Integrated Pest Management (IPM)

For Greenhouse Operations in Maryland's Secondary Schools

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Introduction

Stanton Gill and Sarah Kenney

Spanning over 64,000 square miles from Virginia through New York, the region's Chesapeake Bay watershed is a constant reminder of human impacts on estuarine and environmental health. Several factors have impacted the Bay's health over the past century that include nutrient loads, overharvesting, air quality, agricultural and homeowner runoff, invasive species pressures, urban and suburban development, and human population growth. President Obama declared the Chesapeake Bay a national treasure in his 2009 Executive Order, symbolizing the Bay's environmental and cultural value. The Obama administration's strategy included unprecedented federal involvement in the Chesapeake Bay in direct support of local governments, non-profit organizations, and local citizens. The program targets issues that include nutrient loads of nitrogen and phosphorus, storm water treatment plans, agricultural lands, and oyster restoration.

With such vast and varied factors influencing watershed health, it is easy to disregard the effects a greenhouse may have on the environment. Fertilizers and pesticides used in a greenhouse eventually reach the watershed and local waterways, increasing the total daily maximum load and the quantity of particulates in the waters. Although greenhouse activities may seem like a small piece of the 64,000 square mile puzzle, the practical strategies of Integrated Pest Management can reduce the greenhouse's environmental impact on the Chesapeake Bay. Integrated Pest Management (IPM) practices work to minimize environmental degradation while maintaining quality plants.

The greenhouse environment creates ideal conditions for weeds, pests, and diseases, all of which must be managed through IPM. Part of the IPM approach is to understand biological interactions within a greenhouse. The goal of this IPM program is to instruct high school students on the production of attractive healthy plants through reduced-risk pest and disease controls.

Familiarity with the greenhouse, crop growth patterns, and greenhouse pests are important components of integrated pest management. In addition to these topics, fertility and water management practices are essential to a successful IPM approach. Simple tasks such as cleaning the greenhouse can prevent major pest problems, because weeds and algae buildup serve as a food source for pests and diseases in the greenhouse. The practice of removing pests' habitat and food source promotes responsible greenhouse management. Managing substrate (or growing medium), pH, and nutrients also prevent plants from becoming malnourished or weakened. Because stressed plants become more susceptible to pests and diseases, IPM emphasizes the importance of plant health through fertility and water management as well as pest and disease identification.

High school greenhouse management programs teach students how to grow attractive healthy plants that are relatively pest and disease free. This manual serves as a guide for the high school instruction of Integrated Pest Management techniques to ensure the responsible production of viable greenhouse crops.

The manual introduces students and instructors to the principle components of Integrated Pest Management ranging from preventive methods to proper insect identification and controls. The following guidebook is divided into teachable units based on different aspects of IPM and greenhouse production. Each unit contains learning goals, an overview of the topic, PowerPoint presentations, additional electronic and printed materials, and laboratory exercises in disease, insect, or fertility management. The resources provided in this manual are meant as a guide or source-base from which Maryland instructors may create and tailor lesson plans to their classroom.

This manual serves as a comprehensive outline of greenhouse management and is intended to provide a baseline of information and procedure for secondary education instructors. It is not intended as a mandate for specific lessons or teaching method, but rather as a resource for teachers dealing with greenhouse management and horticulture.

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Unit One: Principles of IPM

1.1: What is Integrated Pest Management and why does it matter?

Skill:

Identify the basic principles of Integrated Pest Management and understand the reasoning behind an IPM approach.

Outcome:

Explain the importance of IPM in terms of resistance, health, safety, and costs

Learning Goals Achieved:

Students will be able to identify the pros and cons of integrated pest management programs.

Students will be able to describe environmental impacts of pest management.

Student will be able to demonstrate an understanding of IPM principles.

Key Questions:

What is the purpose of Integrated Pest Management?

What are the pros and cons of an integrated pest management program?

How can IPM reduce human health risks?

How can IPM impact environmental health?

How has the science of biology, chemistry, and the environment influenced our culture? Discuss influences in literature, art, and music.

Action Strategy:

Review content of Chapter 1; Hold class discussion

Discuss principles goals of IPM

Begin a research project that explores a major pest or disease topic.

Assessment:

IPM Venn Diagram

Materials:

Text or lecture material

Interdisciplinary Connections:

Social sciences

Unit 1: Principles of IPM

Chapter 1

Integrated Pest Management and the Greenhouse

Sarah Kenney

What is Integrated Pest Management?

Integrated Pest Management (IPM) uses pest and environmental information to prevent crop damage using the least toxic and most cost-effective methods.[1] Instead of using a pesticide, an IPM plan may use a beneficial insect to control a pest or reduce crop damage. IPM provides a more responsible pest control approach. IPM is a key component to successful greenhouse management, thus this manual focuses on Integrated Pest Management and its role in ensuring safe and sustainable greenhouse crop production.

The success of any IPM program depends on a knowledge and understanding of plants, pathogens, and insects. While this requires time and attention to detail, the benefits of early detection often outweigh the labor involved in a monitoring program.

Unlike a sterile laboratory experiment, agriculture exists within the dynamic and sometimes unpredictable world. Land, water, air quality, plant, and animal interactions are constantly changing. New pest species are introduced through global trade, and resistance to over-used pesticides can create huge problems.

Why is IPM Important?

IPM is a cost-effective and environmental approach to pest management. Simple strategies such as crop rotation and weed control can reduce the risk of a pest invasion. Likewise, early detection of a problem can prevent crop loss or chemical use.

Resistance

In the 1970s, Rachel Carson argued against high-impact and undiscerning pesticides. Her book *Silent Spring* sparked national interest in the environment. She wrote that pest species could develop immunity, or resistance, to traditional chemicals. Her fear of pesticide resistance was not new. In fact, houseflies had developed resistance to DDT by 1947.[2] DDT is a strong chemical pesticide that was used heavily in the 20th century. It had a widespread impact on the food chain and is banned today.

Since resistance can be a problem, IPM programs suggest a rotation or change in chemicals. Today, an international committee works to educate the public on pesticide resistance.[3] IPM

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[1] Environmental Protection Agency. 2010. Integrated pest management (IPM) principles. *Pesticides: Topical and Chemical Factsheets.* < http://www.epa.gov/opp00001/factsheets/ipm.htm>.

[2] Insecticide Resistance Action Committee. 2010. Resistance. Insecticide Resistance Action Committee < http://www.irac-online.org/about/resistance/>.

[3] Insecticide Resistance Action Committee. 2010. Resistance. Insecticide Resistance Action Committee < http://www.irac-online.org/about/resistance/>.

programs aim to develop diversified, timely, and accurate pest control applications to avoid insect or disease resistance.

Applicator safety
Laws require that the pesticide applicator wear protective clothing and equipment. This information is found on the pesticide product labels and lists the minimum protective clothing that must be worn when using that particular product. This helps to reduce contact with the chemicals and keeps the worker safe. The government requires that growers follow a re-entry interval (REI). An REI is a length of time where workers are not permitted to enter a treated area. REIs can range from a few hours to a few days. They were designed to protect workers from the repeated and prolonged exposure to pesticides. More dangerous chemicals have longer re-entry intervals.

Environmental health
IPM encourages growers to use more selective pesticides. These may be less toxic to humans, fish, birds, and other animals. Another approach uses insects such as wasps and ladybugs instead of chemicals. Beneficial insects prey on plant pests. For example, some wasps lay eggs in caterpillars. The wasp eggs will develop into larvae, feeding on and killing the caterpillar. Caterpillars damage plants by chewing on the foliage.

Cost effective
IPM can reduce pest control costs. Long-term investments in pest prevention means less money spent on pest control. If a crop is susceptible to a specific pest, a grower can use early releases of beneficial organisms to minimize the pest problem. Likewise, early detection allows a grower to use spot treatments of pesticides such as insect growth regulators, which have the least impact on beneficial organisms. Early identification can mean a cheaper and faster pest control method. This keeps crop yields high. It helps to reduce the cost of growing a crop and leads to higher profits for a grower.

Summary:
Integrated Pest Management works to ensure quality control in the most economical and environmentally-sound manner. IPM programs address issues of pest resistance, applicator safety, environmental concerns, and production costs with the ultimate goal of maintaining high quality crop yields.

Key Terms:
Integrated pest management, pesticide resistance, and re-entry interval

Resources:

Basic EPA Pesticide and IPM Information:
http://www.epa.gov/agriculture/ag101/croppesticideuse.html
http://www.epa.gov/agriculture/tipm.html

US EPA Core manual
http://www.nasda.org/workersafety

Biological Control Information Center
http://cipm.ncsu.edu/ent/biocontrol/goodbugs/pirate.htm

Fungicide Resistance Action Committee Website:
http://www.frac.info/frac/index.htm

Total Crop Management for Greenhouse Production, Bulletin 363. Revised 2011. University of Maryland Extension.

Insecticide Resistance Action Committee Website:
http://www.irac-online.org/

Neonicotinoids and Whitefly Resistance:
http://www.irac-online.org/wp-content/uploads/2009/09/IRAC-WF-Poster-RN-v2.1.pdf

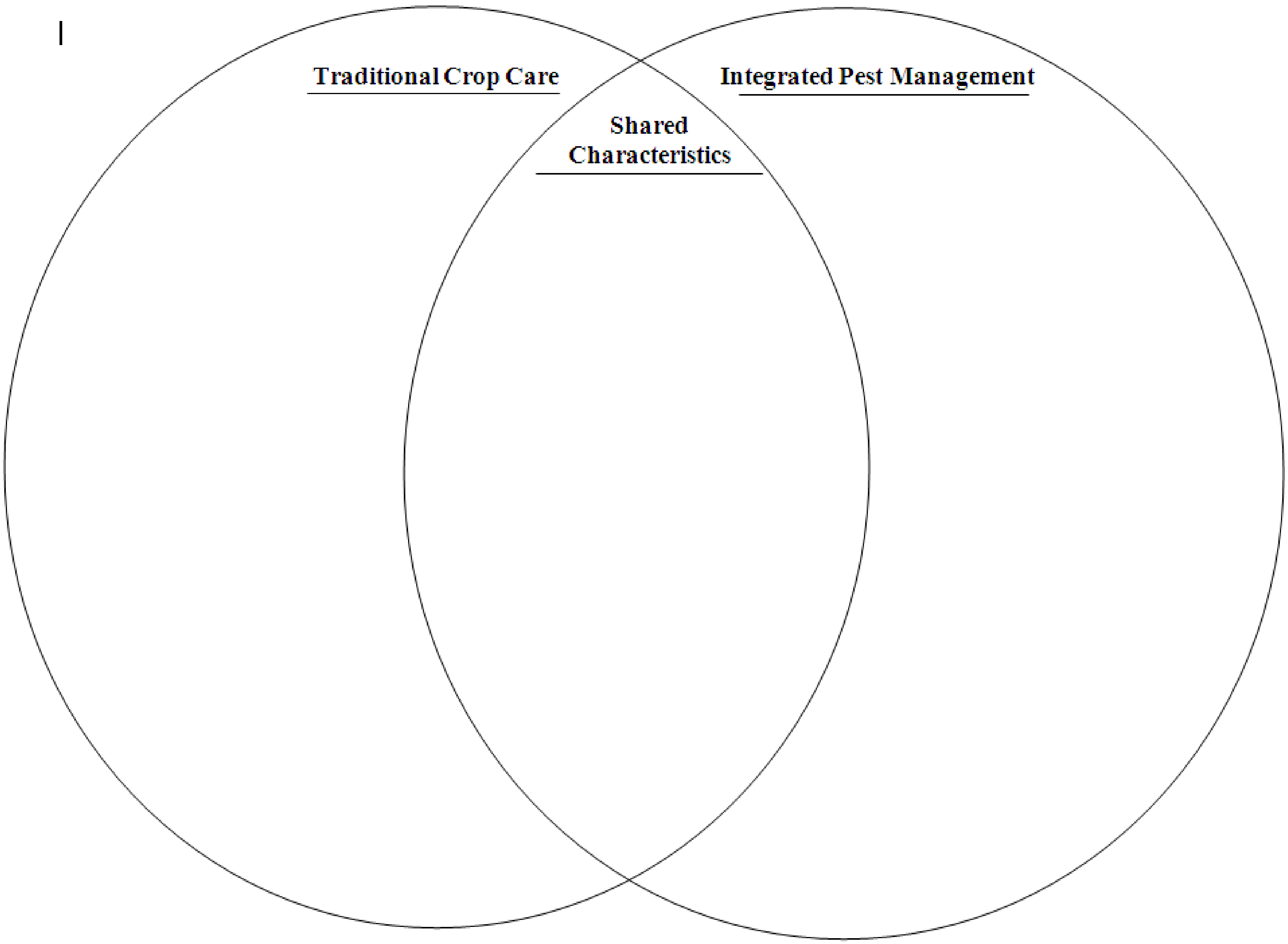
Radcliffe, E. B., Hutchison, W.D., and Cancelado, R.E., eds. 2007. Radcliffe's IPM World Textbook. St. Paul, MN: University of Minnesota http://ipmworld.umn.edu.

Unit 1.1 Assessment Rubric: IPM Venn Diagram

Criteria	Points	Scores
Describes distinct characteristics of IPM	5	
Describes distinct characteristics of traditional pest programs	5	
Explains similarities between the two	5	
Total	15 points	

Assessment 1.1: IPM Venn Diagram

Name: ______________________ Date: ________ Class Section: ________



Unit one: Principles of IPM

1.2: Steps to Integrated Pest Management

Skill:

Communicates orally and in writing on the impacts of pest management strategies

Outcome:

Discussion of major steps and issues that may arise in Integrated Pest Management

Learning Goals Achieved:

Students will be able to explain the IPM process.
Students will be able to discuss the importance of field observation and monitoring.
Students will be able to understand the links among cost-benefit analysis, horticultural planning, and IPM strategies.

Key Questions:

Why is research and cultivar selection important?
How can pest and disease outbreaks be prevented?
Why is scouting important to an IPM program?
What role does an economic threshold play in a grower's decision making process?

Action Strategies:

Review content of Chapter 2; Hold class discussion
"Plant Pathology: Past to Present" by F.H. Tainter (from the American Phytopathological Society)
Develop an IPM How-To Guide
Long Term Research Project Assignment should be initiated: Global Events in IPM

Assessment:

Introduction to Integrated Pest Management Quiz
Develop an IPM How-To Guide for the greenhouse

Materials:

Text or lecture material

Interdisciplinary Connections:

Writing
Speech and communication
Biology

Unit 1: Principles of IPM

Chapter 2

Steps to Integrated and Total Plant Management for Greenhouses

The goal of the Maryland schools' greenhouse education program is to teach students how to grow attractive and healthy plants that are pest and disease free. Reduced chemical inputs will require weed control, soil maintenance, and pest detection.

This chapter lists the steps to a successful IPM program.

1. *Selection:* Selecting the appropriate plant species, cultivars, and supplies.
The first step to a successful season is to find the plants you want to grow and their cultural needs. These include optimal pH levels, alkalinity, water quality, desired soil moisture levels, light and temperature requirements, and time to maturity. You should be aware of common insect, mite, and disease problems as well.

You will need to consider container sizes, planting media, and available space. Be sure to research whether the plants are well-suited to your climate and growing season. The most resilient and resistant cultivars may be the best options. A cultivar is a plant variety developed from a natural species through selective breeding.[4] They are often developed to build disease resistance, color variety, or other desirable characteristics. Important questions to ask are: Who or what is your intended audience? Will you be selling to parents? The neighborhood? When will you be selling the plants? Christmas? Spring?

The Ball Redbook is a valuable reference tool, as well as University of Maryland Extension's Total Crop Management for Greenhouse Production.

2. *Preparation:* Sanitize and prepare the greenhouse.
Before you start a new crop, remove any remnants of previous crops, plants, and debris. Clean all growing surfaces and eliminate weeds from under benches. Eliminate standing water, algae, and permanent "pet," show, or stock plants. These provide ideal conditions for insects and diseases. Repair damaged screening, irrigation or fertilizer systems, and electrical problems before you begin the growing season.

Sanitation helps prevent insects, mites, and diseases. Root rot diseases can spread rapidly through a greenhouse. Substrate materials such as trays, tables, and tools should be sanitized to eliminate pathogens. This is integral to a successful IPM program.

Greenhouse preparation processes are described more fully in Chapters 7 and 8 of this manual.

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[4] "Cultivar" on www.dictionary.reference.com and http://wordnet.princeton.edu/

3. ***Scouting:*** Scouting the Greenhouse

Create a schedule for IPM monitoring. The greenhouse should be monitored regularly every 7-14 days. Scouting or monitoring includes the use of sticky traps, plant inspection, and recordkeeping.

Plant inspection and insect trapping should start when cuttings or plugs first arrive and continue until plants are removed from the greenhouse. Pest infestations, such as aphids, whiteflies, and mites, usually begin in small isolated areas. Sample as many plants as possible throughout the growing area. Walk through the greenhouse and note any sections with discoloration, height or shape differences, drooping, and any other subtle signs of stress or damage. Consult pest identification books, IPM reports, and specialists to identify any trouble insects, mites, or diseases.

Monitoring steps, pest identification, and disease resources can be found in Unit 4.

4. ***Establish a Threshold***

An economic threshold is the level at which crop yield or value declines. For a grower, this is often expressed as population size or density. When a pest population reaches the economic threshold, a control method will be needed to prevent further damage.

IPM encourages growers to establish an economic threshold level. This threshold varies according to the type of plant grown, customer-base, and crop maturity.

If it is determined that the economic threshold has been reached, then a control option is necessary.

5. ***Control Measures***

Once a pest problem has been clearly identified, the grower must examine potential control methods. Treat crops only if the pest population or damage is nearing the economic threshold level.

In most standard chemical control programs, elimination of all pests is rare. The goal of most greenhouse pest management programs should be to maintain pests below an economically damaging level to the plants.

See Chapters 4, 6, 11, and 12 for more details concerning pest control options.

An excellent resource can be found through the University of Maryland Extension Greenhouse IPM Reports. These are published biweekly and provide information on current greenhouse problems, control methods, and upcoming educational events. The Greenhouse Management manual is another excellent tool.[5]

[5] Total Crop Management for Greenhouse Production, Bulletin 363, revised 2011, University of Maryland Extension.

Summary:
Select crops tailored to your intended sale audience and be sure that they are suitable to the greenhouse and region's resources and climate. Understand the plant's cultural requirements and susceptibilities. Begin a crop cycle with a sanitized and pest-free environment to limit infestation issues. Scout and monitor crop on a regular basis and identify problems early for easier control.

Key Concepts:
Cultivar, economic threshold

Resources:

Integrated Pest Management for Commercial Horticulture.
http://ipmnet.umd.edu/

Biweekly IPM Reports for Greenhouse and Cut Flower Operations.
http://ipmnet.umd.edu/greenhouse/grnhsandcutalerts/index.htm

Tainter, F.H. 1998. Plant Pathology: Past to Present. The American Phytopathological Society <http://www.btny.purdue.edu/outreach/PlantPathStory/PlantPathStory-Flash.html>.

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1.2 Assessment Rubric: Develop an IPM How-To Guide

Brochure, Handout, or Poster
Design an informational piece that explains the major steps of IPM planning and application. It should be one page.

Criteria:	Points:	Score:
Identifies each of the 6 steps	6	
Explains each of the 6 steps	12	
Provides an example for each step	12	
Spelling and correct grammar	6	
Creativity and design	4	
Total:	40 points	

1.2 Assessment Rubric: Global Events in IPM

Student chooses a historic plant-related epidemic or event and assesses the control method.

This 3-4 page paper and presentation should:

- Provide background information on the pest issue
- Identify the threat posed by the pest (environmental, economic, social, etc.)
- Identify the ecological role of the pest
  What does it eat? Are there biological controls? If it is a disease, how is it transmitted? If it is an insect, how does it move to new places? Was this a native or imported pest problem?
- Discuss control measures that were taken and whether they were effective
- Propose IPM control measure(s) that could be taken next time the problem arises. If the IPM control method is the same used at the time of the historic outbreak, expain why it is the best option.

Oral Presentations
Paper: 2-4 min. presentation Poster in lieu of paper: 7-10 min. presentation
Examples of research topics could include: Irish Potato Blight, E. coli on spinach, toposvirus on greenhouse plants, grasshoppers and prairie grasses, cicada outbreaks, whitefly resistance in greenhouses, etc.

Criteria:	Points:	Score:	Comments/Explanation:
Complete sentences, proper spelling, and grammar	10		
Explains the pest issue	10		
Identifies the potential threats	5		
Identifies the pest's ecological role and biology	5		
Discusses control measures and results taken	5		
Proposes comprehensible IPM control measures	5		
Sources or reference materials are cited	5		
Presentation is clear and engaging	5		
Total:	50 points		

Unit 1: Principles of IPM
Introduction to IPM Quiz

Name: ______________________________________ **Date:** __________ **Class Section:** _____

Answer the following multiple choice questions.

1. Integrated Pest Management ____________________ .
   a. uses pest and environmental information to determine the least hazardous and most efficient control methods
   b. is a method of determining the best trapping option for insects and rodents
   c. relies on a structured set of procedures for controlling pest problems
   d. always involves the use of a pesticide

2. Houseflies developed a resistance to which broad spectrum insecticide in the 1950s?
   a. Windex
   b. Roundup
   c. DDT
   d. Sevin

3. IPM stands for what?
   a. Insect, Pest, and Mite
   b. Integrated Pest Management
   c. Impervious Pest Membrane
   d. Insect Problem Maintenance

4. IPM programs are based on:
   a. Preventative pesticide applications
   b. The assumption that pests are present
   c. Treating before pest populations become established
   d. Knowledge of the pest and the environment

5. How can IPM help the environment?
   a. IPM programs help produce vegetation with minimized damage to beneficial insects and water sources
   b. IPM can reduce the amount of harmful chemicals that could enter the environment
   c. IPM can help reduce the potential for pest resistance to pesticides
   d. All of the above

6. What is a biological control?
   a. An IPM approach that uses other organisms to control a pest population
   b. A control option that eliminates both harmful and beneficial organisms
   c. A method for improving cell performance and growth
   d. A control method that prohibits a pest from reproducing

7. What is a horticulturalist's definition of REI and why is it important?
   a. Rows of Edible Interest help experimental growers mark edible verses ornamental plants in a greenhouse
   b. A Re-Entry Interval established to promote human safety and reduce exposure to pesticides
   c. An outdoor clothing and gear store that helps commercial growers survive the elements in a greenhouse
   d. A predetermined period of time that a plant can be returned to the greenhouse after removal due to an infestation

1) In your opinion, why would a grower want to use biological control methods?

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Unit two: Understanding the Greenhouse Ecosystem

2.3: Basic Plant Requirements

Skills:

Knowledge of such as photosynthesis, alkalinity, electrical conductivity, pH, and porosity
Identify basic plant requirements and growth-limiting factors

Outcome:

Discussion on the amount of research, planning, and practical analysis involved in horticultural production
Design an experiment assessing soil fertility
Observe and describe the effects of ventilation and moisture in the greenhouse

Learning Goals Achieved:

Students will be able to conceptualize an experiment and develop a hypothesis
Students will be able to list basic requirements for plant production
Students will be able to assess and critique growing conditions
Students will be able to recognize crop planning deficiencies

Key Questions:

How does light influence plant growth?
Why would temperature be important to plant development?
How does substrate porosity relate to root health?
What is more important to regulate: alkalinity or pH? Why?
What benefits can ventilation provide?

