems

1. Pubescent hairs on plant surfaces which capture pathogens above the surface of the plant.
2. Waxy cuticle coverings which prevent penetration by pathogens or fungi.
3. Plant stomata closure at night.
4. Plant resin secreted in response to invasion.
5. Manufacture of chemicals toxic to pathogens in response to invasion:

   Inhibit growth of fungi

   Destroy bacteria.

Plant Disease Prevention

Cultural practices

Removal of plant debris to prevent fungal growth.

Removing weeds that can harbor disease.

Preventing injury to plants from cultivation practices. Injuries allow pathogens to enter plant systems.

Watering during daylight hours to allow soil to dry.

Non-disruption of wet plant surfaces to prevent carriage of water-droplet borne diseases.

Plant breeding for resistance

Developing plants resistant or immune to diseases.

Develop breeds of plants which secrete pathogen-destroying toxins.

Chemical applications

Fungicides

Bactericides

Destroy disease organisms before plant invasion.

Cure plants before pathogens can build up.

Biological controls

Strains of fungi used to combat other soil-borne plant diseases.

Controlling, e.g.,

Powdery mildew

Potato wilt

Verticillium wilt

References

1. Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.
2. Jozwik, F.X. (1992). *The Greenhouse and Nursery Handbook: A Complete Guide to Growing and Selling Ornamental Container Plants*. Mills, WY: Andmar.
3. Reiley, H.E. & Shry, C.L., Jr. (1991). *Introductory Horticulture* (4th ed.). Albany, NY: Delmar.
4. Shroeder, C.B., Seagle, E.D., Felton, L.M., Ruter, J.M., Kelley, W.T., & Krewer, G. (1995). *Introduction to Horticulture: Science and Technology*. Danville, IL: Interstate.

Student Activity

- **Plant “ER”**

Internet Resources

New, Emerging, and Re-emerging Plant Diseases in the United States
Department of Plant Pathology and the Plant Disease and Insect Clinic of North Carolina State University
http://www.ces.ncsu.edu/depts/ent/clinic/Emerging/intro.htm

Biocontrol of Plant Diseases Laboratory
USDS Agricultural Research Service
http://www.ars-grin.gov/ars/Beltsville/barc/psi/bpdl/bpdl.html
See especially “Background Information on Plant Diseases and Biocontrol: FAQ”

Idaho Plant Disease Reporter
http://www.uidaho.edu/ag/plantdisease/

An Online Guide: 1996 Plant Disease Control
Oregon State University Department of Botany and Plant Pathology
http://www.orst.edu/dept/botany/epp/guide/index.html

Transparency

- **The Primary Offense**

Student Activity: Plant "ER"

Purpose

- Identify plant diseases by name, symptom, and causal agent, particularly those having an economic impact on the Idaho horticulture industry.

Materials

- From your county Cooperative Extension agent, obtain the list of Extension publications on plant diseases, also available from Agricultural Publications (see below).
- Notebook (recommended)

Procedure

From the publications list, choose and obtain one *plant disease* publication.
Based on the information found in the publication, research the impact of the disease on local growers:

- Formulate a guiding question for your research.
- Generate an hypothesis about what you expect your research to reveal.
- Interview local growers about the effects of the plant disease on their industry.
- Identify the significance of your findings (did your results meet your expectations; e.g., your hypothesis?. . . or did you find information you did not expect to find?)
- Classify your results.
- Communicate your findings in a paper on your research. Begin with a brief abstract. Be sure to describe each individual grower's situation with the plant disease.
- Give a presentation to the class on your research and results. Accompany your presentation with helpful tables or charts to explain your results. Include a hand-out on points you wish your audience to remember.

Reference

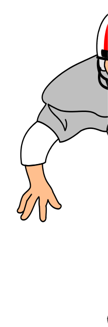
Agricultural Publications
University of Idaho
Moscow, Idaho 83844-2240
(208) 885-7982

The Primary Offense

Viruses

Virus Indexing

Plants are exposed to special suscep
"indicator varieties" to uncover the
presence of specific viruses in plant
symptoms appear, the tested plant
free of the virus.



Bacteria

Proper Sanitation

Selection of Disease-Free Plants

Culture Indexing

Cuttings from mother plants determ
if disease-free by removing sections
of tissue and placing in sterile nutri
media, then watched for bacterial
or fungal growth.

Fungi

Preventive Soil Drenches
of Compatible Fungicides
Environmental Control of Humidity
Immediate Removal of Infected Plants

Ag 514 U - Plant Disease Identification and Control
Unit Test
Answer Key

Place the stages of the Fungi life cycle in their correct order.

____1. Hyphae send out spore-bearing branches from the pant to the outside.

____2. Spores send hyphae into leaf or plant surfaces.

____3. Spores land on leaves or other plant surfaces.

____4. Spores are carried by the wind to begin the cycle again on another host plant.

____5. The leaf wilts and plant cells die.

Fill in the blank

6. Bacteria and viruses spread through __________________________.

List three of the five cultural practices which prevent plant disease.

7. ____

8. ____

9. ____

List at least six symptoms of plant disease.

10. ____

11. ____

12. ____

13. ____

14. ____

15. ____

Matching

____ 16. Bactericides and fungicides

____ 17. Abiotic

____ 18. Plant breeding for resistance

____ 19. Biological controls

____ 20. Biotic

A. Nutrient deficiencies or oversupply of nutrients.
B. Plant disease type
C. Developing plants resistant or immune to disease.
D. Chemical applications
E. Strains of fungi used to combat other soil-borne plant diseases.
F. Virus life cycle
G. Plant cannot take in water or other nutrients.
H. Causal agent for plant mildew.

Ag 514 U - Plant Disease Identification and Control
Unit Test
Answer Key

Place the stages of the Fungi life cycle in their correct order.

__4__1. Hyphae send out spore-bearing branches from the pant to the outside.

__2__2. Spores send hyphae into leaf or plant surfaces.

__1__3. Spores land on leaves or other plant surfaces.

__5__4. Spores are carried by the wind to begin the cycle again on another host plant.

__3__5. The leaf wilts and plant cells die.

Fill in the blank

6. Bacteria and viruses spread through __________________________.
Answer: contact

List three of the five cultural practices which prevent plant disease.

7. ____

8. ____

9. ____

Answers: removal of plant debris to prevent fungal growth
removing weeds that can harbor disease
preventing injury to plants from cultivation practices
watering during daylight hours to allow soil to dry
non-disruption of wet plant surfaces to prevent carriage of water-droplet borne diseases

List at least six symptoms of plant disease.

10. ____

11. ____

12. ____

13. ____

14. ____

15. ____

Answers: wilt
rotting plant parts
brown spots on leaves, fruits, or other plant parts
appearance of powdery white substances
discolored or multicolored appearance for lack or chlorophyll
stunted growth
leaf buds, floral parts, or fruit not developing or falling off
twisted stems or leaves
hallucinogenic if ingested
floral parts are weakly colored

Matching

__D__ 16. Bactericides and fungicides

__A__ 17. Abiotic

__C__ 18. Plant breeding for resistance

__E__ 19. Biological controls

__B__ 20. Biotic

A. Nutrient deficiencies or oversupply of nutrients.
B. Plant disease type
C. Developing plants resistant or immune to disease.
D. Chemical applications
E. Strains of fungi used to combat other soil-borne plant diseases.
F. Virus life cycle
G. Plant cannot take in water or other nutrients.
H. Causal agent for plant mildew.

AG. 514 Botany / Horticulture Plant Science

V. Scientific Method Term Project

Based on: Idaho Science Content Guide and Framework. Grades 9 - 12.
Standard II. Science Themes. Goal A. Change and Constancy.

Goal. Understand how soil is composed of physical and living entities which undergo change and maintain constancy through the interaction of energy and matter.

Performance Objectives. All students will . . .

- Relate the concept of "rate of change" to composting by comparing and contrasting the average rate of decomposition in the natural environment to decomposition in a compost pile.
- Identify the components of soil formation.
- Identify the breakdown rate of different materials appropriate for composting.
- Identify bacteria which aid in decomposition.
- Identify the micro- and macro climatic factors which impact the soil cycle.