Action Strategies:

Reading and lecture material from Chapter 3; Hold class discussion
Substrate Fertility Trial
Pansy Detective: Fertility and Irrigation Problems
Plant Spacing Trial
"Too Wet, Too Dry" PowerPoint Presentation
"Taking Substrate Samples" Power Point
"Taking Water Samples" Power Point

Assessment:

Substrate Fertility Trial
Pansy Detective Responses
Plant Spacing Trial
Too Wet, Too Dry PPT Assessment

Interdisciplinary Connections:

Biology, Physics, Chemistry, English

Unit 2: The Greenhouse Ecosystem

Chapter 3

Basic Plant Requirements

Sarah Kenney

"Sun, soil, and water."

Plants require more complex nutrients and environmental variables than those three simple words. Light requirements vary by species, as do substrate and nutrient demands. Too much or too little water can cause stress and leave the plant susceptible to infestation by insects, mites, or disease. A grower must ensure that greenhouse conditions are well-suited to the plant. This chapter discusses the intricacies of greenhouse plant needs.

Light and temperature

Light is essential to plant growth and development. **Photosynthesis** is the process of producing carbohydrates from light, water, and carbon dioxide. Without light and the photosynthetic process, plants would be starved for energy and cannot survive.

A **chloroplast** is an organelle within the plant cell where photosynthesis occurs. Here, light energy is absorbed and converted into chemical energy. After light energy is converted into chemical energy, the energy is used to break carbon dioxide into a usable material for carbohydrate and oxygen production.

Plants contain **photoreceptors**—special proteins that enable them to detect seasonal changes between night and day. **Photoperiodism** is the plant's response to night and day changes. This photoperiodism links directly to plant maturity and flowering.

How does photoperiodism influence greenhouse growers' plans? Poinsettias are short-day plants and require longer periods of darkness. Lilies are an example of long-day plants. Lights and shade cloths are used to induce or repress plant development. Growers can use colored lights to trigger specific types of growth. White lights are standard and encourage photosynthesis, while red light exposure can help plants heighten and trigger flowering. Blue lights help plants with leaf development and can trigger flowering when used in conjunction with red lighting.

Temperature management is important to horticultural production as well. As you know, plant species are suited to specific seasons and climate regimes. For instance, poinsettias are native to Mexico, where weather is hot and provides favorable growing conditions. North American growers must adjust the greenhouse climate to the ideal growth temperature, which normally varies from the mid-60s to mid-70s. This climate control can be difficult when producing poinsettias around the Thanksgiving and Christmas seasons. Likewise, there may be crops that cannot tolerate high temperatures or require a shade screen.

Plants respond to surrounding temperatures, so an altered environment can help regulate growth and development. **DIF**, or the difference between day and night temperatures, influences plant growth and development. For instance, an increased difference in day and night temperatures can trigger vertical growth in poinsettias. This can be controlled in a commercial setting using growth regulators. Temperatures influence bloom times as well. Extreme high temperatures could delay bloom times, especially in chrysanthemums, while colder temperatures can have a similar effect on crops.

Overheating in a greenhouse can stress or burn plants. A common remedy for high temperatures is a cooling pad system. A cooling pad uses evaporation to cool air as it moves through the greenhouse. Proper ventilation and screening can remedy an overly warm greenhouse system. Some greenhouses are equipped with panels that open to allow natural ventilation, while others install fan systems to create air flow.

Ventilation also regulates temperature through the greenhouse. Growers should consider fan placement, air flow power, air flow direction, and maintenance costs when developing a ventilation system. Without air movement, greenhouse temperatures could vary by up to 15°F.[6] Proper ventilation reduces this range and promotes quality control. Proper air flow will likewise reduce moisture buildup on leaves and can prevent disease development. Other practices that reduce moisture problems include proper plant spacing and weed management.[7] Plant spacing also allows for bushy plant development, encouraging outward growth rather than vertical.

Substrate and nutrients

Substrate or planting media plays a key role in plant health. **Substrate** is the material on which an organism can live. Substrate provides physical stability for a plant to root. True soils hold more water than organic substrates, thus they can create trouble in container production. Although soil can be used, growers typically use soilless substrate. The soilless substrate provides a uniform foundation for plant growth in terms of water holding capacity, pH, and other factors. A well-chosen substrate holds air, water, and nutrients essential to plant health. Materials can range from pine bark to perlite—a volcanic glass that can hold high quantities of water. Growers can mix other substances with their substrate to obtain ideal container weight, drainage, and nutrient availability.

Moisture and capillary forces play an integral role in plant nutrient uptake and water retention. **Capillary forces** refer to the ability of water to move against gravity, and helps water and nutrients remain available for uptake. Without substrate moisture, plants would not be able to access vital nutrients.

Whereas a lack of water hurts a plant, the reverse is also true. You may not immediately think of air as an important component to substrate materials, but air pores promote healthy root stock. Waterlogged substrate creates anoxic (lack of oxygen) conditions that ultimately suffocate the

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[6] Bartok, J.W. 2005. Horizontal air flow is best for greenhouse air circulation. *Greenhouse Crops and Floriculture: Fact Sheets*. UMass Extension. <http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/jb_haf.htm>.

[7] Smith, T., and J.W. Bartok. 2003. Reducing humidity in the greenhouse. *Greenhouse Crop and Floriculture: Fact Sheets.* UMass Extension <http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/humidity.htm>.

root system and prohibit nutrient uptake. Aside from plant stress, overly wet substrates provide ideal growing conditions for unwanted fungal and algal problems.

Air-filled porosity (AFP) and water holding capacity (WHP) are supplementary proportions that together equal the total porosity of a substrate. Air-filled porosity is the ratio of air available within the substrate. Water holding capacity, on the other hand, measures the quantity of water that a substrate can hold. Both are vital to root development and plant health.

One plant may like well-drained sandy soil, yet another may thrive in a moist slow-draining substrate. Understanding the physical and chemical structure of a substrate can impact plant care management, thus is an important aspect of a grower's research and preparation.

Water quality and irrigation

City health officials test drinking water for metals, chemicals, and any unwanted particulates to ensure consumer safety. A grower must likewise test the chemical composition of the irrigation water.

Three characteristics should be carefully monitored. They are electrical conductivity, alkalinity, and pH. **Electrical conductivity (EC)** refers to the ability of a solution to move through a liquid substance. EC measures the soluble salt content. EC influences water and nutrient uptake rates. High soluble salts can inhibit plant growth and can cause root or plant tip burning. Corrections in EC can be made by leaching the substrate to reduce the soluble salt content.

Alkalinity may be the most important water quality factor affecting plant performance. **Alkalinity** is the ability of water to stabilize or buffer acids. Poor alkalinity means that slight acidity changes can easily damage a plant. In the human body, hemoglobin acts as a chemical buffer for pH. Hemoglobin accepts extra hydrogen ions to maintain a steady pH in the bloodstream. This helps to keep the body healthy and in balance. In horticulture, the chemical properties in water can help buffer hydrogen ions and reduce pH changes. Ideal alkalinity ranges vary by the plant and growth stage. For instance, plugs require a lower alkalinity than a 7 week old plant. The ability to stabilize or buffer acidity is necessary to maintain a healthy crop. In a low alkalinity system, the plant will not respond well to pH fluctuation and damage appears. Growers can add substances such as sulfuric acid to the water to alter water's alkalinity.

pH measures the acidity of a material. pH ranges from 0 to 14 and plays a prominent role in plant health and nutrient uptake. Low pH readings indicate a high quantity of hydrogen ions or acidic conditions. Acidity can create toxic conditions. Iron and manganese can become too available in low pH conditions and will create a toxic reaction within the plant. Calcium, sulfate, magnesium deficiencies may occur in low alkalinity and low pH conditions. A high pH corresponds to low hydrogen ion levels and more basic conditions. High pH levels may result in iron and manganese deficiencies. Ultimately, nutrient availability depends on the alkalinity or chemical response to pH levels in the root environment.

Fertigation is an irrigation method that combines water and soluble fertilizers. Fertigation gives a steady and controlled flow of nutrients to the plant material. This provides a continuous supply of nutrients to the plant and allows the grower to adjust fertilizers as crop conditions change. When properly utilized, fertigation is the most efficient means of fertilizing.

Irrigation equipment must be checked routinely, and injectors should be calibrated to ensure accurate application. In a greenhouse environment, fertigation lines should be marked as containing fertilizer. Some growers dye the fertilized water so as not to confuse regular watering and fertilizing practices. Other fertilization options include dry fertilizer prior to planting and controlled release granules.

Summary:
Healthy plants require a variety of resources specific to their species and cultivar. Temperature, air quality, substrate, and water chemistry all play an integral role in healthy crop production and must be monitored regularly to ensure continued optimal growth.

Key Terms:
Alkalinity, capillary forces, chloroplast, DIF, electrical conductivity, fertigation, pH, photoperiodism, photoreceptors, photosynthesis, substrate, ventilation

Resources:

Arizona Cooperative Extension. 1998. AZ Master Gardener Manual: Environmental Factors. University of Arizona <http://ag.arizona.edu/pubs/garden/mg/botany/environmental.html>.

Bartok, J.W. 2005. Horizontal air flow is best for greenhouse air circulation. *Greenhouse Crops and Floriculture: Fact Sheets*. UMass Extension <http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/jb_haf.htm>.

Bilderback, T.E. 2001. Using the PourThru procedure for checking EC and pH for nursery crops. *NC State University Horticulture Information Leaflets*. <http://www.ces.ncsu.edu/depts/hort/hil/hil-401.html>.

Smith, T., and J.W. Bartok. 2003. Reducing humidity in the greenhouse. *Greenhouse Crop and Floriculture: Fact Sheets.* UMass Extension <http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/humidity.htm>.

Whipker, B.E., Cavins, T.J., and Gibson, J.L. 2002. Managing fall pansy fertilization. *NC State University Floriculture Research* <http://www.ces.ncsu.edu/depts/hort/floriculture/Florex/pansy_fert_mgt.pdf>.

University of Maryland Extension. 2011. Total crop management for greenhouse production, Bulletin 363 < http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

2.3 Assessment Rubric: Substrate Fertility Trial

Student will develop a hypothesis and an experimental design to test his/her hypothesis. Hypothesis will deal with the effects of fertilizer or nutrient amendments on plant health.

In designing the experiment, students should examine a control and two different fertilizer regimes. This experiment will run in the greenhouse. Students should be sure to assess the growing area to ensure uniform environmental factors such as temperature, light exposure, and irrigation practices. Effects will be recorded after one, two, and four weeks.

A brief (1-2 page) report should include the objective, hypothesis, materials, methods and experimental design, results, a brief discussion about the results, and a conclusion.
The write-up should discuss whether the experiment supported or disproved the hypothesis.

Criteria:	Points:	Score:	Comments:
Clear hypothesis	7		
Experimental design and methods are explained well	8		
Results are recorded	5		
Discussion of results shows insight and analytical skill development	7		
Student discusses other influencing or limiting factors	5		
Student concludes whether the experiment supports or disproves the hypothesis	7		
Students discuss the effects of fertilizer on plant material	10		
Total:	50 points		

Assessment Activity 2.3: Pansy Detective
Diagnosing Cultural Problems Based on Collected Data

Description:

In this activity students will examine a photo of a plant and cultural data. Students will analyze these sources and attempt to diagnose the plant problem. They will discuss the importance of alkalinity, pH, and fertilizer to plant health and appearance.

Objective:

Students will learn to interpret field data
Students will be able to distinguish the effects of high verses low pH
Students will gain a better understanding of alkalinity and pH requirements

Skills:

Observation and analysis of plant symptoms and fertility data
Critical thinking

Materials:

Notes from Chapter 2.3
Photos and slideshow materials
Worksheet

Resources:

Whipker, B.E., Cavins, T.J., and Gibson, J.L. 2002. Managing fall pansy fertilization. *NC State University Floriculture Research* <http://www.ces.ncsu.edu/depts/hort/floriculture/Florex/pansy_fert_mgt.pdf>.

University of Maryland Extension. 2011. Total Crop Management for Greenhouse Production, Bulletin 363. < http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

Assessment Activity 2.3: Pansy Detective
Diagnosing Cultural Problems Based on Collected Data

Name: ________________________________ Date: ___________ Class Section: _______

Objective:

Students will learn to interpret field data
Students will be able to distinguish the effects of high verses low pH
Students will gain a better understanding of alkalinity and pH requirements

Materials:

Notes from Chapter 2.3
Photos and slideshow materials
Worksheet

Approximate ranges for pansies:

Alkalinity (for plugs):	60-80 $CaCO_3$.
Soluble salts:	700 ppm
Soil-less substrate:	5.4-5.8 pH
Soil-based substrate:	5.6-6.0 pH

You are a contracted plant diagnostician in Maryland. You spend your days visiting greenhouse and nursery operations helping to diagnose problems and develop solutions to cultural and pest problems. The following assignment consists of three pansy scenarios. Each grower is having a similar but slightly unique problem with their pansy production.

Can you solve the pansy mysteries?

In a Pansy Pickle

Sally has been growing pansies for three years now. This year she bought a new piece of land and added a few more greenhouses to expand her business. Sally suddenly notices that her plugs are looking rather yellowed between the veins of almost every leaf. They were planted two weeks ago and looked perfectly healthy before they were potted.

The plants demonstrate no sign of root rot or bacterial disease and her sticky cards have been clean. Her fertilizer regime is the same as she has used at her other greenhouse site for years.

Sally's pansy symptoms are interveinal chlorosis, often associated with a nutrient deficiency. Luckily, Sally loves to collect soil and water samples. You dig through her records and find last month's pH and alkalinity readings.

	pH	**Alkalinity**
8/14	5.8	82
8/20	5.8	85
8/28	5.9	90

You decide to test her water one more time. It is September 4th and her irrigation water has an alkalinity of 90 and a soil pH of about 6.0.

What could be causing the pansies' chlorosis?

Miss Doe's Pansies

Miss Doe's class received a topsoil donation from the local garden center and decided to plant pansies this year. Unfortunately, they do not look healthy and are showing signs of interveinal chlorosis across the crop. Miss Doe sampled the irrigation water for alkanity and found it at 70ppm. They are following the recommended fertilizer rates and the pH is at 5.4.

What could be going wrong?

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What other data might be helpful in assessing Miss Doe's pansy problem?

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Purple Pansy Woes

George is growing pansies for his school's fall sale. Last week he noticed some of the lower leaves had shades of purple in them. Today he noticed almost every plant had purplish lower leaves.

The discoloration is fairly uniform throughout the greenhouse, so George knows it is probably a cultural or nutritional problem and not a disease. The only purple symptom he can think of is a phosphorus deficiency.

George finds the classroom recordkeeping clipboard and flips through the recent pages.

	Weather	Irrigate/Fertilize	Any problems?
9/15	Sunny	Watered with hose	Good
9/17	Sunny	Watered with hose	Pretty clean!
9/19	Cloudy	Watered with hose	Plants looking good
9/23	Sunny	Watered with hose	No
9/25	Sunny	Watered with hose	Good
9/29	Rain	Watered with hose	Should these be growing faster?
10/01	Rain	Soil still wet	Mildew forming, scrubbed algae off tables
10/03	Cloudy	Watered with hose	Looking better
10/06	Sunny	Watered with hose	No problem
10/08	Rain	Watered with hose	No
10/12	Sunny	Watered with hose	Good

George’s pansies are lacking in phosphorus and also in low soluble salts, or electrical conductivity. What is his plant care regime missing that could have alleviated this problem?

Explain what other pieces of information would help you evaluate these pansies.

2.3 Lab Activity
Plant Spacing Trials

Description:

In this activity, we will examine the effects of poor ventilation on specimen health. This activity encourages students to make observations and educated conclusions on plant spacing and airflow within the greenhouse. Students will take notes, draw sketches, or photograph the trial results. This exercise requires an observation period of several days, so be sure to plan your class and lab time accordingly.

Objective:

Students will develop and test a hypothesis.
Students will record and interpret observations.
Students will be able to discuss cultural requirements and environmental factors affecting plant health.

Skills:

Understanding of cause and effect relationships
Critical thinking

Materials:

16 healthy plants (age not a matter, as long as they are beyond the seedling or plug stage)
16 tags or markers, and marking pencil
12 transparent plastic bags (Ziploc big bags, vegetable bags from the produce section, etc., as long as they allow light to penetrate)
Equipment to continue the normal irrigation and fertilizer regime (if applicable)
Scissors
Tape
Camera

*If short on plant material, try 12 plants (3 for each treatment)

Resources:

University of Maryland Extension. 2011. Total Crop Management for Greenhouse Production, Bulletin 363. <http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

2.3 Lab Activity
Plant Spacing Trials

Name: ________________________________ Date: ___________ Class Section:_______

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Materials:

16 healthy plants (age not a matter, as long as they are beyond the seedling or plug stage)
16 tags or markers, and marking pencil
12 transparent plastic bags (Ziploc big bags, vegetable bags from the produce section, etc., as long as they allow light to penetrate)
Equipment to continue the normal irrigation and fertilizer regime (if applicable)
Scissors
Tape
Camera
Worksheet

Ever hear someone tell you to give them space? Or feel clammy in a crowded room? Sometimes too close is too much. Greenhouse plants need space as well. They need an area to grow and branch, but they also need space to increase airflow and reduce excessive moisture.

This trial will incorporate four different treatments:

1. Covered foliage completely (no air flow whatsoever)
2. Covered foliage except for the top (tightly spaced)
3. Covered substrate and lower stem (limited air flow to root system)
4. Control

Form a hypothesis: What do you think will be the outcome of this experiment? What will happen to each of our four treatments?

Outcome: ____

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Trial design and preparation

1. We are going to plan our study area using a randomization method. We will mix the sixteen potted plants, so that they are not in a uniform location. To decide the order of these plants, use a random number generator. The following website will generate the numbers on command: http://stattrek.com/Tables/Random.aspx

   What are the benefits of using a random sampling method verses examining a section of each treatment? ***Discuss.***

2. Examine selected plants for signs of stress or disease issues. Record any visual observations you have about the plants and photograph them for later comparison.

All plants prior to trial:

3. Place transparent plastic bag over three plants so that it forms a dome over the plant. Leave bags unsealed for watering purposes. This will be Treatment 1.

   Place plant in plastic bag, leaving bag open and the top of the plant exposed to air. This will be Treatment 2.

   Cut plastic and cover the substrate and lower stem. Use tape to hold this around, but do not seal the bottom plastic, as you will need access to the substrate for irrigation. This will be Treatment 3.

   Leave three plants as they are. These will be our control, Treatment 4.

4. Continue to water the plants as needed throughout this trial. Water the same way you would the rest of your crop. Remove bags if necessary during the irrigation process.

Observations

5. One to two days later, record observations. What is happening to the leaves, stems, and roots. Does it seem humid or dry? Are there any signs of stress? Also examine the plastic itself covering the plant(s). What do you notice about inside the plastic? Photograph the plants.

Treatment 1:	**Treatment 2:**
Treatment 3:	**Treatment 4:**

6. Three-four days later, record observations. What is happening to the leaves, stems, and roots. Does it seem humid or dry? Are there any signs of stress? Photograph the plants.

Treatment 1:	**Treatment 2:**
Treatment 3:	**Treatment 4:**

7. Ten days later, record observations. What is happening to the leaves, stems, and roots. Does it seem humid or dry? Are there any signs of stress? Photograph the plants.

Treatment 1:	**Treatment 2:**
Treatment 3:	**Treatment 4:**

Critical thinking:

Each treatment represents an extreme case of various environmental conditions that can occur in the greenhouse. Completely covered foliage in Treatment 2 represents a problem with air flow in the greenhouse. Treatment 3, where all of the foliage is covered save for the top of the plant, we see an exaggerated effect of poor plant spacing. Treatment 4, where the substrate and lower stems are covered, indicates a problem with air circulation near the root zone.

Were your hypotheses correct? Which ones were and which weren't? Were you surprised?

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How do the conditions in this trial differ from typical greenhouse conditions?

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Given what you have observed among these treatments, what can you say about the effects of ventilation on plant health?

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Remember, a plant's direct cause of death is not the ventilation itself, but the problems that arise with poor ventilation. For instance, mold development, the inability to photosynthesize, and root rots.

What do you propose could be done to eliminate ventilation problems within a greenhouse?

Assessment Activity 2.3: Too Wet, Too Dry

Name:_______________________________________ **Date:** ________ **Class Section:**_____

Students will be given several substrate samples and must determine the level of wet or dry.

	Sample A	Sample B
Color:		
Water visible:		
Substrate characteristics:		
Consistency:		
Squeeze result:		
Other observations:		

Using the chart and your knowledge from the Too Wet, Too Dry, how would you characterize the moisture content of Samples A and B?

Sample A: **Sample B:**

1. Dry
2. Medium Dry
3. Medium
4. Medium Wet
5. Wet

Unit two: Understanding the Greenhouse Ecosystem

2.4: Pests in the Greenhouse Ecosystem

Skill:

Identify the basic life history stages of complete and incomplete metamorphosis
Know the correlation between insects' feeding method and mouth organs
Able to calculate and graph organisms' growth rates

Outcome:

A student will be able to explain the differences between the two types of metamorphosis
Student can define ecdysis, nymph, larvae, and instar.
Graph and explain trends in data

Learning Goals Achieved:

Student is able to understand the concept of population growth
Student is able to explain why population control is important in a greenhouse environment.
Student is able to convert data to a graph format and explain trends

Key Questions:

What are the major life history stages of an insect?
What is the difference between complete and incomplete metamorphosis?
How do insects create plant damage?
How does predation effect population growth?
What factors may play a role in population growth and female fecundity?

Action Strategies:

Review Chapter 4; Hold class discussion
Insect Anatomy Lab
Insect Life History Lab
"Insect Life History" PowerPoint Presentation
Exponential Growth Activity
Illustrating Entrance Points Activity

Assessment:

Laboratory participation and any worksheets
Exponential Growth Activity
Illustrating Entrance Points Activity
Pests in the Greenhouse Quiz

Materials:

Chapter 4 text and lecture material
Selected Laboratory Exercises

Interdisciplinary Connections:

Biology
Mathematics
Statistics

External Lab Resources:

Diseases

The American Phytopathological Society (www.apsnet.org) publishes several lab activities for plant pathology. The labs require basic supplies such as worksheets, plant material, and dissecting or compound microscopes. One of which includes the inoculation of bean plants with the Tobacco Mosaic Virus. Procedures for this classroom experiment are described in the following link:

Ford, R., and Evans, T. 2003. *Tobacco mosaic virus*. *The Plant Health Instructor.* <http://www.apsnet.org/edcenter/K-12/TeachersGuide/TobaccoMosaicVirus/Pages/default.aspx>.

APS publishes another guided lab activity for water molds (Phytophthora, Pythium, and Downy Mildew). Students use different growing mediums (seeds, plant material, insects, etc.) and observe water mold formations.

Schumann, G.L. and C.A. Jasalavich. 2000. Water molds (oomycetes). *The Plant Health Instructor.* < http://www.apsnet.org/edcenter/K-12/TeachersGuide/watermold/Pages/default.aspx>.

This lab introduces students to nematodes. Students learn to mount slides and observe nematodes under the microscope

Tylka, G.L. and C.A. Jasalavich. 2001. Free-living and Plant-Parasitic Nematodes (Roundworms). *The Plant Health Instructor*. < http://www.apsnet.org/edcenter/K-12/TeachersGuide/Nematode/Pages/default.aspx>.

Insects

Have students observe the life history of milkweed bugs. Bugs can be ordered through several websites.