Progress Indicators. All students will:

- Measure different rates of heat in an active *compost pile*, identifying when the three main types of decomposition-aiding bacteria are active.
- Measure the rate of decomposition of selected materials over a period of five days.
- Measure different rates of heat in a selected *soil plot*, identifying when the three main types of decomposition-aiding bacteria are active.
- Measure the rate of decomposition in the soil plot over a period of five days.
- Record results using a computer spreadsheet program.
- Present findings in the form of graphs indicating the results of recording the heat / bacteria rates of activity and the rates of decomposition between the compost pile and the soil site.
- Document the scientific methods of the study:

    - ♦ **State the Problem.** Write a statement describing a problem which might be resolved in researching soil decomposition and composting. The problem may be written as a question.
    - ♦ **Gather Information.** Research information on composting, soil composition, bacteria and decomposition, as well as the climatic factors which effect the soil plots studied.
    - ♦ **Form an Hypothesis.** Generate an educated guess or idea of the study results.
    - ♦ **Collect Data through Experimentation.** Compare the observations of the compost pile with the observations of the soil test plot.

        - ◊ <u>Materials needed</u>:

- ⇒ 2 liter plastic bottle, clean. See “Bottle Basics” and “Decomposition Column” in *Bottle Biology* (Kendall / Hunt).
- ⇒ Candy thermometer to test soil bacteria heat and air temperature.
- ⇒ At least three different materials for one compost pile:

  - Pine needles
  - Grass clippings
  - Weeds
  - Woody materials
  - Wood ashes (exceptions: coal or barbeque charcoal)
  - Paper
  - Kitchen waste (exceptions: meat, dairy or high fats)

◊ At each measure, include record of:

- ⇒ Ambient temperature - room and outdoor.
- ⇒ Climate - temperature, wind, precipitation, and sun/cloud ratio.

Notes: Compost pile should not be exposed to an outdoor climate.
Soil plots should be sited in undisturbed areas.

- ♦ **Analyze Data and Form a Conclusion.** Determine if the results agree with the hypothesis.
- ♦ **Report Results.** Record the results with a spreadsheet program. Generate graphs comparing the results between the compost pile and the soil study site. Include all variables studied, recording the heat produced, bacteria rates of activity and the rates of decomposition between the compost pile and the soil site. Write a paper documenting the studies and the results.
- ♦ **Propose a Theory.** Explain the results based on the problem statement and the hypothesis generated. The theory should explain why or how the results occurred.
- ♦ **Or . . . Identify Variables for Further Research.** Propose studies with introduced variables; i.e. worms to the compost pile, comparing the rate of decomposition to the soil study site, or variables discovered during the course of the research.

References:

- Jaffe, R. & Appel, G. (1990). *The Growing Classroom: Garden-Based Science*. Menlo Park, CA: Addison-Wesley.
- Ortho Books. (1992). *Easy Composting*. San Ramon, CA: Author.
- University of Wisconsin-Madison. (1993). *Bottle Biology*. Dubuque, IA: Kendall / Hunt.

AGRICULTURAL SCIENCE AND TECHNOLOGY CURRICULUM
SCIENTIFIC METHOD MATRIX

AG. 514 BOTANY / HORTICULTURE PLANT SCIENCE

IDAHO K-12 SCIENCE CONTENT GUIDE AND FRAMEWORK

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	Goal A. Science Processes	Goal B. Values	Goal A. Change and Constancy	Goal B. Systems and Interactions	Goal C. Models, Scale, and Structure	Goal A. Science and Technology in Society	Goal B. History and Cultural Perspective
Potting Soil and Media							
List the Reasons for Variation in Types of Soil	✓						
Splash					✓		
Exploring Soil		✓					
Root It Out		✓					
Examining Roots and Stems	✓						
Root Growth	✓						
Select Plants Tolerant to Various pH Ranges		✓					
Acids and Bases: Make Your Own pH Indicator					✓		
Fermentation: Making Kimchee in Soda Bottles			✓				
Charting Your Course		✓					

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	Goal A. Science Processes	Goal B. Values	Goal A. Change and Constancy	Goal B. Systems and Interactions	Goal C. Models, Scale, and Structure	Goal A. Science and Technology in Society	Goal B. History and Cultural Perspective
Potting Soil and Media							
Cooking with Soils: Experiment with Plant Nutrition				4			
List Several Soil Mixes Identifying Media Data for Each Soil Mix		4					
Identify the Correct Fertilizers to Add for Various Soil Mixes		4					
Salt Effects on Plants			4				
Describe the Importance of Sterilizing a Potting Mix		4					
Sterilize a Potting Mix	4						
Properly Mix Potting Soil	4						
Soil Fertility							
Plant Nutrient Model					4		
Read the Labels						4	
Interpreting a Soil Survey Map	4						

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	**Goal A. Science Processes**	**Goal B. Values**	**Goal A. Change and Constancy**	**Goal B. Systems and Interactions**	**Goal C. Models, Scale, and Structure**	**Goal A. Science and Technology in Society**	**Goal B. History and Cultural Perspective**
Soil Fertility							
Soil Fertility Assignment Sheets #1 through #5	4						
Organic Matter and Fertilizers							
Writing the Researcher						4	
Living in the Soil		4					
Soil Meditations	4						
Space Travelers		4					
The Matchmaker		4					
Decomposition Column			4				
Rot Race: A Decomposition Experiment			4				
What Is All that Rot?		4					
What's to Worry?	4						
Splash					4		
A Day at the Races					4		
If I were a Schefflera . . .				4			
Water, Water Everywhere					4		
Film Can Mysteries: How Dense is Dirt?		4					

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	**Goal A. Science Processes**	**Goal B. Values**	**Goal A. Change and Constancy**	**Goal B. Systems and Interactions**	**Goal C. Models, Scale, and Structure**	**Goal A. Science and Technology in Society**	**Goal B. History and Cultural Perspective**
Organic Matter and Fertilizers							
Using the Textural Triangle					4		
Determine Soil Textural Class by Mechanical Analysis	4						
Determine Soil Textural Class by Feel	4						
Studying Soil Samples	4						
The Origin and Meaning of Color in Soil	4						
What Good is Compost?	4						
Worm Composting: Never Understimate the Power of a Worm		4					
Plant Growth Regulators							
The Sweeter the Rose				4			
Taking Root / Taking Off!	4						
The Amazing Technicolor Test			4				
Tropisms			4				
The Hypocotyl Hypothesis			4				
The Crucifer							

Cross			4				
Key - ☐	**Standard I. Habits of the Mind**		**Standard II. Science Themes**			**Standard III. Nature of Science**	
Section / Activity	**Goal A. Science Processes**	**Goal B. Values**	**Goal A. Change and Constancy**	**Goal B. Systems and Interactions**	**Goal C. Models, Scale, and Structure**	**Goal A. Science and Technology in Society**	**Goal B. History and Cultural Perspective**
Introduction to Sexual Plant Propagation							
Investigating Seeds		4					
Film Can Germination	4						
Seed Maturation and Dispersal		4					
Seedy Character		4					
Development of Seed Parts into Young Plants	4						
Germination	4						
Seed Power	4						
Growing, Growing, Gone	4						
Gardening Systems		4					
Film Can Wick Pots	4						
Bottle Base Reservoir	4						
TerrAqua Bottle	4						
Bottle Cap Gardens	4						
Film Can Garden	4						
Grow Bucket	4						
Plant Growth	4						
It’s Getting Stuffy in Here	4						

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	Goal A. Science Processes	Goal B. Values	Goal A. Change and Constancy	Goal B. Systems and Interactions	Goal C. Models, Scale, and Structure	Goal A. Science and Technology in Society	Goal B. History and Cultural Perspective
Care and Transplanting of Seedlings							
The Hardy Boys and the Case of the Seedy Wilts			4				
Environmental Factors of Plant Production							
Modifying the Atmosphere			4				
The Station Creation				4			
Keeping Track				4			
I’m the Hottest			4				
A Ravishing Radish Party				4			
A Shoebox of Sunshine					4		
A Journey to Different Lands		4					
Introduction to Asexual Propagation							
Check It Out!						4	
Design a Plant					4		
Propagation and Cuttings							
Taking Root: Propagating from Cuttings	4						
Propagation by Layering							
Starting Plants by Layering		4					
Propagation by Separation and Division							
Perennial Division - Making the Cut!		4					