One option is: www.carolina.com

Step by step guide to grasshopper anatomy lab:

http://www.carolina.com/category/teacher+resources/dissection+activities+and+resources/grasshopper+dissection.do.
Grasshopper kits may be ordered through www.carolina.com

The following sites give a lab protocol that develops students' abilities to identify organisms. This lab deals with crickets, earthworms, mealworms, etc., but could be adapted to more relevant greenhouse pests.

Arthropod introduction lab:

http://serendip.brynmawr.edu/sci_edu/waldron/pdf/InvertDiversityProtocol.pdf
http://serendip.brynmawr.edu/sci_edu/waldron/pdf/InvertDiversityTeachPrep.pdf

Unit 2: The Greenhouse Ecosystem

Chapter 4

Pests in the Greenhouse Ecosystem

Sarah Kenney

Insect life history

Successful IPM programs use insect biology to select appropriate treatment options. This chapter will discuss ecology principles necessary for the understanding of the greenhouse ecosystem.

Metamorphosis refers to the transformation from one life stage to another. Insects that undergo complete metamorphosis begin as eggs, emerge as larvae, change into pupae, and develop into adult insects. In general, the adult life stage looks very different from the larval or pupal stages. Consider a moth or butterfly. It begins as a caterpillar and emerges as a winged insect. Other metamorphic insects include ladybugs (ladybird beetles) and moths.

Some insects have incomplete metamorphosis. They do not have a complete transformation, but develop gradually from egg to nymph to adult. The nymph stage resembles the adult, but may have different coloration, undeveloped wings, or different markings. Stink bugs, thrips, and grasshoppers have incomplete metamorphosis.

Developmental changes in the larval or nymph stages are referred to as **instars**. Instars are the stages between molts. Instar identification helps entomologists to determine an insect's age or maturity. Instar references include early, late, or they may correspond to the number of molts the insect undergoes (i.e. 2^{nd} instar, 4^{th} instar, 5^{th} instar).

Why do insects molt? Molting, or **ecdysis**, is the process that occurs when an arthropod sheds its exoskeleton. Ecdysis allows an insect to grow. As an insect moves into the adult stage, it nears sexual maturity. Here, the insect is capable of reproduction.

Reproductive rates are often dependent on the female's **fecundity** or the number of offspring that can be produced. Fecundity refers to the fertility or abundance of eggs created by a female. It corresponds with reproductive potential rather than actual reproductive rates. Environmental factors influence a species' fecundity rates. Humidity levels, temperature, and food availability influence the insect life cycle tremendously.

Insects are more susceptible to pesticides and biological controls at specific life stages. For instance, a scale insect is easier to control when it is in early instar or juvenile forms rather than a settled adult form.

Feeding behavior

Insects exhibit many different feeding methods. While whiteflies and aphids feed by sucking nutrients from the plant, other insects use their mandibles to chew leaves. Still others rasp or scrape the leaf surface leaving a skeletonized leaf behind. Slugs rasp foliage surfaces. Common greenhouse pests can include aphids, true bugs, caterpillars, fungus gnats, leafhoppers, leafminers, mites, mealybugs, sawflies, shoreflies, thrips, and whiteflies.

Many chemical controls take advantage of the insects' feeding habits. For example, systemic applications only affect insects when they consume treated plant material. Other chemicals stop the insect from feeding. Since insects eat more as juveniles, many treatments are more effective in the early life history stages rather than the adult stages.

Populations in a greenhouse

By definition, a population is a grop of organisms of the same species in a given area.[8] Whereas one insect may not cause much damage, a population of 2,000 insects could wreak havoc on a greenhouse crop.

Consider the whitefly. A whitefly is less than a few millimeters long, but the presence of such a tiny insect can cost growers an entire greenhouse. How do these small insects cause damage? The whitefly creates damage in two ways: by feeding and by excretion. Whiteflies puncture the leaf tissue and feed on the phloem of a plan. Phloem tissues transport sugars or sap through the plant. As the whitefly feeds, it alters the pressure by which sugars move through phloem and reduces the plant's food source. Heavy whitefly populations cause discoloration and eventual plant death if left untreated. Whitefly excrement, known as honeydew, falls to lower foliage. Sooty mold forms and slows the photosynthetic process.

Let us examine population growth of the greenhouse whitefly. A single greenhouse whitefly produces about 209 eggs when the greenhouse is 70°F.[9] If a greenhouse whitefly population had only 10 impregnated whiteflies, there could be as many as 2,090 mature adult whiteflies within a month (10 x 209). As you can see, a small population can expand rapidly.

In a landscape or natural environment, natural enemies and environmental factors restrain the whitefly survivorship rates. A whitefly population in the landscape rarely causes problems.

Rapid population growth is true for plant diseases as well. Disease can spread through air currents, water droplets, or direct plant contact. For this reason, proper plant spacing and water regimes can drastically reduce pest disease issues.

Invasive species pose an immense challenge to the horticultural industry. With few known natural enemies in the region, an invasive species can run rampant in new environments. In fact, APHIS, the United States Department of Agriculture's Animal and Plant Health Inspection Service, quarantines many insect and disease pests to prevent widespread damage in United States greenhouses. Chrysanthemum white rust is an APHIS monitored disease. A fungal

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[8] "Population" on http://wordnet.princeton.edu

[9] UMass Extension, 2009, "A Grower's guide to using biological control for silverleaf whitefly on poinsettias in the Northeast United States," *Pest Management Fact Sheets,* University of Massachusetts Extension < http://www.umass.edu/umext/floriculture/fact_sheets/pest_management/slwf.html>.

pathogen from Asia, chrysanthemum white rust could devastate chrysanthemum crops in the United States.

Summary

An uncontrolled pest can create severe economic and ecological damage to any greenhouse operation. Understanding the biology, life history, and ecology of the new species can help researchers to determine the appropriate control treatments. A pesticide or fungicide regime can most likely control an invasive species, but the adverse affects of harsher chemical treatments encourage many people to search for alternative IPM approaches.

References:

2007. "Introduction to Whiteflies." *Pest Identification and Diagnosis.* Adopted from NC State University Cooperative Extension. Regents of the University of Minnesota < http://www.entomology.umn.edu/cues/inter/inmine/Whitefa.html>.

2010. Chrysanthemum white rust. *Plant Health.* Animal and Plant Health Inspection Service <http://www.aphis.usda.gov/plant_health/plant_pest_info/cwr/index.shtml>.

Gill, S. 2005. "Whitefly Alert—New Biotype to Watch Out For in 2005." University of Maryland Extension <http://ipmnet.umd.edu/factscheets/qwhitefly.pdf>.

Hoddle, M.S. 1999. The Biology and management of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) on greenhouse grown ornamentals. University of California <http://www.biocontrol.ucr.edu/bemisia.html>.

McDonough, M.J., Gerace, D., Ascerno, M.E. 2008. Whiteflies in commercial greenhouse poinsettia production. University of Minnesota Extension. <http://www.extension.umn.edu/distribution/horticulture/dg7373.html>.

UMass Extension. 2009. A Grower's guide to using biological control for silverleaf whitefly on Poinsettias in the Northeast United States. Greenhouse Crops and Floriculture: Fact Sheets. UMass Extension <http://www.umass.edu/umext/floriculture/fact_sheets/pest_management/slwf.html>.

2.4 Assessment Rubric: Illustrating Entrance Points

Students will design (hand-draw, on computer, paint, etc.) a detailed map of the greenhouse, its benches/crops, and potential entrance points or ideal growing conditions for pests. Entrance or growing conditions should be clearly labeled.

Criteria:	Points:	Score:	Comments:
Clear map layout	10		
Identifies significant features within the greenhouse	10		
Insect vectors are labeled	5		
Disease vectors are labeled	5		
Spelling	5		
Total:	35 points		

2.4 Lab Activity
Exponential Population Growth

Description:

In this lab activity, students will learn how bacterial and insect populations expand. They will also consider influential factors such as temperature, moisture, and nutrient sources. A class discussion will address these factors and review basic ecological concepts.

Objective:

Students will calculate and graph a population's growth rate
Students will be able to understand and explain population growth
Students will discuss limiting factors in population dynamics

Skills:

Knowledge of key terms such as population and population growth rate
Ability to apply mathematical functions to a real world situation
Ability to graph and interpret data

Materials:

Worksheet
Calculator

Resources:

Microbe Multiplication Magic. *Department of Health and Human Resources: Centers for Disease Control and Prevention.* http://www.bam.gov/teachers/activities/epi_4_microbe_magic.pdf

Hoddle, M.S. 1999. The Biology and management of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) on greenhouse grown ornamentals. University of California <http://www.biocontrol.ucr.edu/bemisia.html>.

2.4 Lab Activity
Exponential Population Growth

Name:______________________________ Date: __________ Class Section: ______

Objective:

Students will calculate and graph a population's growth rate
Students will be able to understand and explain population growth
Students will discuss limiting factors in population dynamics

Materials:

Worksheet
Calculator

A **population size** is the number of organisms of a species in an area. For instance, the world population estimates the number of humans on Earth. A **population growth rate** measures the rate of change over time.

Different species reproduce at different rates. For instance, an *E. coli* population will double every 15 minutes, while a human population requires years to double.

Exponential population growth

E. coli doubles in population size every 15 minutes.

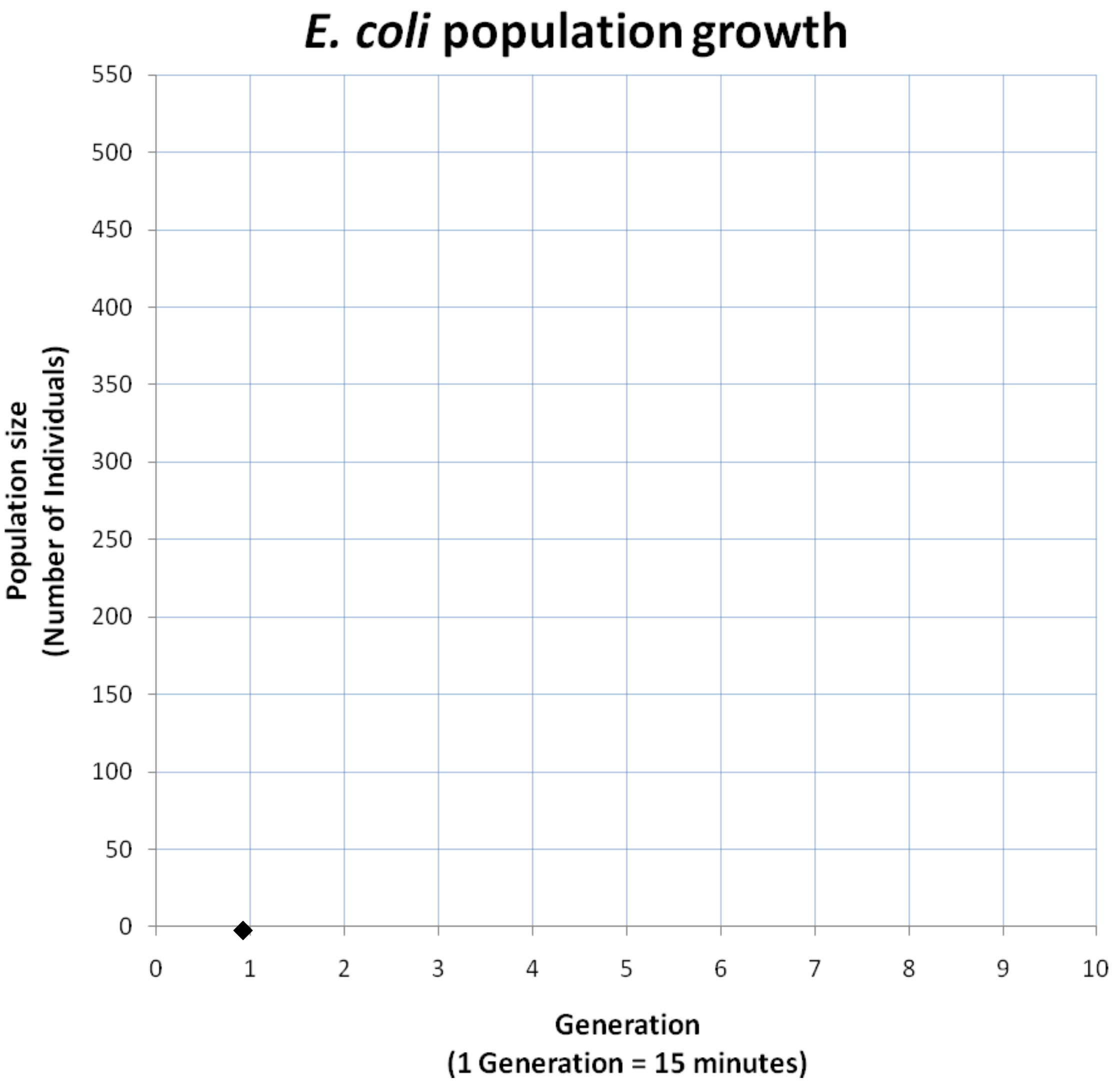
Complete the chart below:

Time (minutes)	**0**	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**
Population size (bacteria count)	**2**	**4**							

Calculate population growth again, where one generation is 15 minutes:

Generation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
# of bacteria	**2**	**4**							

Plot the values from the chart. The first point (1, 2) has been plotted for you.



The *E. coli* growth rate is an exponential function: $y = x^2$

Population size is the **dependent variable** (y-axis). It changes as the generation time changes. Generation time is the **independent variable** (x-axis). The independent variable is not influenced by the changing population.

Other factors affect population growth. For instance, low temperatures may slow growth rates. Suppose the population doubles every 30 minutes instead of every 15. After two hours, what will the population size be?

Time (hh:mm)	**0:00**	**--**	**0:30**	**--**	**1:00**	**--**	**1:30**	**--**	**2:00**

Population	**2**	**--**	**4**	**--**		**--**		**--**	

Discuss: What other factors might influence a population growth rate?

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Population growth in the greenhouse

The whitefly life cycle lasts between 30 and 170 days depending on temperature and other environmental factors. One study examined temperature changes whitefly reproduction. The table looked like this:

Strain B Whitefly:	Mean eggs laid per female	Mean days to hatch
60°F	60	46
72°F	91	17
83°F	96	10

Can you detect a trend among temperature and the number of eggs laid per female? Is temperature the dependent or independent variable?

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Temperature affected the whitefly lifespan. Higher temperatures meant that the whitefly matured at a more rapid pace and had a shorter lifespan.

For an extra challenge:
Looking at an exponential graph, it seems as though a population size will continue to expand into the millions. There is, however, a limit to population growth in the natural world. Limiting factors include: predation, food and shelter availability, temperature, humidity, disturbance, competition for resources.

A more realistic growth curve is shown below:

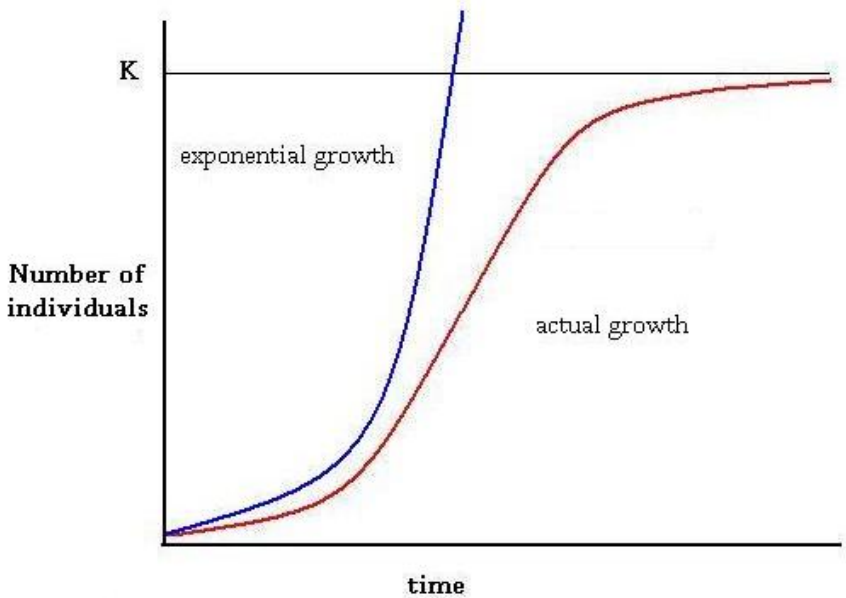

Image from: Shanholtzer, S. 2002. Population study of flour beetles. *Environmental Studies 1401*. Georgia Perimeter College. < http://facstaff.gpc.edu/~apennima/ENVS/pop_study.htm>.

A **carrying capacity** (K) is the maximum population size that can be sustained in a given environment. If the population rises above the carrying capacity, there will not be enough resources to support the population and organisms will either slow reproduction or dieback. Ecologists use the curve above ("actual growth") to describe population growth in the natural environment. As a population builds, predation may also increase. Competition for space and food can create conflict within a population as well, resulting in poor nutrition, disease, death, or emigration from an area.

Critical thinking:

If a population will stop expanding beyond the carrying capacity, why should growers treat for pests at all?

Joan is growing poinsettias in her greenhouse this winter. During her routine scouting, she notices a heavy whitefly population has continued to grow. Joan decides not to treat, hoping the population will soon crash. Two weeks later, Joan's poinsettia plants look bleached and chlorotic. The plants look horrible and she will not be able to sell them at market. What was wrong with Joan's logic and choice to avoid treatment?

Pests in the Greenhouse Quiz
2.4 Pests in the Greenhouse Ecosystem

Name:_______________________________________ **Date:** ________ **Class Section:**_____

1. ____________ transports sugars through the plant.
   a) Phloem
   b) Vacuum tubes
   c) Chloroplasts
   d) Pollen

2. The whitefly feeds by _______.
   a) chewing leaves
   b) rasping
   c) parasitizing fungus gnats
   d) sucking

3. Slugs damage plants by ___________.
   a) sucking
   b) rasping
   c) chewing
   d) transmitting viral infections

4. Fecundity refers to ____________.
   a) a plant's ability to uptake nutrients
   b) an insect's excrement patterns
   c) insect feeding patterns
   d) female reproductive capabilities

5. Incomplete metamorphosis differs from complete metamorphosis in that _______.
   a) juvenile stages appear similar to the adult stage in incomplete metamorphosis
   b) insects never reach full maturity in incomplete metamorphosis
   c) coloration and wing development is stunted in incomplete metamorphosis
   d) the insect skips instar stages in incomplete metamorphosis

6. Instars are ____________.
   a) insects more favored than others in behavioral ecology
   b) developmental stages in the larval or nymph periods
   c) stages that occur after an insect reaches sexual maturity
   d) predatory insects

7. Which of the following is NOT a stage of incomplete metamorphosis:
   a) egg
   b) nymph
   c) pupa
   d) adult

8. What is ecdysis? (2 points)

9. Explain why pest problems occur more rapidly in a greenhouse than in an open field (4 points):

10. Draw and label the four stages of complete metamorphosis for a moth. The first stage is labeled for you (7 points total):

Stage 1: **EGG**	Stage 2:
Stage 3:	Stage 4:

Unit two: Understanding the Greenhouse Ecosystem

2.5: Practical biological controls: Host species and predators

Skill:

Identify the three categories of biological control organisms
Be able to identify an organism's role in trophic relationships

Outcome:

Able to explain the differences among pathogens, parasites, and predators
Understand the implications one organism might have on another species

Learning Goals Achieved:

Students will be able to identify an organism's role in the trophic system
Students will be able to understand the ecological dependencies from one species to another.
Students will be able to recognize the differences among pathogens, parasites, and predators.
Students will be able to explain how a pest species can be affected by biological controls.

Key Questions:

What is the difference between a specialist and a generalist?
What is different between the greenhouse environment and the natural environment?
How can a predator affect a pest population?
How can a parasite affect a pest population?
How can a pathogen affect a pest population?
With which organism might a grower see faster results? (predator, pathogen, parasite)

Action Strategies:

Review Chapter 5; Hold class discussion
Trophic Relationships Project
Biological Controls PowerPoint

Assessment:

Trophic Relationships Project
Assessment on "Biological Controls"

Materials:

Text or lecture materials
"Biological Controls" Power Point

Interdisciplinary Connections:

Biology and Ecology

Unit 2: The Greenhouse Ecosystem

Chapter 5

Practical Controls: Host Species and Predators

Sarah Kenney

The greenhouse provides ideal living conditions for insects and mites: an enormous food supply, unobstructed access to plant material, and protection from natural enemies and weather patterns. In human terms, a greenhouse offers a free hotel room and an all-you-can-eat buffet. The same is true for diseases. The greenhouse environment consists of close standing plant material where moisture and bacteria buildup is common.

A **biological control** is the use of one organism or species to regulate or control the population of another.[10] In an IPM program, predators, parasites, or pathogens are released to feed on or parasitize the pest population.

Just as in nature, the introduction of natural enemies can help to control pest populations. In fact, one study found that a single wasp could kill approximately 95 greenhouse whitefly nymphs in its lifetime.[11] Knowing this, a grower could introduce a high volume of parasitic wasps in a greenhouse to control the pest.

Biological controls can lead to excellent control regimes. They can eliminate the need to apply pesticides. These strategies take natural ecological relationships (such as a ladybird beetle feeding on aphids) and intensify the population density of the biological control organism to reduce a pest population within the greenhouse. Biological controls are most effective when applied to an early pest population and used in combination with intelligent research and species selection. As with any trial in the natural environment, unexpected results can occur. Timing and environmental factors can influence the viability of an application and overall results, thus extensive research and planning must be done in order to have an effective biological control program.

Predators

A predator lives by feeding on another organism.[12] Predators can be host-specific (specialists), or they can be generalists. A specialist typically has a narrow range of food species, while a generalist will feed on a variety of species. Within a greenhouse, predators can include ladybird beetles, lacewings, some mites, beetles, bugs, and midges. A few predators, such as spiders, are generalists and eat a variety of insects, while others have a more narrowed feeding range, such as ladybird beetles.

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[10] Orr, D., S. Bambara, and J. Baker. 2006. "Biological Pest Control: An Introduction." Biological Control Information Center. *North Carolina State University*. <http://cipm.ncsu.edu/ent/biocontrol/>

[11] UMass Extension. 2009. "A Grower's Guide to Using Biological Control for Silverleaf Whitefly on Poinsettias in the Northeast United States." Pest Management Fact Sheets. University of Massachusetts Extension <
http://www.umass.edu/umext/floriculture/fact_sheets/pest_management/slwf.html>.

[12] "Predator" on http://wordnet.princeton.edu

Parasites

A parasite is an organism that lives in or on another organism, using the host organism as a food and habitat source.[13] Parasites are specialists and feed on a host species. In many cases, the host organism dies as the parasite feeds and grows. A parasitoid deposits its eggs in or on another organism. The eggs and larvae use the host insect as a habitat and food source before they emerge from the carcass. Common parasites include a variety of wasps and flies. Parasites play a key role in controlling natural populations of caterpillars, aphids, and other plant pests.

Host specific predation is an important concept when dealing with biological controls. The parasitic wasp *Aphidius colemani* parasitizes green peach aphids and melon aphids, but has little effect on potato aphids. Using this information, a grower needs to consider the pest species (in this case, the species of aphid) and the available parasitoids in order to obtain optimal control.[14]

Pathogens

Pathogens are another form of biological control. A disease-producing agent, pathogens can be microorganisms or viruses.[15] Pathogens are microorganisms that cause disease and eventual death within the pest population. Microorganisms including virus, bacteria, fungus, or nematodes can sicken and eventually kill a greenhouse pest. *Bacillus thuringiensis (Bt)* is a common bacterial control against caterpillars.

While some nematodes can be pests to a crop, entomopathogenic nematodes are parasitic—they release pathogens and can help reduce a pest population. University of Maryland Extension worked on a biological control trial for fungus gnat populations using entomopathogenic nematodes. In this trial, nematodes (or roundworms) were applied to limit the growth of the fungus gnat population.[16]

Summary

Although pest populations can build quickly, horticulturalists can manipulate nature to their benefit. Understanding species-specific interactions can lead to a successful biological control program. Predators, parasites, and pathogens will reduce pest populations and is a safe alternative to the use of pesticides.

References:

UMass Extension. 2009. A Grower's Guide to Using Biological Control for Silverleaf Whitefly on Poinsettias in the Northeast United States. Fact Sheets. University of Massachusetts Extension <http://www.umass.edu/umext/floriculture/fact_sheets/pest_management/slwf.html>.

Orr, D., S. Bambara, and J. Baker. 2006. "Biological Pest Control: An Introduction." Biological Control Information Center. *North Carolina State University*. <http://cipm.ncsu.edu/ent/biocontrol/>

[13] "Parasite" on http://wordnet.princeton.edu

[14] Gill, S. 2010. "Biological Control of Aphids Using Banker Plants."University of Maryland Extension. <http://ipmnet.umd.edu/research/docs/BankerPlantsforAphids-UMD.pdf>.

[15] "Pathogen" on http://wordnet.princeton.edu

[16] Gill, S. 2010. "Biological Control of Aphids Using Banker Plants."University of Maryland Extension. <http://ipmnet.umd.edu/research/docs/BankerPlantsforAphids-UMD.pdf>.

2.5 Assessment Rubric: Host Species and Predators

Trophic relationships

Student will use a variety of media to illustrate ecosystem interactions among three trophic levels. Student will be assigned a top-down predator or a bottom-up species and will demonstrate the interaction between the levels.

With this project, students will:

- Identify a species in each trophic level.
- Demonstrate their habitat (ie- live on substrate, fly, crawl, etc.)
- Demonstrate the trophic relationship (ie- is this a disease that suffocates the root system? Is this a bird that eats the insect?)
- Demonstrate creativity in their projects using shadowboxes, dioramas, animation, posters, or other media deemed appropriate.

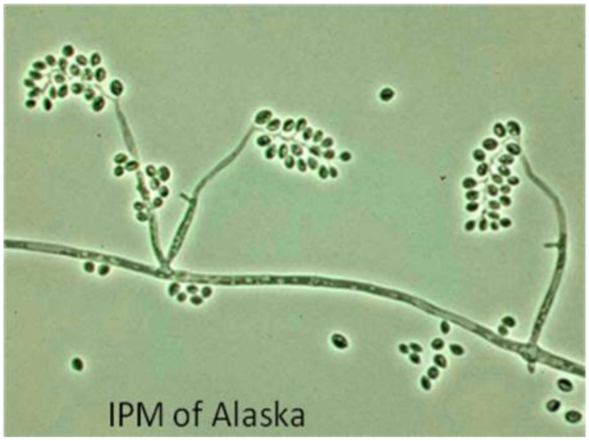
Criteria:	Points:	Score:	Comments:
Identifies at least three species	10		
The levels or order of predation is clear	10		
Each species' habitat and other characteristics are apparent	10		
Identifies the means of predation	10		
Creativity and clarity	10		
Total:	50		

2.5 Assessment Activity
Biological Controls PowerPoint

Name: ______________________________________ **Date:** ________ **Class Section:** _____

Match the term or description to the picture.

Parasitoid Pathogen Predator



________________________________ ____________________________________

____

What kind of biological control do you think killed this aphid?

Is the praying mantis a specialist or generalist?

What would happen to a ladybird beetle (ladybug) population if there were more ladybird beetles than aphids?

Cal has two cats that live in his barn. They help to keep his rodent population to a minimum. Are his cats functioning as predators, parasites, or pathogens? Explain.

Unit 3: Interdisciplinary IPM
3.6: Greenhouse Management Policies

Skill:

Identify the major laws and requirements that deal with pest management
Read and comprehend technical documents relating to pesticides
Convert pertinent measuring units of temperature, mass, volume, and calculating area

Outcome:

Recognize major pesticide regulations and their impacts
Interpret a Material Safety Data Sheet and Specimen Label

Learning Goals Achieved:

Students will be able to read and interpret complex documents
Students will be able to interpret labels and prepare applications
Students will be able to explain the importance of regulatory standards and worker safety
Students will be able to discuss the impacts of invasive species on the environment.

Key Questions:

How do state and federal laws influence pest management practices?
Why are the Worker Protection Standard Procedures and other safety requirements important?
What is a restricted use pesticide and why are restrictions in place?

Action Strategies:

Review content of Chapter 6; Hold class discussion
"Learning Conversions," "Calculating Volume and Area," Label and MSDS Activities
"Personal Protective Equipment" and "Safe Pesticide and Fertilizer Storage" PowerPoints
IPM Legislation Research project and presentation

Assessments:

IPM Legislation Research Project
How to Read a Pesticide Label and Understanding a MSDS Activities
Learning Conversions Activity; Calculating Volume and Area Activity
"Personal Protective Equipment" and "Safe Pesticide and Fertilizer Storage" Assessments
Pesticide Regulations Quiz

Materials:

Text, Power Point Presentations, Labels and documents for assessments

Interdisciplinary Connections:

Political Science, Environmental Science, Mathematics, and Human Health

Unit 3: Interdisciplinary IPM

Chapter 6

Greenhouse Management Policies

Sarah Kenney

Running a greenhouse operation requires more than a horticulture degree or experience in propagation. Policies concerning nutrient management, plant material, and pesticide applications also affect greenhouse operations. Non-profit organizations and government agencies such as the Maryland Nursery and Landscape Association (MNLA), the Maryland Greenhouse Growers Association (MGGA), Maryland Department of Agriculture (MDA), and University of Maryland Extension (UME) can help to bridge the gap between policies, regulations, and industry standards. The following unit discusses policies, regulations, and decisions that affect a horticultural pest control program.

Pesticide Regulations

Environmental regulations are mandated by the federal government through the U.S. Environmental Protection Agency (EPA). The EPA protects both human health and the environment.

Several federal laws regulate pesticides. The primary law is the Federal Insecticide, Fungicide, and Rodent Act (FIFRA) which establishes the framework to regulate the sale, distribution, and use of pesticides within the United States. Products must be registered with the EPA and meet EPA safety regulations. The Food Quality Protection Act (FQPA) of 1996 established a single, health based standard to be used when determining risks of pesticide residues to food and feed. These safety standards take into consideration the total dietary exposure and other non-occupational sources of exposure. The law restricted many pesticides that were commonly used in agricultural production, as well as pesticides used by horticultural and structural pest control industries. The Endangered Species Act also impacts pesticide application procedures.

Pesticides are also regulated on the state level; in Maryland, the Maryland Department of Agriculture (MDA) is the agency responsible for regulating the sale, distribution, and use of pesticides within Maryland. These laws include the Maryland Pesticide Applicators Law, Integrated Pest Management, and Notification of Pesticide Use in a Public School Building or on School Grounds Law. The states have signed agreements with the U.S. EPA where states will also enforce the federal laws on behalf of EPA along with the state laws within each respective state. State laws can be more stringent than federal laws, and most are, but they cannot be more lenient. Like the federal pesticide laws, state pesticide laws and regulations work to protect human health and the environment.

Maryland applicator certificates and licenses include private applicator certificates, commercial pesticide certificates, business licenses, pest control consultant licenses and certificates, “not-for-hire” licenses, and applicator certificates. A licensed pesticide business must employ a certified applicator, have liability insurance, and pay an annual fee. Applicators seeking certification as a

Private applicator must pass an exam administered by MDA, while individuals seeking certification as a commercial applicator must also satisfy some initial experience and/or educational requirements in addition to passing the exam. Certifications and licenses must be renewed periodically. For commercial applicators, this means training and recertification every year, while a private applicator (ie- the greenhouse operation owner or employee) must renew his or her certificate every three years.

When reading about pesticides, you may hear the term “biorational.” Biorational is a loose term used to define pesticides with low toxicity and little ecological impacts. These chemicals are often less caustic and require fewer safety precautions than other pesticides. They include plant-derived pesticides, biological or microbial pesticides, mineral applications, and some synthetic or man-made substances.[17] Example biorationals can include insecticidal soap, neem oil products, and bacterial sprays such as *Bacillus thuringiensis*.

Reduced-risk pesticides are non-biological pesticides that pose less human and environmental health risks than other conventional pesticides. Reduced-risk pesticides tend to lack neurotoxins, carcinogens, and other harmful chemical properties, and their registration process is often much faster than those of conventional and highly toxic pesticides. IPM plans often recommend mixtures of biorational, reduced-risk, and conventional pesticides. Very rarely will an IPM program recommend a Restricted Use pesticide, however.

Pesticides are classified as either “General Use” or “Restricted Use.” A General Use pesticide can be purchased and used by the general public while Restricted Use pesticides have more stringent regulations. Restricted use pesticides are often more toxic to humans or wildlife or have special environmental concerns when not properly used. Potential human and environmental health issues include toxicity to humans or toxicity to fish and birds. Restricted use pesticides can only be sold and used by a certified applicator or someone under the certified applicator’s direct supervision. A dealer permit must be obtained in order to sell or distribute restricted use pesticides. For the most part, restricted use pesticides are not recommended in IPM plans, but are occasionally used when lighter materials are ineffective against a pest.

Storage and Disposal

Improper pesticide storage can lead to spills, environmental contamination, or even a fire. Pesticides must be stored in a dry and secure area separate from living or working spaces. Pesticide containers must be clearly labeled and in good condition. If pesticides are stored in a container other than the original container, commonly referred to as a service container, it should be identified with the trade name, common or chemical name, EPA registration number, and the percent concentration. Pesticides should never be stored in food or beverage containers. Empty containers cannot be reused for any purpose. After a container is empty it must be disposed of according to label directions.

Notification

[17] Vern Grubinger. “Biorational pesticides.” *University of Vermont Extension* <http://www.uvm.edu/vtvegandberry/factsheets/biorationals.html>.

The state of Maryland also requires a warning via sign or poster to inform the public of potential hazards for certain applications. The sign must include the application date, name of licensee, and contact information. It must remain visible for 48 hours following an application.

Employee/Worker safety

Workers who come into contact with pesticides need to be trained in basic pesticide safety. Training includes the ability to understand a pesticide label; to recognize health related symptoms from pesticide exposure; to understand personal protective equipment (PPE) requirements and proper use; and how to administer proper first aid.

The minimum personal protective equipment (PPE) requirements vary from product to product and are listed on each pesticide label. The appropriate PPE for each pesticide is based on the product's toxicity, chemical makeup, formulation, and the route of exposure to the body. PPE includes the clothes, gear, and coverings that help to protect an individual from chemical or physical hazards. PPE can include gloves, vests, goggles, masks, boots, specific clothing, and hardhats. PPE requirements apply to many industries that include manufacturing, tree care, medical research, and pest control. In general, a horticulturalist must wear PPE when applying pesticides. Personal protective equipment (PPE) requirements are listed on each pesticide label and correspond to the toxicity and volatility of the chemical. This means that a restricted use pesticide with a signal word of Danger or Danger Poison will generally require more protective equipment than a product with the signal word Caution, such as horticultural oil. The PPE requirements differ according to each chemical, so careful examination of a pesticide label and MSDS are integral to human safety. In general, most pesticides require the minimum PPE of a long-sleeved shirt, long pants, socks, and shoes.

Employees of commercial businesses or public agencies that handle pesticides make pest control recommendations, or conduct pest control sales must complete an approved training program that includes: pesticide laws and regulations, label comprehension, safety and emergency procedures, proper pesticide handling and storage, pest identification and control recommendations, pesticide application techniques, environmental and health concerns, and integrated pest management principles.

Under the EPA's federal Worker Protection Standard (WPS) owners of agricultural operations such as, farms, forests, nurseries and greenhouses are required to provide safety training to agricultural workers who may come into contact with pesticides, or pesticide residues, as part of their job in order to reduce their risk to pesticide poisoning, injuries or exposure. Similarly, pesticide handlers who mix, load and apply pesticides at agricultural operations must also receive pesticide safety training. The WPS requires that workers be notified about areas that have been treated with a pesticide recently and that a sign be posted in a central and visible place in the treated area.

Material Safety Data Sheets (MSDS) are required by the Department of Labor under the Occupational Health and Safety Administration's (OSHA) Hazard Communication Standard. This regulation requires that an MSDS is made available to workers in manufacturing or to applicators using the concentrated product. The MSDS provides detailed information about the product's physical and chemical properties, such as the composition, environmental hazards, toxicology, precautions, and first aid procedures. Unlike pesticide labels, there is no standard form for an MSDS. The MSDS should never be used in place of a pesticide label.

Recordkeeping

The state of Maryland requires that pesticide application records for both general and restricted use pesticides, along with pest inspection records, be maintained for two years. This includes information such as the name of applicator/consultant, date, target pest or pest identification, crop or site treated, total area, owner and address of property, trade or common name and EPA registration number of the applied pesticide, rate and concentration, total amount applied, equipment used, weather conditions, and time of day. Maryland's biggest enforcement violation is the failure to maintain complete application, or inspection records. Keeping meticulous records may not seem important, but thorough records also provides valuable information in the case of legal actions, in determining the effectiveness of an application, and in making decisions in regards to integrated pest management programs.

Plant Material Control

The United States Department of Agriculture (USDA) conducts research, produces publications, and regulates the movement of noxious or invasive species. The Animal and Plant Health Inspection Service (APHIS) performs regular inspections of imported materials to keep foreign pests from the United States. Their website lists recent quarantines, importation problems, and other news stories relevant to plant and animal control.

Maryland also has several regulations that deal with invasive species. The Maryland Weed Control Law requires landowners to control noxious weeds such as thistle and Johnson grass. Control of these weeds is accomplished through an integrated pest management program. Maryland law also prohibits anyone from selling invasive weeds. The state requires an annual inspection of plant material at nurseries, greenhouses, garden centers, and chain stores by MDA for harmful plant diseases or pests.

MDA is also involved with the development, management, and evaluation of biological and IPM programs for controlling insect and weed pests. Insect pest species include Mexican bean beetle, Colorado potato beetle, and corn earworm. Weeds include various thistles, multiflora rose, hedge bindweed, and phragmites. Various species of insects are reared to support pest suppression, rearing, establishment, or evaluation programs in biological control.

Nutrient Management

The Water Quality Improvement Act (WQIA) came into law after the *Pfiesteria* outbreaks of the 1990s to protect human health and water resources. The algae were blamed for fish kills and alleged human health issues. Water quality improvement became a major political concern because increased nutrients are directly connected to algal development.

Maryland’s WQIA falls under the jurisdiction of MDA and requires agricultural operations that make more than $2500 a year to submit a nutrient management plan that addresses both nitrogen and phosphorus. This legislation represented a shift from voluntary nutrient management programs to mandated practices in Maryland and provides both short and long term strategies for reducing nutrient loads in streams, rivers, and the Chesapeake Bay.

Summary
A successful horticulturalist must have an understanding of current pest control policies, safety precautions, laws, and regulations. The ramifications of improper pesticide use, storage, or recordkeeping can be costly, both in terms of fines and in terms of worker safety and crop health. There are, of course, many other laws and regulations that pertain to greenhouse operations that were not discussed in this chapter. Contact your local extension office for more information.

Key Terms:
APHIS, MSDS, restricted use pesticide, specimen label, Water Quality Improvement Act

Resources:
Department of Entomology. 2010. Pesticide education and assessment program. University of Maryland <http://www.pesticide.umd.edu/>.

Environmental Protection Agency. 2010. Pesticides <http://www.epa.gov/pesticides/regulating/laws.htm>.

University of Maryland Extension. Pesticide Information Leaflets. <http://www.entmclasses.umd.edu/peap/leaflets/PIL2.pdf >.

University of Maryland Extension. 2011. Total crop management for greenhouse production, Bulletin 363 <http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

Whitford, F., Gunter, D., Contino, J., Doucette, R., Ambler, B., and Castleman, J. 2001. Pesticides and Material Safety Data Sheets: An Introduction the hazard communication standard. Purdue Pesticide Programs, Purdue University Cooperative Extension Service <http://www.ppp.purdue.edu/Pubs/PPP-37.pdf>.

Additional Resources/Discussions: the *Pfiesteria* crisis and WQIA. Article explaining the link between the Bay and environmental legislation: http://www.joe.org/joe/2006october/a3.php

3.6 Assessment Rubric: IPM Legislation

Understanding legislation

The student will research a pesticide- or IPM- based law (federal or state) and report on the legislation in a 2-3 page response.

The report should include:

- The title of the law
- What the law does
- Who proposed and favored the law?
- Who opposed the law?
- Why was this law proposed? For instance, what event, issue, or situation led to its proposal?
- Why is this law important?
- What impacts does it have on the horticulture industry?

Criteria:	Points:	Score:	Comments:
Identifies the law and its purpose	5		
Proponents and opponents of the law are clearly distinguished	10		
Background history of the law or debate is presented	5		
Explains the importance of the law and its implications on the horticulture industry	10		
Demonstrates an understanding of the complexities of the law	5		
Demonstrates effective written communication skills	15		
Total:	50		

Assessment Activity 3.6:
Reading the Pesticide Label

Name:_______________________________________ **Date:** ________ **Class Section:**_____

While pesticide applications will rarely occur in a high school greenhouse, pesticides are used in the commercial horticultural industry for controlling insects, mites, diseases, and weeds. By both federal and state law, a pesticide is defined as a product or mixture of products intended to prevent, destroy, repel, or mitigate unwanted living organisms; pesticides include insecticides, fungicides, herbicides, rodenticides, bactericides, and disinfectants. In addition, plant growth regulators, repellants, desiccants, and defoliants are also classified as pesticides under both federal and state law. Any grower, applicator, or IPM scout needs to have an understanding of the state and federal regulations, safety precautions, and chemical application methods for the pesticides they use or recommend. Labels are a legal document and must meet standards required by the EPA. Labels provide directions on how to mix, apply, store and dispose of the pesticide product, Material Safety Data Sheets are provided by the manufacturer and provides information on the chemical properties, toxicity, first aid procedures, personal protective equipment, hazards and emergency procedures in the event of a spill, leak, fire, or accident while transporting the product. Remember, there are federal regulations as well as state regulations concerning the use of pesticides. It is important to consult your local extension office to help in selecting an appropriate, effective, and low toxicity pesticide. Your extension office can also help to explain the proper handling and application methods.

This activity will help you to interpret and understand the technical information listed on an EPA-approved pesticide label. Use the label provided by your teacher to answer the following questions:

Identifying the Product

Examine the front page of the label. What is the product's trade name? A trade name refers to the company or brand name, rather than the active ingredient.

Growers may choose a generic brand of a product, thus it is important to know and understand a product's common name or active ingredient. What is the product's common name?

What is the percent of active ingredient?

What percent of the pesticide's ingredients are inert or inactive?

Now add the percent active ingredient and percent inert ingredients together. The active and inert ingredients should equal 100%.

Each pesticide product has a word designation on its label called a "signal word." The "signal word" indicates how toxic a product may be to humans based on a single exposure or acute toxicity. Note the signal word on the label and see if it lists "Caution," "Warning," "Danger," or "Danger-Poison." The degree of toxicity increases from Caution to Warning then Danger and finally Danger-Poison. A "Caution" indicates that it is a generally lower risk pesticide, while a "Danger-Poison" signal word indicates that it is highly toxic. All pesticide labels must carry a statement to keep the product out of reach from children.

All pesticides are classified as either "General Use" or "Restricted Use". Those products classified as "General Use" can be purchased and used by the general public. Some pesticides have special concerns regarding their use. Restricted Use pesticides can only be used by a certified applicator, or someone under their direct supervision. These products will have a prominent statement in bold stating "Restricted Use Pesticide" and a listing of the reason it is classified as restricted use.

What is this label's signal word?

Does it have a restricted use classification? If so, why is it classified as a Restricted Use Pesticide?

On the label you can also find two EPA numbers: EPA Registration No. and the EPA Establishment No. The EPA Registration Number indicates the product number assigned by EPA when the pesticide was originally registered. Each pesticide product has its own unique registration number. The Establishment Number indicates the location where the pesticide was manufactured. For instance, 14774-FL-07 refers to a manufacturing plant in Florida by a company called JMS Flower Farms, Inc. If the number were to contain "CHN," the product was manufactured in China.

What is this product's EPA Registration Number? ___________________________________

Where do you think this product was manufactured?

____

____

The manufacturing location is not always the same as the company's office location. As you read the label, you will find the company's address.

Where is this company's corporate headquarters or main office located?

____

____

____

Precautionary Statements.

All pesticide labels contain additional statements to help the applicator determine what precautions must be taken to protect them self, other persons and animals from exposure. This includes statements indicating how it can come in contact with the body and the hazards associated with the exposure. They also will list the personal protective equipment that should be used along with other safety procedures.

What protective equipment or clothing should an applicator wear when applying this pesticide?

____

____

Directions, Application Information, and/or Mixing Instructions.

All pesticide labels have directions that provide information for using the product. These instructions include a listing of crop, animal or site on which the product can be used, the pests it will control, how to properly mix the product, how much to apply (rate) and when, possible damage its use may have to desirable plants, and other special restrictions or precautions regarding its use. A pesticide cannot be sprayed onto a plant unless it has been adjusted to the proper application rate. The application rate is established to give efficient and effective control and coverage, to avoid plant burn, and to comply with EPA regulations. Pestiicdes should never be applied at higher or lower rates than those listed on the label. Applications may also be dependent on weather, time of day, and plant life stages; therefore, it is important to read the label instructions carefully.

Class Discussion: Why shouldn't you apply more or less than the recommended rates? What are possible reasons for this regulation?

REI is the restricted entry interval. This is the time period in which no one can enter the treated area following a pesticide application. REIs are based off the pesticide's toxicity. Which pesticide do you think is safer, one with an REI of 24 hours or one with an REI of 8 hours? Why?

____

____

Information on the Worker Protection Standard is found under the heading "Agricultural Use Requirements." What is the REI for this product?

____

Pests and Crops

The label will list sites or locations and crops where the product can be applied. These sites and crops are the ONLY place that the pesticide can be legally applied. To apply a pesticide to a specific crop, you must ensure that the product is labeled for use on that crop. For instance, many pesticides labeled for use on ornamental landscape plants are not labeled for use in greenhouses.

Is this product labeled for use on food crops?

___

What is the recommended application rate for treating whiteflies in a greenhouse? Can it be used to treat spider mites as well? If so, what rate?

___

___

On what sites and crops can this product be applied? (List up to ten)

___

___

___

For more information, visit the EPA's website: www.epa.gov/pesticides/

Assessment Activity 3.6:
Understanding a Material Safety Data Sheet

Name:______________________________________ **Date:** ________ **Class Section:**_____

To complete this assessment, you will need a Material Safety Data Sheet and notes from lecture.

1. What agency or administration mandates that a Material Safety Data Sheet be provided to workers manufacturing or handling a pesticide product?