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	Goal A. Science Processes	Goal B. Values	Goal A. Change and Constancy	Goal B. Systems and Interactions	Goal C. Models, Scale, and Structure	Goal A. Science and Technology in Society	Goal B. History and Cultural Perspective
Propagation by Tissue Culture							
Culturing Plants from Embryonic Plant Tissue	4						
Propagation by Budding							
Demo the T-Bud and Patch Bud	4						
Propagation by Grafting							
Demonstrating the Whip and Tongue and the Cleft Grafts		4					
Plant Identification							
In Search of Inflorescence		4					
Identify a Selection of Plants; Write a Basic Description	4						
Plant Pests and Their Control							
The Best Offense is a Good Defense						4	
Oh Deer!				4			
Birds of Prey				4			
Weeds and Their Control							
Travelin' Plants		4					
Adapt-a-Seed					4		
Who Fits Here?				4			

Key - ☐	Standard I. Habits of the Mind		Standard II. Science Themes			Standard III. Nature of Science	
Section / Activity	Goal A. Science Processes	Goal B. Values	Goal A. Change and Constancy	Goal B. Systems and Interactions	Goal C. Models, Scale, and Structure	Goal A. Science and Technology in Society	Goal B. History and Cultural Perspective
Beneficial and Non-Beneficial Insects							
Insect-Watching		4					
Pesticides and Eggshell Thinning	4						
One-Two Pest Punch		4					
Plant Disease Identification and Control							
Plant "ER"						4	

Agricultural Science and Technology

Ag 514

Botany / Horticulture Plant Science

Additional Resources

Supplies

Carolina Science and Math
(800) 334-5551
Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
USA

Educational Products
Life, Earth, & Environmental Sciences
Forestry Suppliers, Inc.
P.O. Box 8397
Jackson, MS 39284-8397
(800) 647-5368
(800) 543-4203 (fax)

Nature Watch
9811 Owensmouth Avenue #2
Chatsworth, CA 91311
(800) 228-5816
(800) 228-5814 (fax)
E-mail: Nature wat@aol.com

References

The Concise Oxford Dictionary of Botany
Michael Allaby, Ed.
Oxford University Press
Walton Street, Oxford, UK

The Dictionary of Ecology and Environmental Science
Henry W. Art, Gen. Ed.
Henry Holt and Company
New York, New York, USA

Merriam-Webster's Collegiate Dictionary
Merriam-Webster, Incorporated
Springfield, Massachusetts, USA

Activities

The Microcosmos Curriculum Guide to Exploring Microbial Space
Boston University
and
Garden of Microbial Delights: A Practicl Guide to the Subvisible World
Dorion Sagan and Lynn Margulis
from
Kendall / Hunt Publishing Company
4050 Westmark Drive
P.O. Box 1840
Dubuque, IA 52004-1840

Investigating Plants: Hands-On, Low-Cost Laboratory Exercises in Plant Science
and
Learning Biology with Plant Pathology
from
National Association of Biology Teachers
11250 Roger Bacon Drive #19
Reston, Virginia 20190-5202
(800) 406-0775
(703) 435-5582 (fax)

Media Catalogs

AAVIM
AgriScience Catalog
Books/Videos/Computer Softward/CD-Rom
220 Smithonia Road
Winterville, GA 30683
(800) 228-4689
(706) 742-7005 (fax)

A.C. Burke and Company
Intelligent Tools for Your Garden
Videos, Software, Books, Accessories
2554 Lincoln Boulevard Suite 1058
Marina Del Rey, CA 90291
(310) 574-2770
(310) 574-2771 (fax)

Visual Education Productions
California Polytechnic State University
San Luis Obispo, CA 93407
(800) 235-4146
(805) 756-5550 (fax)

Newer Editions of Texts Referenced

1. Hartman, H.T. & Kester, D.E. (1983). *Plant Propagation: Principles and Practices* (4th ed.). Englewood Cliffs, NJ: Prentice-Hall.
2. Reiley, H.E. & Shry, C.L., Jr. (1997). *Introductory Horticulture* (5th ed.). Albany, NY: Delmar.

Recommended Texts

Herren, R.V. (1997). *The Science of Agriculture: A Biological Approach*. Albany, NY: Delmar.

Additional Internet Resources

General Technique Sheets
National Science Teachers Association
http://www.gsh.org/nsta_scripts/SSC_Techs.idc?MU_ID=901
(See Technique Sheets: “Graphing Experimental Data,” “How to Construct a Line Graph,” and “How to Construct a Bar Graph” included with the introduction of this unit.)