____

2. Can this product be stored below freezing?

____

3. Does this product list any hazardous ingredients?

____

4. Describe the appearance, odor, and physical state of this product:

____

____

5. What are the potential health effects from chronic skin contact?

____

____

6. Describe the emergency first aid measures to be taken if an individual swallows this product:

____

____

____

____

7. What are the skin protection requirements?

____

8. What are the ventilation requirements?

____

9. Describe the spill procedures:

____

____

____

____

10. Given what you know from this Material Safety Data Sheet, is there a connection between this chemical and environmental degradation? Explain why or why not.

____

____

____

Assessment Activity 3.6
Learning Conversions

Description:

This activity introduces the student to basic mathematical conversions necessary in the IPM field. They will utilize basic mathematics skills such as multiplication and division to determine unit conversions from the American to SI system.

Objective:

Students will understand the necessity of detail-oriented procedures.
Students can explain why conversion skills are important.

Skills:

Ability to perform basic conversions and to determine the quantity of materials needed based on label rates as well as surface area and temperatures.

Materials:

Worksheet
Pencil
Calculator

Assessment Activity 3.6: Learning Conversions

Temperature Measurements

Name: ______________________________________ Date: ____________ Class Section: _______

Objective:

Students will understand the necessity of detail-oriented procedures.
Students can explain why conversion skills are important.

Materials:

Worksheet
Pencil
Calculator

Introduction:

Calculations and conversions play an integral role in greenhouse plant production. Whether you are making assessments on hand irrigation efficiency, determining fertilizer rates, setting up sticky cards, glazing the greenhouse, or preparing for a pesticide application, the ability to calculate and convert temperature, area, mass, and volume are invaluable.

Imagine the ramifications if Brian the grower accidentally tripled his fertilizer rate. While plants may grow dramatically, burn and poor uptake rates could result from the increase in soluble salts and micronutrients.

Think of the problems that would ensue if Suzie adjusted the greenhouse temperature to 50 degrees Celsius rather than 50 degrees Fahrenheit. Her poinsettia crop will not make it to November.

What if Joel measured an insecticide rate for 1,000 square feet but applied it to 10,000 square feet of plant material? The low concentration and coverage would only weaken an insect population and could aid in resistance-development in his whitefly or thrips population.

This activity, "Learning Conversions," is fairly extensive and will introduce you to various conversion and calculation processes that horticulturalists and pest control applicators face in their day-to-day activities.

Conversions
America, Great Britain, and a few other nations operate under the American or English measurement system while a majority of the world uses the metric system or SI (Le Système Internationale d'Unités). In an increasingly globalized world, we must be able to convert between the two systems. Whether performing a cost-benefit analysis, finding fertilizer rates, measuring potting soil, or monitoring the DIF (temperature change from day to night), growers use math continuously throughout the day. Because there are so many different ways to quantify substances, one must understand and be able to apply basic mathematical conversions. The following exercises will familiarize the student with applicable conversions.

Show your work on each exercise!

Temperature
Celsius, Kelvin, and Fahrenheit measure temperature or thermal energy. Americans use Fahrenheit, but the scientific community often uses Celsius or Kelvin.

To convert Fahrenheit (F) to Celsius (C), use the following equation:

$$y°F = (9/5)x°C + 32$$

To reverse this, or to solve for Celsius, you would use this equation:

$$y°C = (5/9)x°F – 17.78$$

To convert Celsius to Kelvin (K), simply add 273:

$$y°K = x°C + 273$$

If it is 10 degrees Celsius, what is the temperature in degrees Fahrenheit?

$y°F = 9/5 (10) + 32$
$9/5 (10) + 32 = 50 °F$

Exercise 1:
It is 75 °F in the greenhouse. What is the degree Celsius?

What is the temperature in Kelvins?

The new crop of poinsettias needs temperatures between 60 and 70 °F. Charlie's greenhouse is registering at 14 °C. Does he need to change the temperature for his poinsettias? Show your work.

Make the following conversions:

16°C = ______ °F

65°F = ______ °C

25°C = ______ °F

32°F = ______ °C

289°K = ______ °C

265°K = ______ °C

Assessment Activity 3.6: Learning Conversions

Mass Measurements

Name: ______________________________________ Date: ____________ Class Section: _______

Mass

Metric conversions
The metric system is based on units of 10. Standard prefixes can be applied to measures of length, mass, and volume. For instance, 1 meter contains 10 decimeters, 100 centimeters, or 1,000 millimeters. That same meter is equivalent to 0.1 dekameters, 0.01 hectometers, and 0.001 kilometers. In reverse, 1 kilometer is equal to 1,000 meters and 1,000,000 millimeters. The following table shows metric prefixes and unit equivalents.

Kilo	Hecto	Deka	Unit	Deci	Centi	Milli
1000	100	10	1	0.1	0.01	0.001

Mass is measured in grams. When given a mass in kilograms, simply multiply by 1,000 to achieve the grams equivalent. When given the mass in grams, simply divide by 1,000 to have the kilogram equivalent.

Example:

0.054 mg = ___ g
0.054mg × 1,000 = 54 g

1.5 kg = ___ g
1.5 kg × 1,000 = 1500 g

Pounds and ounces
The English system requires a little more mathematics when converting.
One pound equals 16 ounces and one ton equals 2,000 pounds or 32,000 ounces.

$\frac{x \text{ oz.}}{16 \text{ oz.}} = \frac{0.5 \text{ lb.}}{1 \text{ lb.}}$

Cross multiply and you have:
x = (16) × (0.5) = 8 8 ounces = 0.5 lb.

$\frac{7.5 \text{ oz.}}{16 \text{ oz.}} = \frac{x \text{ lb.}}{1 \text{ lb.}}$

Cross multiply and you have:
(16) × (x) = (7.5) x = (7.5) ÷ (16) x = 0.47 lb.

For a shortcut, remember: when given units in pounds, simply multiply by 16 and you will have the ounce equivalent. When given ounces, simply divide by 16 and you will have the pound equivalent.

Example:

0.75 lb. = (0.75) × (16) = 12 oz. 13 oz. = (13) ÷ (16) = 0.81 lb.

Grams and ounces

How do you convert the metric gram to the American or English ounce?

1 gram is equal to 0.03527 ounces.

Multiply by a factor of 0.03527. 1g = 0.03527 oz.

(1)g × (0.03527) = 0.03527 oz.

Example:

A label calls for no more than 310 grams of product per acre. John has been using ounces all season. What is the maximum amount (in ounces) that John can apply per acre?

$$\frac{310 \text{ g}}{1 \text{ g}} = \frac{x \text{ oz.}}{0.03527 \text{ oz.}}$$

310 × 0.03527 = x oz. x = 10.93 ounces

If you want to convert ounces to grams, multiply the ounces by a factor of 28.3495.

1 oz. = 28.3495 grams

Example:

Your mixture weighs 8oz. How many grams does it weigh?

8oz. × 28.3495 = ___ g 226.8 grams

Make the following conversions:

17 g = _____ oz.

1.5 oz. = ______ g

651 g = ____ oz.

31 g = _____ mg

1.5 lbs. = ______ oz.

283 g = ____ oz.

17 oz. = _____ g

3.2 oz. = ______ lbs.

170 g = ____ kg

Challenge:

32 oz. = ____ kg

Assessment Activity 3.6: Learning Conversions

Volume Conversions

Name: ______________________________________ Date: ____________ Class Section: _______

Volume Conversions

Ounces and milliliters
When dealing with pesticide applications, conversions between ounces (fluid) and mL are often necessary.

To convert ounces to mL, you must multiply by a factor of approximately 29.57.

1 oz. = 29.5735 mL

For example, if the application rate calls for 18 ounces of solution per plant, you would need to multiply 18 by the conversion factor.

18 oz. = x mL (18) × (29.57) = x mL 18 oz. = 532.3 mL

Suppose your directions are given in mL, but you only have measuring tools in ounces. You will need to convert the mL application rate to ounces. To do so, multiply milliliters by the conversion rate (0.0338).

1 mL = 0.0338 oz.

If an application requires 15 mL to be mixed in 1 L of water, you need to multiply mL by 0.0338

(15) × (0.0338) 15 mL = 0.51 oz.

Make the following conversions:

34 mL = ____ oz.	2.3 oz = _____ mL	28 mL = ______ oz.
17 mL = ____ oz.	13 oz = _____ mL	1 L = ______ oz.
473 mL = ____ oz.	473 mL = _____ lbs.	5 mL = ______ oz.

Assessment Activity 3.6: Volume and Area

Calculating Volume and Area

Name: ____ Date: _____________ Class Section: _______

Area

Area is the measurement of a two-dimensional surface within an enclosed boundary (ie- a square foot). The units of measurement may differ depending on the area of interest, but the concept remains the same. For instance, the area of a football field is often expressed in yards (including the end zones, a football field is 6400 square yards: 120 yards long by 53⅓ yards wide).

Volume is a measure of how much space a three-dimensional object occupies. It is commonly expressed in terms of mL, cm^3, in^3, and ft^3.

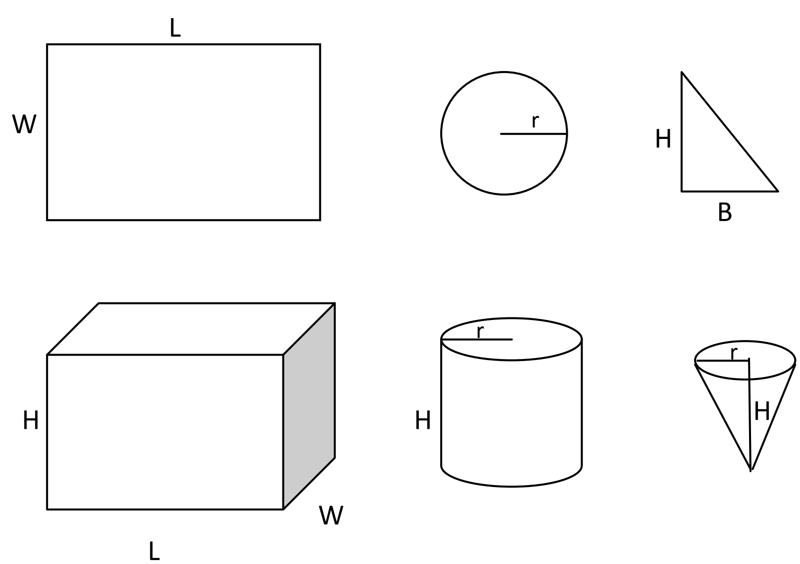
Proper measurements of area and volume are important to anyone in the horticulture or pest control industry. Horticulturalists need to know their production area, plant size and spacing needs, and their sprayer or boom coverage areas, among others. These basic pieces of information will be applied to other important production issues as well. For example, to determine the quantity of plants to be grown, a grower must know the crop's plant spacing needs as well as the available greenhouse space. Fertilizer regimes depend on crop area, as do irrigation plans, pesticide applications, and IPM scouting routines. You cannot apply the same quantity of pesticide to a 20 square foot area of sunflowers as you would to an acre of sunflowers. While the rate or percent concentration should be uniform, the quantity of product changes in relation to the treatable area. In some cases, particularly when dealing with substrate fertility or plant needs, volume must be assessed as well.

The following exercises will help you to calculate area and volume in IPM-related situations. Before you begin, you need to know a few basic formulas.

Calculating Area:
Square Area = $L \times W$
Triangle Area = $\frac{1}{2}b \times h$
Circle Area = πr^2

Calculating Volume:
Cylinder Volume = $\pi r^2 \times h$
Cubic Volume = $L \times W \times H$
Conic Volume = $\frac{1}{3}B \times H \times \pi r^2$

Conversions:
$\pi = 3.14$
$1 ft^2 = 144 in^2$
$1 ft^3 = 1728 in^3$



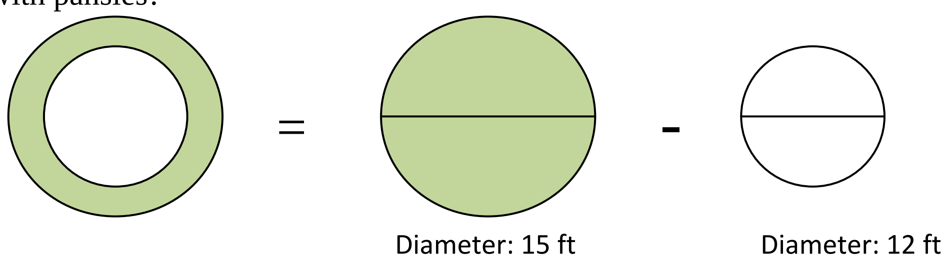
Plant Spacing

1. Charlene ordered 500 begonia plugs for her small greenhouse operation. She hopes to grow them to 4-inch pot size. What is the *minimum* bench area needed for her 500 4-inch begonias?

Landscape Design

2. Joe landed a landscaping contract with a local shopping center. The shopping center has demanded that the outer three feet of the circle should be covered in pink and white pansies. The circle measures fifteen feet in diameter. What is the total area to be planted with pansies?

Hint:



*R = ½ diameter

3. By spacing his pansies 6" apart (giving him 4 plants per square foot), how many pansies will Joe need to order?

Insecticide Application

4. Steve wants to release a parasitic wasp in his greenhouse to control the aphid population. The company recommends one package per 1,000 square feet. His greenhouse measures 20 x 36 feet. Will he need to order more than one package?

5. Aphids have become established in the southeast corner of Earl's greenhouse. He has decided to apply an insecticide on his pansies and begonias. The flats fill 10 benches. Benches are 20 ft long and 4 ft wide. How much area will Earl spray?

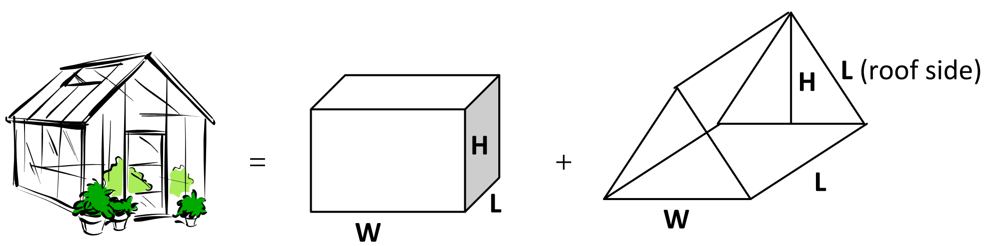
6. The label recommends a rate of 1.7 fl. oz. (or 50 mL) per 3000 square feet. How many fluid ounces should Earl apply to cover his 10 benches?

7. If Earl only has mL measuring equipment, how many mL should Earl apply to cover his 10 benches?

8. Earl can use NO LESS than 2 gallons of water per 1,000 square feet when applying this product. What is the MINIMUM volume of water that Earl can use to cover his 10 benches?

Growing space

9. Alice Jane is trying to estimate her heating bill budget for the next four months. Before she can make this estimate, she needs to know the volume of her greenhouse. What is the volume of a greenhouse whose measurements are width 10 ft, height 10 ft at corners, a 13.18 ft tall roof, and a total 23.18 ft at tallest point, length 25 ft, roof side length 14.1 ft?



Cubic Volume = L × W × H

+ Roof Volume = ½*B* × *H* × *L*

Volume Concepts

Container shape can affect irrigation regime needs. Take a look at the following container shapes. Each contains the same volume of growing medium, but holds a different volume of water after saturation. A low and wide container will need less water than a tall slender container. As you can see, a water loving plant might to better in a shallow wide container than a tall slender container.

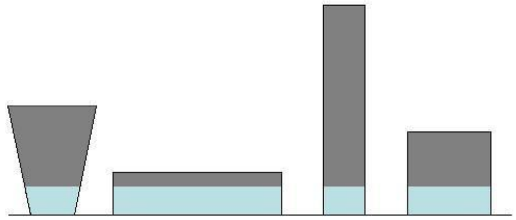


Image from: http://www.smart-fertilizer.com/articles/growing-media

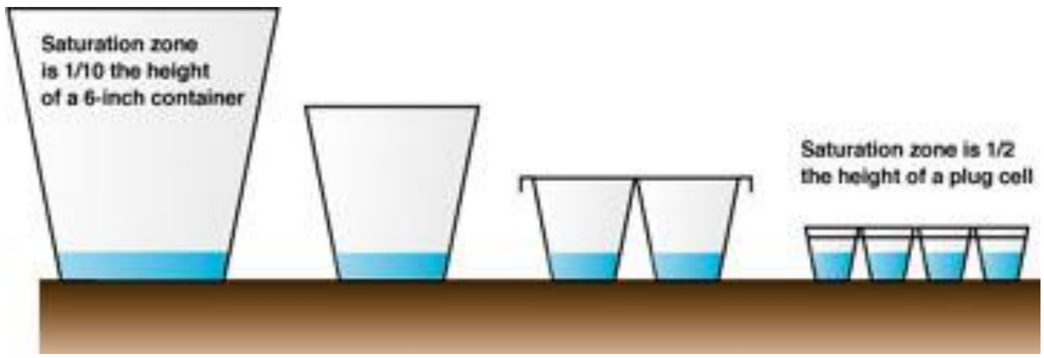
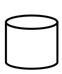


Image from: http://ohioline.osu.edu/hyg-fact/1000/1251.html

Understanding volume, water holding capacity, and air-filled porosity are integral to successful greenhouse management and the production of healthy pest free plants. This photo gives a prime example of the importance of mathematics in determining the proper irrigation regime.

10. John needs to place a second order of growing medium for his chrysanthemum crop. He hopes to fill 2,000 more 4-inch containers and 1,000 6-inch containers. Assuming the container length, width, and height are equal, what is the volume of growing media that he will need to order?

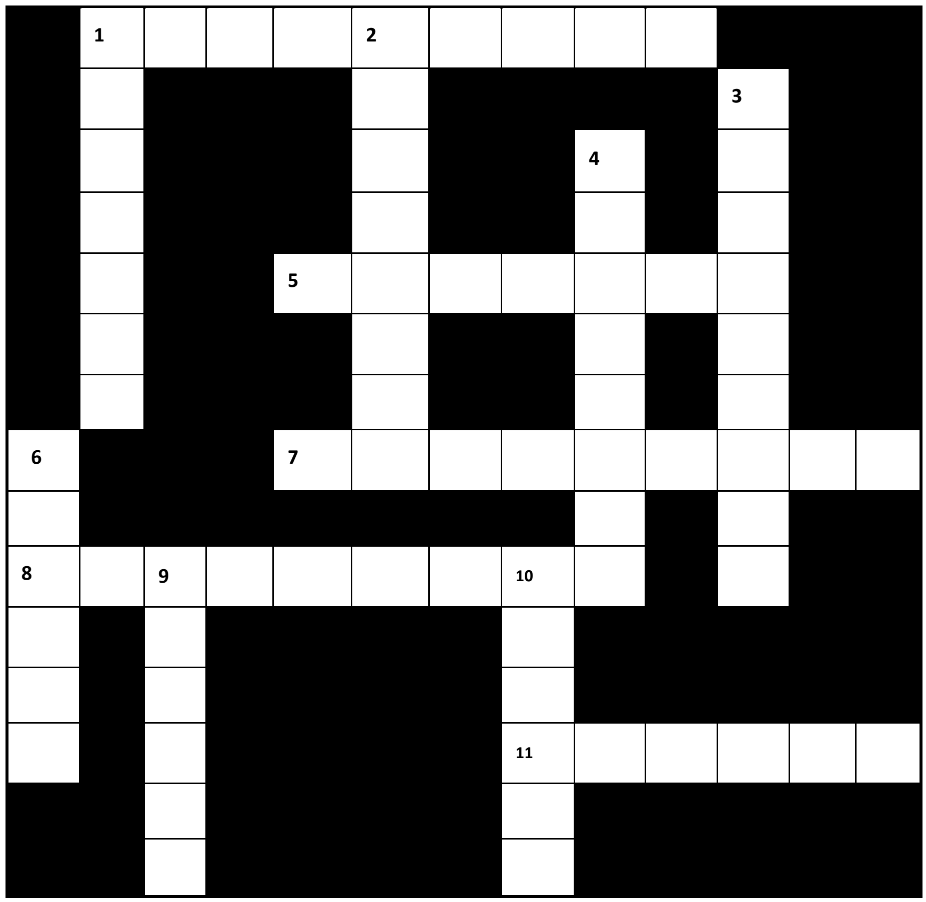
11. Dek needs to make a drench application of for his poinsettia plants. He has 400 cylindrical containers with a diameter of 6 inches and height of 10 inches. What is the volume (in^3) of each container? What is the total volume of his 400 containers?



Hint: Cylinder Volume = π $r^2 \times$ h

Assessment Activity 3.6:
Safe Pesticide and Fertilizer Storage

Name:_______________________________________ **Date:** ________ **Class Section:**_____



Across:

1. This pesticide product represses growth in a plant: growth ______.

5. Keep out!

7. Always use the appropriate and standard _________ utensils.

8. It can be a fungicide, an herbicide, a growth regulator, or an insecticide.

11. Some pesticides can stunt plant _____.

Down:

1. Documentation of all pesticide and fertilizer applications and the amount in storage.

2. If it is a secure pesticide structure, then the door will be ________ or able to be secured.

3. This can prevent diseases.

4. Type of damage caused by inclement weather and the reason you should store pesticides and fertilizers in a tight, dry, and secure space.

6. Ventilation is a safety precaution to remove harmful fumes or ______.

9. A lock ensures that chemicals are _____.

10. What a warning sign might say.

UNIVERSITY OF MARYLAND EXTENSION
Solutions in your community

Personal Protective Equipment Quiz
3.6 Greenhouse Management Policies

Name:_______________________________________ **Date:** ________ **Class Section:**_____

Quiz: Open-note

Answer the following questions:

1. What does the abbreviation PPE mean?

2. What is the purpose of a respirator?

3. What is the purpose of the approval codes found on respirators?

4. Does a half-face respirator cover the eyes?

5. What is the difference between a supplied air respirator and a half-face chemical cartridge respirator?

6. How do you check boots and gloves for leaks?

True/False

7. When mixing pesticides, it is a good idea to wear leather gardening gloves. _________

8. Gloves should be washed once a month. _________

9. Wear eye protection when mixing and applying pesticides. _________

10. As long as you use the cold cycle, pesticide-exposed clothes can be washed with the family laundry. ________

Assessing for Personal Protective Equipment

Peppermint Patty has received her pesticide certification license and is anxious to make her first pesticide application in the greenhouse. Based on this picture, what clothing items are wrong? What protective items are missing?

Wrong Clothes:

____

____

____

Missing:

____

____

____

(Images taken from Microsoft Office Clip Art)

Pesticide Regulations Quiz
3.6 Greenhouse Management Policies

Name: ________________________________ **Date:** ________ **Class Section:** _____

1. Maryland's Water Quality Improvement Act of 1998 did which of the following?
   a. changed drinking water standards for rural residents
   b. all agricultural businesses were required to follow the WQIA
   c. provided quality drinking water for cattle and horses in Maryland
   d. represented the first mandated nutrient management practices on Maryland farmers

2. What is the most commonly cited pesticide application violation, according to the Maryland Department of Agriculture?
   a. improper glove protection
   b. sprayers that have not been properly calibrated
   c. incomplete or missing records
   d. dumping pesticides in local waterways

3. APHIS is an acronym for what USDA service?
   a. Aphid Inspection Service
   b. Animal and Plant Health Inspection Service
   c. Agricultural Pest Help Investigation System
   d. Agriculture Production and Health System

4. Pesticide labels must be registered with which federal regulatory agency?
   a. U.S. Environmental Protection Agency
   b. U.S. Department of Agriculture
   c. U.S. Center for Disease Control
   d. U.S. Department of Education

5. What is the difference between a restricted use and reduced risk pesticide?

____

____

____

Unit 3: Interdisciplinary IPM
3.7: Careers: Training and Licensing

Skill:

Understand the broad scope of the horticulture industry
Recognize the various education backgrounds necessary for horticultural occupations

Outcome:

Recognize occupational opportunities, organizations, and requirements within the green industry

Learning Goals Achieved:

Students will be able to discuss potential areas of growth and development in the green industry

Key Questions:

How do government policies and consumer demands influence horticulture?
What are some basic skills that would be useful in a horticulture career?
What interdisciplinary connections can you make with horticulture and other industries?

Action Strategies:

Review content of Chapter 7; Hold class discussion
Class discussion on globalization and marketing
"Green Industry Careers" PowerPoint
Field trip to a commercial greenhouse and/or interview individuals within the horticulture industry

Assessments:

Information Packet Design
Synopsis of interviews

Materials:

Text

Career Exploration:

Visit greenhouse operation sites or have guest speakers from the horticultural industry

Interdisciplinary Connections:

Political Science
Environmental Studies
Business Management and Marketing

Unit 3: Interdisciplinary IPM

Chapter 7

Careers: Training and Licensing

Sarah Kenney

Integrated Pest Management is used in many different fields. From museum maintenance to rodent extermination to crop production, IPM has become a widespread practice. An IPM grower needs more than an understanding of entomology and chemistry. Successful IPM requires a range of education and experiences. Helpful areas can include business management, environmental studies, sociology, economics, geography, pathology, horticulture, and engineering. Skill sets can include artistic vision for mapping and design, statistics and mathematics to establish thresholds and control measures, science skills to understand the biology and chemistry of IPM, and communication skills to educate others.

Licensing

If you are considering a career in Integrated Pest Management or horticulture, remember that not anyone can pick up a sprayer and apply fungicide; not anyone can sell themselves as a certified grower or IPM scout. There are regulations concerning training, education, and experience.

License requirements in Maryland include the Maryland Plant Dealer, Nursery Inspection, and Plant Broker License for anyone selling plants in Maryland. The Pesticide Applicator's License must be current for any business applying pesticides. Landscapers need the Home Improvement Contractor's License. Salesmen and consultants for pesticide control must be licensed as well.

Pesticide certification requires the licensee to demonstrate specific knowledge and understanding of various certification areas. These categories include basic agriculture (field crops, livestock, grains), forestry, ornamental and turf, aquatic, seed treatments, public health, aerial, and many more. Individuals must be able to understand pesticide laws, labels, material safety data sheets, pest control options, environmental concerns, health concerns, and the principles of Integrated Pest Management. Applying this knowledge and understanding will help to keep the applicator, laborers, and environment safe.

Careers

Careers linked to commercial horticulture are extensive and varied. They include research-based, application-based, and customer-based fields. These include chemical manufacturing, construction, sales and marketing, engineering (mechanical, electrical, and ecological), horticulture and propagation, entomology, nutrient and water quality management, and many others. The following section will explore the various careers linked to greenhouse production, the horticulture industry, and education opportunities. (For more information, try www.thelandlovers.org, a student-geared non-profit websites dedicated to engaging youth in the green industry.)

The Maryland Nursery and Landscape Association lists the following requirements for entry level positions: reading, math, language, positive work ethic, ability to understand and follow directions, and the ability to work well within a team. Jobs beyond the basic entry level require experience, college credits, industry certifications, vocational classes, a driver's license, etc. Managerial positions often require a four year degree. Continued education and hands on experience will provide a job seeker with a valuable competitive edge.

Educational opportunities are available within the Maryland university system at the University of Maryland College Park, Cecil College, CCBC, Montgomery College, Morgan State University, and Anne Arundel Community College. Pennsylvania, Virginia, and Delaware also offer horticulture and landscape-based programs.

Horticulture programs include: Ornamental Horticulture, Environmental Horticulture, Landscape Horticulture, Landscape Architecture, Plant Pathology, Agricultural Engineering, Agronomy, Plant Physiology, Botany, Landscape Gardening, Botanical Garden Management, Greenhouse Management, Floriculture, Nutrient Management, Horticultural Therapy, Biology, etc. Other helpful fields of study are Business, Management, Environmental Science, Chemistry, Entomology, and Forestry.

While state systems can offer scholarships, some green industry organizations offer scholarship and networking opportunities as well. They include the Maryland Greenhouse Growers Association, the Maryland Nursery and Landscape Association, and the Association of Specialty Cut Flower Growers.

Resources:

The Land Lovers. http://thelandlovers.org

American Nursery and Landscape Association. http://www.anla.org/

American Society for Horticultural Science. http://www.ashs.org/

The Association of Cut Flower Growers.
<http://www.ascfg.org/index.php?option=com_frontpage&Itemid=1>.

The Maryland Greenhouse Growers Association <http://www.mdgga.org/>.

The Maryland Nursery and Landscape Association <http://mnlaonline.com/home.html>.

3.7 Assessment Rubric: Career Interview

Students give a synopsis of an interview with or talk from someone who works in the green industry. Synopsis should be 1-2 pages in length.

Criteria:	Points:	Score:
States individual's name and occupation	5	
Discusses how the individual incorporates IPM principles in their operation	5	
Describes how the individual became interested or started working in the green industry	5	
List any education, licensing, or training did he/she needed	5	
At least one new thing learned about the industry	5	
Total:	25 points	

3.7 Assessment Rubric: Information Pamphlet

Students are assigned a particular career path and must create a pamphlet or poster that describes the education, skills, and experience necessary. The pamphlet should also describe the job role, typical hours, demands, and possible benefits.

This assignment can be given based on class discussion and reading or based on personal interviews or visits with members of the green industry.

Criteria:	Points:	Score:
Identify and describe a job within the green industry	5	
Explains whether the job involves research, application, or retail	5	
Students present the potential demands and benefits of the job	5	
Describes the education, skills, and experience needed in the job	10	
Demonstrates organization and creativity	5	
Total:	30 points	

Unit 4: Pest and Disease Control Options

4.8: Greenhouse Structure, Maintenance, and Sanitation

Skill:

Student can identify sanitation issues within a greenhouse
Student recognizes the extent to which greenhouse maintenance affects plant health
Students can research and determine what mesh size is needed to block certain pests.

Outcome:

Students will use basic math skills to calibrate equipment
Students will identify vectors and entry points for insects, mites, and diseases

Learning Goals Achieved:

Students will be able to assess points of entry within a greenhouse
Students will be able to explain why sanitation is important in the production process
Students will be able to relate greenhouse maintenance themes to other real world maintenance issues such as house care, car care, or body care.
Students will be able to apply mathematics to the greenhouse production environment

Key Questions:

What would happen if a greenhouse's ventilation system was not working? How could you temporarily resolve this issue?
What are the effects of algal buildup in a greenhouse?
What are the similarities and differences between a weed and a pet plant?
Why would a grower want to sanitize plug transplant trays?

Action Strategies:

Lecture and discussion on Chapter 8
Perform a research activity on mesh screening
"Small Sprayer Calibration" PowerPoint
"Disinfecting the Greenhouse" PowerPoint
PowerPoint series and discussion on "Greenhouse Maintenance"

Assessments:

Selecting Mesh Screening Assessment Rubric
Sprayer Calibration Activity
"Greenhouse Maintenance" Series Assessment

Interdisciplinary Connections:

Engineering
Math
Biology
Chemistry

Unit 4: Pest and Disease Control Options

Chapter 8

Greenhouse Structure, Maintenance, and Sanitation

Sarah Kenney

Greenhouse structure, maintenance, and sanitation play a crucial role in the overall function and productivity of a greenhouse operation.

Structures

Structural styles can be freestanding or gutter-connected. Perhaps the most easily recognized is the Quonset frame with its rounded plastic sidewalls. Though it is easily constructed, its round structure limits space and headroom along the sides. Gothic frames are similar to the Quonset design and give more headroom along the sidewalls. Rigid-frame construction maximizes interior space and allows for increased air circulation. Rigid frames make use of right angles to provide more side and upper height area. Post and rafter frames are very sturdy but require more materials than other styles. They too allow for maximized interior space and easy air circulation.

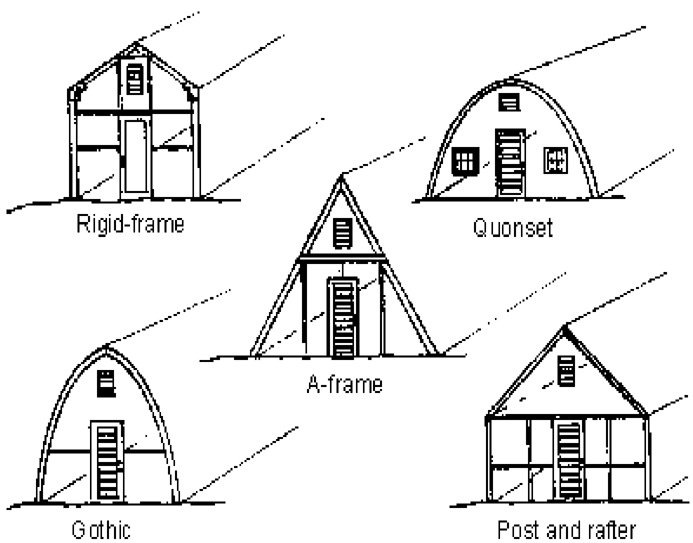


Image from University of Maryland Extension Fact Sheet 645 by David Ross

These structures can be designed as free standing greenhouses, as extensions of other buildings, or as gutter-connected systems. These designs depend on the available capital, growth plans, and needs of an operation. Gutter-connected systems reduce energy costs and enable larger growers to house their entire production system under one roof. The gutter connected system often includes a head house, or an area for plant production supplies to enter the greenhouse and for shipments to be organized and prepared.

Covering material ranges from plastic film to glass panels. Grime and solar damage can cloud greenhouse paneling and block light energy from reaching plant material. This buildup requires that growers replace paneling every so often. Though more expensive, glass requires little maintenance when compared to other covering materials and allows up to 90% light penetration. Fiberglass, on the other hand, requires a resin coating every 10 to 15 years. Low grade fiberglass materials will deteriorate quickly. Film plastic has the lowest structural and initial investment costs, but must be replaced frequently. Film plastic made of polyethylene lasts 12 to 18 months, polyvinyl chloride plastics last 5 years, and copolymer film plastics last 2 to 3 years total. Double wall plastic sheeting made of acrylic or polycarbonate materials carry 10 year warranties before light quality diminishes. Double glazing reduces heat costs considerably and UV inhibitors can be applied to many coverings to reduce impacts of UV damage on the material.

Maintenance

Just as a car owner must check oil levels and schedule a regular tuning, a grower must check and repair greenhouse equipment before a major problem develops. Imagine the consequences of a fertigation system that was not calibrated: how much fertilizer is being applied? And how does the grower know that the fertilizer is spread evenly throughout the irrigation system? A lack of maintenance could result in uneven crop quality, plant stress, or stunted growth. Ventilation and heating systems require maintenance as well, as limited air flow help rots and mildews form. A faulty thermostat could result in unnecessarily high greenhouse temperatures while, at the same time, a broken heating system could result in frost that kills an entire greenhouse. Large commercial operations may hire a full time mechanic or technician to deal with various tractor, filler machine, spray equipment, irrigation system, and structural issues.

Sanitation

Brandon is sitting in the family living room when he hears his friends call him outside to play. He asks his mom and runs out the door. He hears her shout as he leaves, “Shut the screen door! These stink bugs are everywhere!” Brandon shakes his head, shuts the door and heads towards his neighbor’s backyard.

How does this relate to a greenhouse operation? Brandon and his mother just discussed the concept of a “point of entry.” Invasive weeds, insects, and diseases require a means of transport and a point of entry. In a greenhouse environment, old planters, dirty trays, and unclean plant material serve as habitats for unwanted pests, while cracks, tears and holes, and infected plant material can also serve as the point of entry.

Screening can prevent unwanted pests and seeds from entering the greenhouse environment. A mesh screen should be large enough to encourage air flow but small enough to block thrips and other unwanted pests. These screens should be checked periodically to clean any dirt or grime buildup. A Dutch system uses a mesh wall to provide a second barrier against insects and particulates entering through vents. This mesh needs routine maintenance so air flow or light penetration is not blocked or restricted. Cracks and spaces around joints, panes, and doorways allow pests to migrate into the greenhouse as well. These spaces also encourage heat loss, increase energy demands, and should be fixed as soon as possible.

Weed control, sanitation, and repairs in and around the greenhouse perimeter must be made prior to planting. While protecting the greenhouse from unwanted pest entry is a key IPM strategy, interior sanitization is equally as important. Standing water, algal buildup, weeds, and pathogens can remain in substrate, growing surfaces, and the greenhouse structure itself. These provide excellent pest and disease conditions that develop before a crop even begins to grow. Between seasons, clear the greenhouse of plant and substrate materials. Sanitize the remaining surfaces and tools including trays, tables, and hoses using a solution of isopropyl alcohol, bleach, quaternary salt, or other recommended solution. If the greenhouse is not being used during the summer, close the greenhouse and allow solar energy to kill unwanted insects and pathogens with the heat. Sanitation practices need to continue throughout the growing season. For example, dispose of infected plant material, sanitize propagation or repotting areas, and sanitize any tools on a regular basis to reduce the chance of contamination. Remember to keep the outer areas of the greenhouse weed and plant free to minimize exposure within the greenhouse through ventilation and walkways. Compost and cull piles should remain far from the greenhouse as well.

Before a new crop is started, monitor the greenhouse for insect problems. Placing yellow sticky cards in the greenhouse will give you an indication of insects present in the greenhouse. Inspect leftover hanging baskets, stock plants, and new plant material before it enters your greenhouse. Remember, viruses can be present in weeds and stock plants, even if they do not show symptoms. Thrips may lay eggs on these infested plants and the larvae carry the virus. After these larvae pupate, the virus infected adult thrips will carry the pathogen to new plant material. Sanitation is the ideal prevention method for viral infections prior to a new crop.

Summary:
Beginning or expanding a greenhouse operation requires capital, goal-setting, and research. Understanding the basic greenhouse structures and paneling issues can lead to better investment decisions that will maximize plant quality and minimize costs. Greenhouse maintenance and sanitation serve as preventive measures against crop production setbacks including crop failure or pest buildup. Preventive maintenance and sanitation are excellent tools in horticulture.

Key Terms:
Point-of-entry

Resources:

Ross, D.S. 1998. Planning a home greenhouse. University of Maryland Extension. http://extension.umd.edu/publications/pdfs/fs645.pdf

University of Maryland Extension. 2011. Total crop management for greenhouse production, Bulletin 363.

4.8 Assessment Rubric: Greenhouse Maintenance

Student will assess a greenhouse for maintenance concerns based on the maintenance issues discussed in the power point series "Greenhouse Maintenance" and Chapter 8.

Student will enter a greenhouse and create a list of items to be checked, calibrated, cleaned, or replaced. This includes structural and system issues. For instance, the chimney of a heated greenhouse should be checked for blockages and cleaned periodically.

Criteria	Points	Scores
Describes calibration issues within systems	5	
Describes distinct structural issues or concerns	5	
Describes ventilation issues	5	
Describes bench and equipment issues	5	
Total	20 points	

4.8 Assessment Rubric: How small is small enough?

Selecting Mesh Screening

This small research project requires the student to assess the size of the pest insect and the mesh screen size to determine an appropriate screening material for the greenhouse. The student's report will be 1-2 pages in length (double spaced) and will discuss why mesh screening is important, the pest's damage and significance, and the reasoning for the mesh size choice.

Criteria	Points	Scores
Describes insect of concern	5	
Discusses the importance of screening	5	
Demonstrates a selected mesh size	10	
Explains reasoning for mesh size selection	10	
Total	30 points	

4.8 Lab Activity
Sprayer Calibration

Description:

In this lab activity, students will learn how to calibrate equipment. They will utilize basic mathematics conversion and logical steps to determine flow rates and equipment efficiency.

Objective:

Students will understand the math and advanced planning involved with pesticide applications

Students will understand the concept of sprayer calibration

Skills:

Ability to calculate spray rates and volumes in a calibration process

Ability to interpret a pesticide label's recommended rates

Materials:

Stop watch
Flags or flagging tape
Sprayer
Water
Measuring cup
Pesticide label
Worksheet and Pencil
Calculator

Resources:

Schuster, Chuck. 2003. Small Sprayer Calibration Presentation. *Integrated Pest Management (IPM) for School Greenhouse Operations*. University of Maryland Extension.

4.8 Lab Activity
Sprayer Calibration

How much spray do you use?

Name: ______________________________________ Date: ____________ Class Section: _______

Objective:

Students will understand the concept of sprayer calibration
Students will be able to calculate spray volumes.

Materials:

Stop watch
Flags or flagging tape
Sprayer
Water
Measuring cup
Pesticide label
Worksheet and Pencil
Calculator

Introduction:

Over time, pumps, nozzles, tips, and other factors may loosen, crack, or weaken. These problems can lead to leakage or pressure loss. Not only that, one individual might spray plants at a much faster rate than another. Thus, calibration is integral component to proper pesticide and fertilizer applications preparation.

Material and methods are adopted from Chuck Schuster's presentation on Small Sprayer Calibration. Chuck Schuster is an Extension Educator with Montgomery County Extension.

Methods:

1. ***Mark off a measured area of plants to spray with flags or flagging tape***

Record observations about this area. What type of plants are they? How old? Are the plants in quart or gallon pots? 6-pack flats?

____

____

____

What is the surface area?
Remember:

A rectangle or square formula is Area = Length X Width.
A circular area is Area = πr^2

____

____

Why are these observations and calculations important?

Think about a foliar spray application… To achieve full coverage, an applicator will have to use much more spray on 8 week old poinsettias than on 3 week old pansies.

2. *Consult pesticide label*

   What is the recommended application?
   (i.e. - spray, drench, lightly cover, and spray to drip)

   ____

   ____

   ____

3. *Fill sprayer with a known quantity of water (i.e. - 2 L)*

4. *Time yourself*

   Time yourself or the applicator spraying to cover plants as directed on pesticide label
   Record time when plant material has been covered appropriately

   Time: ____________________

5. *Measure water sprayed*

   Spray into measuring cup for the same amount of time as recorded in Step 4.

   Record water volume:

   Volume: ____________________

7. *Calculate spray ratio*

You have collected enough data to determine your application spray ratio. This ratio is equal to the quantity of water you sprayed divided by the area you covered.
Use a ratio formula to determine how much spray you would need to cover 1000 ft^2.
Circle your final answer.

$$\frac{\text{(quantity water sprayed)}}{\text{(measured area sprayed)}} = \frac{(x)}{(1000\ ft^2)}$$

If you wanted to spray 2,000 ft^2 of plant material, how much spray mixture would you need?

Pesticide labels recommend spraying at a specific rate of ounces per gallon or milliliters per liter. Given a rate of 2 mL/L, can you figure out how much *pesticide* will be needed to cover 1,000 ft^2?

Use the label provided by your teacher to determine the amount of spray and pesticide needed to treat 1,000 ft^2 of plant material for aphids.

Recommended rate on label:

____

How much spray you need to cover 1000 ft^2:

____

How much pesticide product will you need to treat this 1000 ft^2 area?

____

8. *Critical Thinking.*

What could happen if someone failed to calibrate their equipment before spraying?

____

____

____

____

____

Unit 4: Pest Control Options

4.9: Early Detection

Skill:

Student can record and assess pest symptoms
Students can sample plant populations and collect data
Students can use disease test kits with proficiency

Outcome:

Students will use basic math skills to calculate population densities
Students will identify plant problems in the field
Students will practice recording and interpreting observations
Students will gain experience using laboratory test kits

Learning Goals Achieved:

Students will be able to collect field data
Students will be able to triangulate evidence to reach a conclusion. Evidence will include symptoms of plant injury, weather patterns, insect presence, etc.
Students will be able to make educated guesses as to vulnerable areas, or points of entry, for pests entering the greenhouse system.

Key Questions:

Why are past records important to an IPM scout?
How could weather affect plant health inside a greenhouse?
If pests are present, does that mean they are causing the damage?
What are some likely causes of a root rot disease?
What kind of economic thresholds would you recommend for the school's greenhouse?

Action Strategies:

Lecture and discussion on Chapter 9
Gain hands-on experience scouting the school greenhouse
PowerPoint presentations on "IPM Scouting Steps" and "Disease and Viral Test Kits"

Assessments:

IPM Scouting Lab Activity
IPM Scouting Steps Quiz
Disease and Viral Test Kits Activity

Interdisciplinary Connections:

Math
Meteorology
Ecology

Unit 4: Pest Control Options

Chapter 9

Early Detection

Sarah Kenney

As with any problem, early pest detection and action gives a greater chance of control or resolution. Whether it is a chemical spill, the beginning of a head cold, or a leaky tire, the best management practice is to identify the problem and solve it before the situation worsens. You have seen how quickly insect and disease populations can increase and spread through the greenhouse. Their rapid deployment and population growth requires timely action. Routine monitoring and IPM scouting will enable the grower to exercise effective control methods and maintain optimal plant health during a growing season through the use of an IPM program.

Scouting Equipment

Scouting equipment includes a hand lens, forms to record information, a greenhouse map, flags, gloves, plastic bags, vials or containers, a camera, yellow and/or blue sticky cards, and a temperature and humidity meter. Remember to wear gloves when examining plants to reduce your chances of spreading pests and of contacting any harmful products.

Let the Scouting Begin…

Before scouting begins, the scout must review each crop's history, growing requirements, and the characteristics of a healthy crop. Once this is known, a scout can begin the process of assessing plant health and diagnosing any plant problems. Irrigation, fertigation, and pesticide application records, as well as potting and pinching dates are important. Environmental observations are important to the scouting process, as they can help to explain plant health issues. Observe and record greenhouse air and soil temperatures, humidity, odors, residues, standing water, weeds, structural damage, and any other peculiarities within the greenhouse.

Why are these cultural and environmental factors important? A cultural condition such as algal buildup could cause disease symptoms on a crop. Therefore, examining the larger greenhouse environment can give clues to smaller plant problems.

The simple, effective, and probably most familiar means of greenhouse monitoring is through the use of sticky cards. Growers and scouts use yellow sticky cards, which are thought to be attractive to the majority of greenhouse pests. However, there are a few insects that are attracted to blue sticky cards. If your crop typically attracts thrips, for instance, then blue sticky cards will be useful as well. Some greenhouses may use sticky tape instead of sticky cards, but the cards are easier to handle and provide a uniform surface area for insect monitoring. Monitoring cards should be placed throughout the greenhouse at a rate of about 3 cards/1,000 square feet. Additional cards can also be placed near doors, vents, or other entrance points to detect early invasion.

A scouting spreadsheet is helpful and allows the scout to record and monitor the insect population changes over time. An example data sheet can be seen in the "IPM Scouting Steps" PowerPoint presentation.

Each program should develop its own pest threshold level that is adapted to each specific crop and growing conditions. Growers should base their thresholds on scouting records. The number of pests that are counted on sticky cards or from foliar inspections, as well as the amount of plant damage should be recorded. Be sure to record information concerning control tactics and the quality of the finished crop.

Plant Inspection
Inspect plants at random—sampling 10-15 plants per 1,000 square feet. Make sure to inspect the foliar growth, flowers, stems, and root systems that are all equally important to the scouting process. Any signs of insect presence, damage, disease, nutrient deficiency, or toxicity should be recorded. Information should include the pest symptoms, life stage, number of pests detected, the percent of crop affected, and any potential causal agents. Collect substrate for pH and electrical conductivity tests. Ensure that alkalinity samples were taken of irrigation water as well.

Root inspections should also be conducted since poor roots could indicate irrigation, nutrient, or disease problems. If root rot or a foliar disease is suspected, collect a sample for further examination. This can be performed by using an in-house diagnostic test kit or by using a commercial diagnostic lab.

Unknown insect species should also be collected for a proper diagnosis. It is important that the scout make general observations of the overall condition of the plants and examine the greenhouse for any off-color plants, poor growth, or foliar damage. These plants, if not already sampled in the routine monitoring process, should be examined closely.

Flag areas of concern for further investigation or prescribed treatments.

A weekly scouting report will help everyone to remain aware of problems and address pest issues in a timely manner. The following chapter provides diagnostic tools to ID insects, mites, and diseases.

Resources:

University of Maryland Extension. 2011. Total crop management for greenhouse production, Bulletin 363. < http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

4.9 Lab Activity
The Basics of IPM Scouting

Description:

In this activity students will explore the steps involved in scouting a greenhouse, from examining weather patterns to foliar and root inspections. Students will record their observations and share their findings in a teacher-led class session.

Objective:

Students will learn to sample a population and to collect field data.
Students will practice insect and disease identification.
Students will make connections between environmental conditions and pest problems.
Students will gain a better understanding of greenhouse ecology.

Skills:

Observation and analysis of pest symptoms
Calculate the mean (average) number of pests per plant
Drawing a map or visual representation of greenhouse crops
Sampling methods for scouting and sample collection for disease tests
Critical thinking

Materials:

Notes and photos for insect and disease identification
Plants and greenhouse
Worksheet
Paper and pencils
Hand lens
Pruners
Plastic bags, vials, and/or petri dishes
Flagging tape (or flags)
Sticky cards
Calculator
Camera (Optional)

Resources:

Whipker, B.E., Cavins, T.J., and Gibson, J.L. 2002. Managing fall pansy fertilization. *NC State University Floriculture Research* <http://www.ces.ncsu.edu/depts/hort/floriculture/Florex/pansy_fert_mgt.pdf>.

Total Crop Management for Greenhouse Production, Bulletin 363. 2011. University of Maryland Extension.

4.9 Lab Activity
The Basics of IPM Scouting

Name: ________________________________ Date: ___________ Class Section:_______

Goals:

To introduce students to scouting techniques and insect identification

Objective:

Students will learn to sample a population and to collect field data.
Students will practice insect and disease identification.
Students will make connections between environmental conditions and pest problems.
Students will gain a better understanding of greenhouse ecology.

Materials:

Data sheet to record notes
Pen
Waterproof permanent marker or pencil
Hand lens
Pruners
Plastic bags for plant and soil samples
Vials or Petri dishes
Flags or flagging tape
Ruler
Insect and Disease ID guides
White piece of paper
Sticky cards
Calculator
Notebook
(Optional) On-site diagnostic kits
(Optional) Camera

Introduction:

Routine monitoring of a greenhouse environment is essential for pest detection. In a commercial setting, many operations hire IPM scouts to examine and monitor production sites. With practice, a scout can recognize insect, disease, nutritional, and environmental problems. Efficient scouting should occur about once a week, with additional monitoring when outbreaks occur.

The following activity gives an introduction to scouting techniques and proper recordkeeping. It DOES NOT include all steps that IPM scouting requires, rather it gives the student an introduction to scouting methods and complexity. This activity may take several class periods to complete, but gives a guided understanding of scouting procedures.

Methods:

1. Record the date, minimum and maximum temperatures, and weather. This information should be recorded daily by the grower or scout.

Date:	Average Temp:	Min. Temp.:	Max. Temp.:	Weather:

What has the weather been like for the past week? Overcast? Sunny? Freezing? Humid?

____

____

2. Walk through the greenhouse and examine the plant material, inspecting indicator plants and plants in production. Your teacher will assign you an area within the greenhouse.

3. Examine your assigned area from a distance. Do you any plants look stressed, stunted, or discolored compared to others?

Record your observations:

____

____

____

4. Choose 10 plants from each of your assigned sections, pulling from the edges and middle of benches. Mark these with flags, as you will be using these same plants in Part Two of this lab. Visually inspect for color variations or signs of stress, and record these observations.

____

____

____

5. Using a ruler, measure the height of plants and calculate the mean.

____

____

____

____

____

____

____

____

____

____

Sum of Plant heights = ___________

Divided by 10 = ____________

6. Record the number of buds or flowers on each plant. Calculate the mean.

____

____

____________________ Sum of Buds or Flowers = __________

____

____

____________________ Divided by 10 = __________

____

____

____

____

7. You or your team will need to determine a rating for foliar and root health. Record any observations on the foliar and root systems.

Foliage	Roots

8. If you have a camera, snap some pictures of the plant damage for recordkeeping.

Sketch a damaged leaf

Describe the damage

10. If you can see visible stippling or yellowed dotting on the leaves, tap the leaves and blooms over a white piece of paper. This is the tap test used to detect thrips.

Examine the paper closely for any movement, or evidence of thrips.
Record your observations.

9. Using your magnifying lens, examine any areas of the greenhouse where plants are showing signs of damage to determine if it is caused by insects or disease. Check the underside of leaves and all areas of the foliage, from the stems to the old and new growth.

Sketch the insect(s):

Record the number of insects per plant (1-10) by type:

	Insect A	(Insect B)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Any guesses as to what the insect may be?

____

____

How many insects per plant (average)?

____

Is this a light or heavy population?

____

Using a flag or flagging tape and a permanent marker, tag any plants with a heavy infestation. You may need to remove the plants from the greenhouse once you assess your count data.

11. Using pruners, clip a sample or two of foliage with damage or pest presence.
Place insects in Petri dishes or vials for inspection under the microscope.
Label these to include the host plant, location, and date.

12. Sticky cards help us to identify insect presence in greenhouses. In general, greenhouse insects are attracted to the yellow color of the sticky cards. Blue cards are used as well because they attract Western Flower Thrips.

Remove the sticky card and replace it with a fresh card.
You will examine the card and record your insect counts back in the classroom.

13. Root rot is commonly the result of overly moist conditions. As you inspect each plant, examine the root system. Take photos or sketch any unhealthy root conditions.

Sketch a healthy root.

If you see any, sketch a root problem and collect a tissue sample from the roots.

Do you notice any damping off (plant collapse at base of stems) or stem problems? If so, record them and flag the plants.

Foliar diseases have several different forms. They can look like white powder, browning edges, or dark spots. If you have a camera, take a picture. Collect a leaf sample and draw the symptoms in the space below:

Tissue samples can be used with in-house diagnostic kits to determine diseases. A commercial plant diagnostics lab can also perform the necessary tests.

13. On a chalk board or projector, record each students' or team's results. Include the crop, greenhouse location, and discuss any environmental observations. As a class, you will average the class' subjective visual assessments of overall plant health, root health, disease problems, insect damage, etc. Be sure to note where heavy populations or problems occurred.

14. While these numbers are being posted, students can identify and count insects on their sticky cards. These will be posted on the blackboard and students can use paper and pencil or a calculator to find the mean (average) aphid, whitefly, fungus gnat, or thrips populations.

Results:

What did you find? What was the average population size per pot?

____

____

Was a specific section of the greenhouse more heavily infested than another? Why or why not?

____

____

Are you seeing damage from these insects?

____

____

Did you find any beneficial insects?

____

Discussion:
Do you think the populations you found warrant a control treatment of any kind?

____

What could have been done to prevent the infestation?

____

____

Can you think of any beneficial insects that could help control the pest population?

____

____

If you found diseased plants, what environmental conditions may have influenced disease development?

____

____

Sketch a map of the greenhouse and pest problems.

Where do you think the pest population began?

____

____

____

4.9 Lab Activity
Disease and Viral Testing

Description:

In this activity, students will learn to use in-house test kits. The process for this lab is based on instructions and methods of test kit manufacturers: Neogen and Agdia.

Objective:

Students will formulate and test a hypothesis, following the scientific method
Students will understand and perform an in-house virus or bacterial test using the methods described in the in-house test kit presentation.

Skills:

Observation and deduction
Tissue sampling
Interpretation of technical instructions
Interpretation and analysis of laboratory results

Methods/Materials:

Alert or other plant tissue test kit.
Suspected infected plant

Resources:

Testing Kits from

Agdia, Inc.
30380 Country Road 6
Elkhart, IN 46514
http://www.agdia.com

Neogen Corporation
The Dairy School
Auchincruive, Ayr
KA65HW, Scoutland, UK
http://plant.neogeneurope.com

4.9 Lab Activity
Disease and Viral Testing

Name: _________________________________ Date: ___________ Class Section:_______

Goal:

To introduce students to viral and disease testing

Objective:

Students will formulate and test a hypothesis, following the scientific method
Students will understand and perform an in-house virus or bacterial test using the methods described in the in-house test kit presentation.

Methods/Materials:

Alert or other plant tissue test kit.
Suspected infected plant

1. Sketch and describe the foliar or root symptoms

2. Does this seem like a virus or disease?
Any guesses as to which disease or virus it may be?

3. Formulate a hypothesis. For example: This plant is infected with Impatiens Necrotic Spot Virus.

4. Select the test kit that corresponds with the symptoms and potential diagnosis. Run the test.

   Which test kit did you use?

5. Evaluate the results. Do they support your hypothesis?

6. Draw a conclusion.

IPM Scouting Steps Quiz
4.9 Early Detection and Diagnosis

Name: ________________________________ Date: ___________ Class Section:_______

Quiz: Open Note

Fill in the blank.

1. What are the steps to IPM?

1) Prepare
2) Monitor
3) Inspect _______________________
4) Inspect substrate and __________________
5) Research and investigate
6) Draw conclusions

2. It is important to know crop requirements, crop history, and what a __________ crop looks like.

3. High soluble salts can lead to what plant symptoms?

   Marginal ___________ burning and poor __________ growth

4. Substrate samples should be taken to measure pH and ______________________ (a soluble salts measurement.

True or False.

5. Brown wetted roots are healthy. (T/F) ___________

6. Inspect plants from the middle of benches only. (T/F) ______________

Response questions.

7. List three common greenhouse insect or mite pests:

   a) _____________________
   b) _____________________
   c) _____________________

8. Where should sticky cards be placed in a greenhouse?

Challenge question: Why is it important to know the life stage of a greenhouse pest?

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Unit 4: Pest Control Options

4.10 Understanding Your Pests

Skill:

Student can identify greenhouse pests.
Students can investigate potential control options.

Outcome:

Students will understand the basic differences among biopesticides and insect growth regulators.
Students will be able to identify common greenhouse pests based on feeding habits, damage, and images.

Learning Goals Achieved:

Students will be able to triangulate evidence and develop preliminary diagnostics of plant problems.
Students will understand the importance of thorough monitoring, recordkeeping, and research when determining pest problems and solutions.

Key Questions:

What is the difference between an insect growth regulator and a traditional broad-spectrum pesticide?
What damage is common for caterpillars? For fungus gnats? Powdery mildew?
Why is it important to recognize the differences among cultural, disease, and insect problems?
What are the implications of a false diagnosis?

Action Strategies:

Gain hands-on experience scouting the school greenhouse
PowerPoint presentations on various insects, disease, and cultural problems:
“Aphids,” “Caterpillars,” “Fungus gnats,” “Spider mites,” “Thrips”, “Whiteflies,” “Other pests,” “Disease,” and “Cultural problems”
“IPM Insect Controls” PowerPoint
Presentation on Selected Crop Production
Review “Diagnosing Plant Problems” (see Appendix)

Assessments:

Presentation on Selected Crop Production
Insect Quizzes
IPM Insect Control Assessment Activity

Interdisciplinary Connections:

Biology, Chemistry

Unit 4: Pest Control Options

Chapter 10

Understanding Your Pests:
Biological Controls and Reduced-Risk Pesticides

Sarah Kenney

By now you should understand the damage a small insect or fungal spore can cause. Optimal management of these pests can be achieved through an understanding of the pest's life cycle, ecology, and susceptibility to other organisms and chemicals.

Three lines of defense provide effective control against unwanted pests. The first line of defense is achieved through cultural and preventive control methods. The second defense uses biological knowledge to influence the population through the use of predatory, parasitic, or pathogenic species. The third line of defense calls upon pesticide treatments. These treatments can range from biopesticides and insect growth regulators (IGRs) to traditional and sometimes harsher pesticides such as imidacloprid or lambda-cyhalothrin. This chapter will focus on the use of biological controls and reduced-risk pesticides to manage insect and mite populations. Because regulations make traditional pesticides an unlikely application in a high school greenhouse, they will not be discussed here. More information on conventional pesticides can be found in University of Maryland Extension's Bulletin 363 and by contacting your local extension office.

Biological controls

Biological control is a method that uses predators, parasites, and/or pathogens to reduce pest populations. In this manner, the grower or pest control expert manipulates natural ecological conditions for the benefit of a crop. The use of biological control requires advanced planning and research. For this reason, factors such as population size, temperatures, humidity, available optimal light, and timing are integral to a biological control's success. For instance, the parasitic wasp *Aphidius colemani* has a specific optimal temperature range of 50-76°F. If temperatures extend beyond this range, the wasp will be neither active nor effective against aphid populations.

Some biological suppliers encourage their customers to order organisms well in advance—often over a month before they plan to use the biological control. In some cases, a grower will have to keep the predatory population well-fed on other insects before releasing the predator at the right time. The University of Maryland Extension organized a trial using banker plants and barley-feeding bird cherry oat aphids to sustain a parasitic wasp population for use on melon and green peach aphids. A banker plant can be thought of as a rearing laboratory or feeding chamber. They provide a temporary habitat and resources for the selected biological control. In this case, bird cherry oat aphids lived on the barley (banker) plants. Bird cherry oat aphids are host-specific and feed on grasses and grains rather than broadleaf perennials and annuals. These aphids help sustain a parasitic wasp population before the greenhouse grower's melon and green peach aphids reach the economic threshold.

Host specificity is another important issue to consider. Some wasps only parasitize a narrow range of aphids or whiteflies. *Encarsia formosa* tends to parasitize the greenhouse whitefly, while the *Eretmocerus* species parasitize silverleaf whiteflies. This specificity illustrates the need for proper identification of greenhouse pests through IPM scouting. A variety of parasites, predators, and pathogens can be used against greenhouse pests. Parasitic wasps, predatory midges, lacewings, and lady bird beetles can control aphid populations. Entomopathogenic nematodes are microscopic organisms that release pathogenic bacteria, causing disease in insects. Early infestations of fungus gnats may be controlled by entomopathogenic nematodes, while caterpillars can be controlled through parasitic wasps and microbial insecticides such as *Bacillus thuringiensis*. Often referred to as Bt, the bacteria *Bacillus thuringiensis* inhibits caterpillar feeding and eventually causes the caterpillar to die. Viral strains can be released within the greenhouse as well to control specific species.

Biopesticides

Biopesticides are derived from natural ingredients such as bacteria or minerals. For the most part, biopesticides tend to have a short REI or re-entry interval and require less regulation and restrictions in the EPA's registration process. While they are typically less harmful than traditional pesticides, not all biopesticides have lower toxicities. For this reason, it is important to research the chemical and its effects regardless of its name or bio-friendly label.

Biopesticides include microbials, reduced-risk, and biochemical compositions. Microbial insecticides are bacterium, fungal, or viral applications used to control pest populations. *Bacillus thuringiensis* and *Beauveria bassiana* are two popular commercially available microbial insecticides. Reduced-risk pesticides have short residual activity and are traditionally low in toxicity. As a result, they are expedited through the EPA's registration process. Biochemical pesticides, those derived from substances such as oils, alcohols, and soaps, are biopesticides as well.

Reduced-risk pesticides often have a narrow control spectrum and can be helpful in a greenhouse situation. Spinosads are reduced-risk pesticides that are only effective when ingested. This allows many beneficial organisms to thrive while pests are affected by the chemical application.

Insect Growth Regulators

Insect growth regulators or IGRs prevent insect development and maturation. IGRs alter hormone production and chemical signals that enable an insect or mite to produce chitin, ecdysone, and other products necessary in the growth and molting processes. Chitin synthesis disruptors prevent the development of the organism's exoskeleton and cause the organism to die. Other IGRs disrupt or mimic hormones that will prevent an organism from maturing or completing metamorphosis. IGRs can kill an insect or mite in the egg, larval, and juvenile adult stages.

Diseases can spread rapidly throughout a greenhouse and destroy a crop. Disease problems can be fungal, bacterial, or viral and are often spread through air currents, water droplets, or physical

contact. Diseases have three major requirements: 1) a susceptible host or plant, 2) a pathogen, and 3) environmental conditions favorable for spreading disease.
While this manual focuses on pest management as a whole, the majority of lessons and activities are geared towards insects. The second half of this chapter discusses the major plant disease types and their control options.

Bacterial diseases
A bacterium is a single-celled organism that lacks a defined nucleus and can grow in a myriad of environmental conditions. Most bacteria in a greenhouse environment will be spread through water molecules. Excessive irrigation, poor drainage, and high humidity levels increase the chances for bacterial growth. Some common bacterial diseases include bacterial leaf spot (common on chrysanthemums and zinnias), bacterial blight (common on geraniums), and bacterial soft rot (common on poinsettias).

Fungal diseases
Unlike bacteria, fungi have defined nuclei and their spores spread through air and water. Moisture often encourages fungal development, and certain insects, such as fungus gnats, can spread the disease to other plants. Rusts are another form of fungi that have a reddish appearance.

Viral disease
A virus contains genetic material and can only replicate when using a living host. However, a virus is not considered a living organism. While we may think of a virus as a human disease, plants are susceptible to viral infection as well. In fact, the first virus ever discovered was the Tobacco Mosaic Virus which still attacks plants today. Tomatoes are particularly susceptible to the tobacco mosaic virus, and the virus is known to infect other vegetables and ornamentals such as peppers, snapdragons, and petunias.[18] Insects serve as vectors for plant viruses, transferring the virus from one plant to the next. Other common viral infections include the INSV or Impatiens Necrotic Spot Virus and Hosta Virus X.

Controls for bacterial diseases include managing irrigation and air currents. Pesticide applications include a microbial biopesticide, *Bacillus subtilis*, and copper-based productsm though the toxic materials in copper products will cause visible discoloration or mottling of the foliar surface known as phytotoxicity.

Once established, the virally-infected plant material should be removed from the greenhouse. Insect control is an important preventive measure, as whitefly and other insects can spread viral and fungal diseases from plant to plant.

Summary:
Proper diagnosis is crucial to successful IPM, as is a general understanding of the various control options. When a pesticide must be used, select a product that is effective with a low toxicity. Understanding the difference between a broad spectrum insecticide and a selective insect growth

[18] Pfleger, F.L., and R.J. Zeyen. 2008. Tomato-Tobacco Mosaic Virus Disease. University of Minnesota Extension. http://www.extension.umn.edu/distribution/horticulture/DG1168.html

regulator can mean a world of difference in producing a quality plant while maintaining the environmental integrity of an operation. Prevention and timely insect, mite, and disease diagnostics will cut costs, plant loss, and stress to any greenhouse operation.

Key Terms:

Biological control, biopesticide, insect growth regulator, phytotoxicity

Resources:

University of Maryland Extension. 2011. Total crop management for greenhouse production, Bulletin 363. < http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

IPMLabs. 2011. < http://ipmlabs.com/home.php>. This biological control company gives a brief synopsis of each biological control option.

Leppla, N.C., and Johnson, II, K.L. 2010. Guidelines for purchasing and using commercial natural enemies and biopesticides in Florida and other states. *University of Florida, IFAS Extension* < http://ipm.ifas.ufl.edu/pdf/Natural_Enemy_Guidelines.pdf>. Lists natural enemies that are available to combat pests.

4.10 Assessment Rubric: Integrated Pest Management Crop Production

Each student or pair is assigned a potential greenhouse crop. They must determine the cultural requirements, time to maturity, special propagation needs, susceptibilities to pests, and any unique traits of specific cultivars. The project should investigate whether the crop is suitable to be grown during a school year.

Each student should submit a 1-2 page writeup on the topic or give a 5 minute presentation on their crop. A list of notes and sources is required.

Criteria:	Points:	Score:
Cultural requirements are explained	15	
Time to maturity and special propagation needs (such as pinching times) are presented	10	
Susceptibility to pests are discussed	15	
Resale value and recommendations to the class	5	
Use multiple sources and demonstrates understanding of the topic	5	
Total:	50 points	

Aphids Quiz
4.10 Understanding Your Pests

Name: ________________________________ Date: ___________ Class Section:_______

Quiz: For use with the "Aphids" PowerPoint

True or False:

1. Aphids can have wings. **T / F**
2. When monitoring for aphids, pink sticky cards are recommended. **T / F**
3. Check the underside of leaves when inspecting a plant. **T / F**
4. Cast skins can be a good indication of an established population. **T / F**
5. *Chrysoperla carnea,* or lacewings, feed only on aphids. **T / F**
6. Systemic insecticides work best on new growth and on the upper foliage of herbaceous plants. **T / F**
7. Ants are predatory insects that feed on mature aphids. **T / F**
8. Honeydew is a special serum made only by the melon aphid. **T / F**
9. Melon aphids are yellow with yellow-green sphericals. **T / F**
10. *Aphidius spp.* are often selective feeders on aphids. **T / F**

Caterpillars Quiz
4.10 Understanding Your Pests

Name: ______________________________ Date: __________ Class Section:______

Quiz

To be used with the "Caterpillars" PowerPoint

True or False

1. Caterpillars are the juvenile forms of Lepidoptera**. T / F**
2. Caterpillars excrete honeydew rather than frass**. T / F**
3. Caterpillars cause foliar damage through rasping or scraping**. T / F**
4. Caterpillars will always have 7 pairs of prolegs**. T / F**
5. Sawfly larvae will always have more than 5 pairs of prolegs**. T / F**
6. The variegated fritillary is a beneficial insect that feeds upon early instar Lepidoptera species**. T / F**
7. In some cases, the *Nucleopolyhedrosis* virus (NPV) can be applied as a microbial biopesticide for caterpillar control**. T / F**

Critical thinking (3 points)**:**
Most insecticides target early life stages of an insect (for instance, the larval or early instar stages) rather than pupal and adult life forms. Why do you suppose insecticides target these earlier stages in the greenhouse environment?

____

____

____

____

Fungus Gnats Quiz
4.10 Understanding Your Pests

Name: ________________________________ Date: ___________ Class Section:_______

Quiz

For use with the "Fungus Gnat" PowerPoint Presentation

True or False:

1. Fungus gnats prefer dry soils. **T / F**
2. Potato wedges can be used to monitor for fungus gnats. **T/ F**
3. Wasps are an effective fungus gnat control. **T/ F**
4. Nematodes work best on adult fungus gnats. **T/ F**
5. Adult fungus gnats can move from plant to plant. **T/ F**
6. A heavy population of fungus gnats can increase chances of diseases spreading. **T/ F**
7. *Bacillus thuringiensis israelensis* can be used for fungus gnat control. **T / F**

Answer the following:

8. Explain how entomopathogenic nematodes can affect a fungus gnat population.

____

____

____

9. Draw a nematode or several nematodes within a fungus gnat larva.

Spider Mites Quiz
4.10 Understanding Your Pests

Name: ________________________________ Date: ___________ Class Section:_______

Quiz

For use with the "Spider Mites" PowerPoint

True or False

1. Spider mites produce webbing on foliage. **T / F**

2. Spider mite damage consists of shotholes in foliage. **T / F**

3. Spider mite damage can include a stippled yellow appearance. **T / F**

4. Spider mites distort leaves but not flower buds. **T / F**

5. There are mites that feed on other insects and mites that feed on plant material. **T / F**

6. Mites prefer cool and moist environments. **T / F**

7. Draw a spider mite adult.

Thrips Quiz
4.10 Understanding Your Pests

Name: ________________________________ Date: ___________ Class Section:_______

Quiz

For use with the "Thrips" PowerPoint Presentation

True or False

1. Female thrips are reddish brown while the males are yellowish in color. **T / F**

2. Thrips undergo complete metamorphosis. **T / F**

3. Damage from thrips can include silvery-white streaks on flower petals and deformed new growth. **T / F**

4. *Bacillus thuriengensis* can be used to treat thrips. **T / F**

5. Thrips help spread INSV and TSWV. **T / F**

Answer the following

6. Name the fungus that will help in controlling thrips populations:

____

Answer the following after the presentation:

7. Describe the "tap test."

____

____

____

____

Whiteflies Quiz
4.10 Understanding Your Pests

Name: ________________________________ Date: ___________ Class Section:_______

Quiz
For use with the "Whiteflies" PowerPoint Presentation

True or False

1. Whitefly damage can be characterized by chlorotic foliage, weakened plants, and honeydew buildup. **T / F**

2. Whiteflies serve as a vector for viral transfer. **T / F**

3. Whiteflies feed on the tops of leaves. **T / F**

4. The whitefly undergoes complete metamorphosis. **T / F**

5. Whiteflies damage plant material by chewing the leaves. **T / F**

6. Early instar whiteflies can be found on the underside of leaves. **T / F**

7. The *Encarsia* wasp will parasitize the whitefly by laying an egg in a whitefly nymph. **T / F**

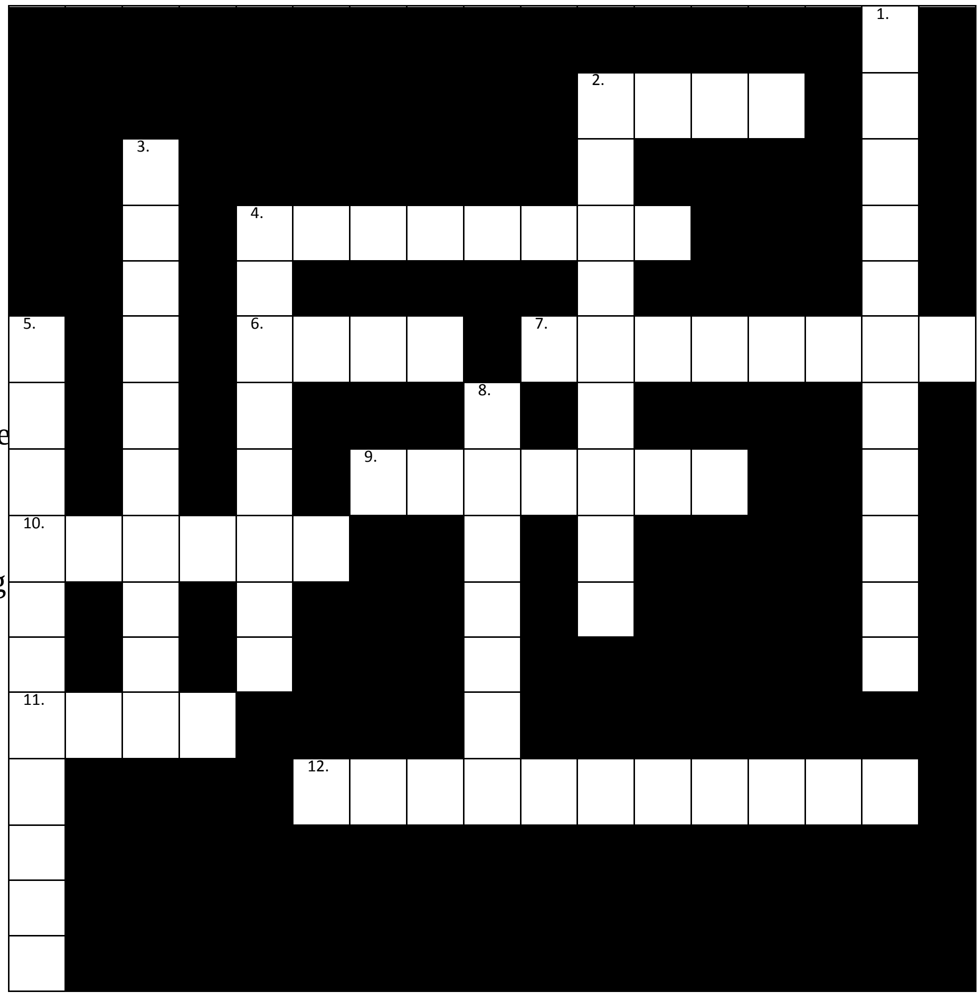
8. Draw whiteflies in their sessile stage:

Assessment Activity 4.10:
IPM Insect Control

Name: ________________________________ Date: ___________ Class Section:_______

Crossword Puzzle

Use the clues to complete the puzzle.



Down.

1. Insects that help control pest populations

2. Type of insect that feeds on other organisms

3. Not synthetic

4. An organism such as a braconid wasp or nematode that benefits from another species

5. Chemical created using biological organisms

8. Relating to an organism's level or position in the food web

Across.

2. Insect, mite, or disease

4. An infectious agent that causes disease in its host; virus, bacterium, or fungi

6. Some pesticides reduce this; while restricted use pesticides have increased _____

7. Single-celled organism that lacks a nucleus

9. Chemical compound that sends messages or signals to an organism's cells

10. Main component of an insect's exoskeleton

11. Another term for ecdysis

12. Pesticide form that must be mixed before it is ready to use; Emulsifiable _____

Appendix

Learning Goal Indices

To the teachers:

Each chapter within this IPM Manual opens with a listing of the potential skills, outcomes, learning goals, discussion questions, action strategies, assessments, and interdisciplinary connections it contains. The chapter continues with a brief written portion introducing the topic, explaining key terms, example scenarios, and additional resources. Classroom and lab activities, independent study projects, lecture and class discussion assessments, and visual aids (PowerPoint presentations) are provided as well. Further diagnostic and control information can be obtained from your local extension office, Bulletin 363, or through the Central Maryland Research and Education Center's IPM website: http://ipmnet.umd.edu.

What follows in this section is a complete listing of key concepts and terms, skills, interdisciplinary connections, and activities corresponding to the Maryland High School Core Learning Goal 1 for Biology.

Key Concepts and Terms:

1.1

Integrated pest management
Pesticide resistance
Re-entry interval

1.2

Cultivar
Economic threshold

2.3

Alkalinity
Capillary forces
Chloroplasts
DIF
Electrical conductivity (EC)
Fertigation
Photoperiodism
Photoreceptors
Photosynthesis
Substrate
Ventilation

2.4

Carrying capacity
Ecdysis
Fecundity
Exponential growth

Instar
Metamorphosis (complete and incomplete)
Population
Variables (dependent and independent)

2.5

Biological control
Parasite
Pathogen
Predator

3.6

APHIS
MSDS
Restricted use pesticide
Specimen label
MSDS

3.7

4.8

Point of entry

4.9

4.10

Biological control
Biopesticide
Chitin
Insect growth regulator
Phytotoxicity

Skills:

1.1

Identify basic principles of integrated pest management.
Compare and contrast two pest control approaches.

1.2

Identify and explain an economic threshold.
Describe basic steps of IPM

2.3

Apply biological concepts to greenhouse management.
Identify basic plant requirements and growth-inhibiting factors

2.4

Identify life history stages for complete and incomplete metamorphosis
Calculate exponential growth

Illustrate invasive species and pest population concepts

2.5

Identify three types of biological controls
Explain an organism's role in the ecosystem or a trophic relationship

3.6

Comprehend technical pesticide documents
Able to understand and explain major pest management laws and requirements
Perform conversions of temperature, mass, area, and volume

3.7

Recognize the variety of career options associated with IPM and the background education and experiences that correspond to these careers

4.8

Draw connections between sanitation and maintenance and plant health
Research, interpret, and assess crop production issues

4.9

Perform sampling and data collection
Record and interpret data
Working knowledge of in-house viral and disease test kits

4.10

Identify, assess, and develop solutions to pest problems within the greenhouse

Interdisciplinary connections:

Writing

1.2 Steps to Integrated Pest Management
2.3 Basic Plant Requirements
2.5 Practical Biological Controls: Host species and predators
3.6 Greenhouse Management Policies
3.7 Careers: Training and Licensing
Presentation on Selected Crop Production

Speech and Communication

1.2 Steps to Integrated Pest Management
3.6 Greenhouse Management Policies
3.7 Careers: Training and Licensing
Presentation on Selected Crop Production

Art and Design

1.2 Steps to Integrated Pest Management
2.5 Practical Biological Controls: Host species and predators
3.7 Careers: Training and Licensing

Biology

1.2 Steps to Integrated Pest Management
2.3 Basic Plant Requirements

2.4 Pests in the Greenhosue Ecosystem
2.5 Practical Biological Controls: Host species and predators
3.6 Greenhouse Management Policies
4.9 Early Detection and Diagnosis

Physics

2.3 Basic Plant Requirements
4.8 Greenhouse Structure, Maintenance, and Sanitation

Chemistry

2.3 Basic Plant Requirements
3.6 Greenhouse Management Policies
4.8 Greenhouse Structure, Maintenance, and Sanitation
4.9 Early Detection and Diagnosis

Mathematics

2.4 Pests in the Greenhosue Ecosystem
3.6 Greenhouse Management Policies
4.8 Greenhouse Structure, Maintenance, and Sanitation
4.9 Early Detection and Diagnosis

Social Studies

1.1 What is Integrated Pest Management and why does it matter?
1.2 Steps to Integrated Pest Management
3.6 Greenhouse Management Policies

Maryland High School Core Learning Goals:

Biology
Goal 1: Skills and Processes for Biology Assessment

Learning Goals:

The student will demonstrate ways of thinking and acting inherent in the practice of science.[1]
The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.[1]

Outcome:

Student will explain why curiosity, honesty, openness, and skepticism are highly regarded in science.[1]

Assessment:

Students will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.[1]

1.1 IPM Venn Diagram

2.3 Pansy Detective
2.4 Illustrating Entrance Points
4.10 Understanding Your Pests

Outcome:

The student will pose scientific questions and suggest investigative approaches to provide answers to questions.[1]

Assessment:

The student will identify meaningful, answerable scientific questions.[1]

2.3 Substrate Fertility
2.3 Plant Spacing Trials

The student will formulate a working hypothesis. [1]

2.3 Substrate Fertility
2.3 Plant Spacing Trials

The student will test a working hypothesis. [1]

2.3 Substrate Fertility
2.3 Plant Spacing Trials
4.9 Disease and Viral Test Kits

The student will select appropriate instruments and materials to conduct an investigation. [1]

2.3 Testing Substrate Fertility
2.3 Too Wet, Too Dry
2.3 Plant Spacing Trials
4.8 Selecting Mesh Screening
4.9 IPM Scouting

The student will identify appropriate methods for conducting an investigation. [1]

2.3 Substrate Fertility
2.3 Plant Spacing Trials
4.9 IPM Scouting Steps Quiz
4.9 IPM Scouting

The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory. [1]

2.3 Too Wet, Too Dry
2.3 Substrate Fertility
2.3 Plant Spacing Trials
2.4 Exponential Growth
Biological Controls Discussions

The student will defend the need for verifiable data. [1]

2.3 Substrate Fertility
2.3 Pansy Detective

2.3 Plant Spacing Trials
4.9 IPM Scouting

Outcome:

The student will carry out scientific investigations effectively and employ the instruments, systems of measurement, and materials of science appropriately. [1]

Assessment:

The student will develop and demonstrate skills in using lab and field equipment or perform investigative techniques. [1]

2.3 Too Wet, Too Dry
2.3 Substrate Fertility
2.3 Plant Spacing Trials
4.8 Sprayer Calibration
4.8 Greenhouse Maintenance
4.9 IPM Scouting
4.9 Disease and Viral Test Kits

The student will recognize safe laboratory procedures. [1]

3.6 Personal Protective Equipment
3.6 Safe Pesticide and Fertilizer Storage
3.6 Understanding the Material Safety Data Sheet
4.9 Disease and Viral Test Kits

The student will demonstrate safe handling of the chemicals and materials of science. [1]

2.3 Substrate Fertility
3.6 Understanding the Material Safety Data Sheet
3.6 How to Read a Pesticide Label
3.6 Personal Protective Equipment
4.9 Disease and Viral Test Kits

The student will learn the use of new instruments and equipment by following instructions in a manual or from oral direction. [1]

2.3 Too Wet, Too Dry
3.6 Personal Protective Equipment
4.8 Greenhouse Maintenance
4.9 Disease and Viral Test Kits

Outcome:

The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication. [1]

Assessment:

The student will organize data appropriately using techniques such as tables, graphs, and webs. [1]

2.4 Exponential Growth
4.9 IPM Scouting

The student will analyze data to make predictions, decisions, or draw conclusions.[1]

2.3 Pansy Detective
2.3 Plant Spacing Trials
2.4 Exponential Growth
4.9 IPM Scouting

The student will use experimental data from various investigators to validate results. [1]

1.2 Global Events in IPM
Biological Controls Trial

The student will determine the relationships between quantities and develop the mathematical model that describes these relationships. [1]

2.4 Exponential Growth
3.6 Learning Conversions
4.8 Selecting Mesh Screening
4.8 Sprayer Calibration

The student will check graphs to determine that they do not misrepresent results. [1]

2.4 Exponential Growth

The student will describe trends revealed by data. [1]

2.3 Pansy Detective
2.3 Plant Spacing Trials
2.4 Exponential Growth
4.9 IPM Scouting

The student will determine the sources of error that limit the accuracy or precision of experimental results. [1]

2.3 Pansy Detective
2.4 Exponential Growth
4.9 IPM Scouting

The student will use models and computer simulations to extend his/her understanding of scientific concepts. [1]

2.4 Exponential Growth

The student will use analyzed data to confirm, modify, or reject a hypothesis. [1]

2.3 Plant Spacing Trials
2.3 Substrate Fertility
2.3 Pansy Detective

Outcome:

The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation.[1]

Assessment:

The student will demonstrate the ability to summarize data. [1]

2.3 Plant Spacing Trials
2.5 Trophic Relationships

The student will explain scientific concepts and processes through drawing, writing, and/or oral communication. [1]

2.3 Plant Spacing Trials
2.4 Exponential Growth
2.4 Illustrating Entrance Points
2.5 Trophic Relationships
4.8 Selecting Mesh Screening
4.9 IPM Scouting

The student will use computers and/or graphing calculators to produce the visual materials that will be used for communicating results. [1]

2.4 Exponential Growth
2.5 Trophic Relationships

The student will use tables, graphs, and displays to support arguments and claims in both written and oral communication. [1]

1.2 Global Events in IPM
2.5 Trophic Relationships
3.7 Information packet Design
3.7 Synopsis of Interviews

The student will create and/or interpret graphics. [1]

2.3 Plant Spacing Trials
2.4 Exponential Growth
4.9 IPM Scouting

The student will read a technical selection and interpret it appropriately. [1]

3.6 How to Read a Pesticide Label
3.6 Understanding a Material Safety Data Sheet

The student will use, explain and/or construct various classification systems. [1]

2.3 Plant Spacing Trials
2.5 Trophic Relationships
4.9 IPM Scouting

The student will describe similarities and differences when explaining concepts and/or principles.[1]

1.1 IPM Venn Diagram

1.2 **Global Events in IPM**
1.2 **Introduction to IPM Quiz**
2.3 **Plant Spacing Trials**

The student will communicate conclusions derived through a synthesis of ideas.[1]

1.2 **Global Events in IPM**
1.2 **How-To Guide for IPM**
1.2 **Presentation on Selected Crop Production**
2.3 **Too Wet, Too Dry**
2.3 **Substrate Fertility**
2.3 **Pansy Detective**
2.3 **Plant Spacing Trials**
2.4 **Exponential Growth**
2.5 **Trophic Relationships**
4.8 **Disease and Viral Test Kits**
4.9 **IPM Scouting**

Outcome:

The student will use mathematical processes.

Assessment:

The student will use ratio and proportion in appropriate situations to solve problems.[1]

2.3 **Plant Spacing Trials**
3.6 **Learning Conversions**

The student will use computers and/or graphing calculators to perform calculations for tables, graphs, or spreadsheets.[1]

2.4 **Exponential Growth**

The student will express and/or compare small and large quantities using scientific notation and relative order of magnitude.[1]

2.4 **Exponential Growth**
4.9 **IPM Scouting**

The student will manipulate quantities and/or numerical values in algebraic equations.[1]

3.6 **Learning Conversions**

The student will judge the reasonableness of an answer.[1]

2.3 **Pansy Detective**
2.3 **Plant Spacing Trials**
2.4 **Exponential Growth**
4.9 **IPM Scouting**
4.9 **Disease and Viral Test Kits**

Outcome:

The student will show that connections exist both within the various fields of science and among science and other disciplines including mathematics, social studies, language arts, fine arts, and technology.[1]

Assessment:

The student will apply the skills, processes, and concepts of biology, chemistry, physics, or earth science to societal issues.[1]

1.2 How-To Guide for IPM
1.2 Global Events in IPM
2.3 Plant Spacing Trials
2.4 Illustrating Entrance Points
4.8 Greenhouse Maintenance

The student will identify and evaluate the impact of scientific ideas and/or advancements in technology on society.[1]

1.2 Global Events in IPM
2.4 Illustrating Entrance Points

The student will describe the role of science in the development of literature, art, and music.[1]

1.1 Class Discussion
3.7 Careers: Training and Licensing

The student will recognize mathematics as an integral part of the scientific process.[1]

2.3 Substrate Fertility
2.4 Exponential Growth
3.6 How to Read a Pesticide Label
3.6 Learning Conversions

The student will investigate career possibilities in the various areas of science.[1]

3.7 Information Packet Design
3.7 Synopsis of interviews

The student will explain how development of scientific knowledge leads to the creation of new technology and how technological advances allow for additional scientific accomplishments.[1]

Plant Pathology: Past to Present by Purdue
2.3 Plant Spacing Trials

[1] Denotes a direct quotation from the Maryland High School Learning Goals published through http://mdk12.org

IPM Career Resources

Careers:

The Land Lovers
http://www.thelandlovers.org/
A basic but informative and effective website that outlines major career areas within the green industry, as well as the common education and skills required.

Green Industry Jobs
http://www.greenindustryjobs.com/
This website compiles the job search engines for several green industry categories including landscape, tree care, nursery, turf, pest control, and maintenance, as well as bilingual resources.

Department of Plant Science and Landscape Architecture.
http://www.psla.umd.edu/plsc/career.cfm

Industry Organizations:

Certified Professional Horticulturalist
http://www.cphquality.org/index.html

Maryland Nursery and Landscape Association
http://www.mnlaonline.org/

Maryland Greenhouse Growers Association
http://www.mdgga.org/

The Association of Specialty Cut Flower Growers
http://www.ascfg.org/

Maryland Arborist Association
http://www.mdarborist.com/

American Society for Horticultural Science
http://www.ashs.org/

American Nursery and Landscape Association
http://www.anla.org/index.cfm

Regulatory Information

Maryland Department of Agriculture
http://www.mda.state.md.us/

Legislative updates in Maryland:

MaGIC
http://www.mnlaonline.org/

Steps to Diagnosing Pest Problems

Rondalyn Reeser and Suzanne Klick,
University of Maryland Extension

Problem Solving Steps:

1. Know what a healthy plant looks like.

Detect problems as they arise. To do so, you need to be able to recognize what plant problems compared to healthy and acceptable variations in plant growth.

2. Notice that there is a problem.

This step requires recognizing that a plant is exhibiting symptoms different from healthy plant characteristics. Routine monitoring will aid in this step.

3. Note specific symptoms.

What do the symptoms look like? When did the symptoms first appear? How are specific symptoms distributed on the plant (upper, lower or middle foliage, etc.)?
Are the symptoms only on one side of the plant?
How are the symptoms distributed throughout the greenhouse: Confined to one location, uniformly distributed, scattered, or limited to one or several varieties?

4. Look for possible causes of these symptoms.

Signs of insects: fecal spots (droppings); frass; spittle; pitch tubes; chewed leaves; honeydew; wax; silk; defoliation; discolored leaves or blossoms; dieback of shoots; twigs or branches; wilting; discolored speckles on leaves; stunted new growth; chlorosis

Signs of diseases: fungal pathogens (foliage, stems, roots); chlorosis; wilting; water soaked or greasy appearance; dead or brownish areas on leaves; curled leaves; abnormal plant growth; necrosis; plant dies suddenly

Signs of environmental disorders: dieback; leaf scorch; sunscald; physical damage to bark or root; thickened and distorted growth; necrosis

Signs of cultural problems: chlorosis; circling roots; necrosis; wilting plants (watering practices); stunted growth (timing of pinch); thickening stems

Nutrient deficiency symptoms:
Symptoms that first appear on older or lower leaves.
- Nitrogen-lower leaves yellow; overall plant is light green; stunted growth; small leaves
- Phosphorus: foliage red; purple or very dark green; stunted growth
- Potassium: tips and edges of leaves are yellow then turn brown; stems weak
- Magnesium: interveinal chlorosis; growth stunted
- Zinc: interveinal chlorosis; leaves thickened; growth stunted

Symptoms appear first on younger or upper leaves.
- Calcium: buds and young leaves die back at tip
- Iron: interveinal chlorosis; growth stunted
- Sulfur: young leaves light green overall; growth stunted
- Boron: young leaves are pale green at base and twisted; buds die
- Copper: young leaves are pale and wilted with brown tips
- Manganese: interveinal chlorosis on young leaves with brown spots scattered throughout leaf
- Molybdenum: interveinal chlorosis; growth stunted

5. Narrow down the possibilities.

Many symptoms have more than one possible cause. Any activity that causes the loss of plant chlorophyll can cause chlorosis. Diseases, insects, and low nutrients can all cause yellowing on leaves by breaking down plant cells. Some insects only feed on one layer of a leaf so distinctions between insects and diseases can be determined due to whether damage to the leaf goes all the way through or not. It is necessary for you to investigate and consequently eliminate plant growth factors in order to come to a proper diagnosis.

Talk to the greenhouse manager and other students to get more information on growing practices of this crop. Refer to your own notes to answer some of your questions such as: What pesticides have been used on or near the crop? How often are plants fertilized? Has the heating or cooling system been functioning properly? When were plants pinched? Have the temperatures been too high? Is this greenhouse using DIF? Are HAF fans installed correctly?

Consult reference books and materials. Take a sample to your extension specialist if necessary.

Can the cause be?

An insect?
- Appear slowly and are not uniformly distributed on the plant or on the site
- Will be able to find the insect on the plant or traces that it had been there
- Some damage symptoms are specific to insects
- Insects are present beyond acceptable threshold levels

A disease?
- Appears slowly and is not uniformly distributed on the plant or on the site
- Most plant diseases are host-specific (only one or two plant species or varieties will be affected)
- Can find evidence of fungal or bacterial pathogens
- Use an Alert test kit or tospovirus kit to test for *Pythium*, *Rhizoctonia*, *Phytophthera*, or INSV/TSWV

Environmental?

- Most problems caused by non-living agents will appear suddenly and affect a wide variety of plants on the site, weakening a plant, which may lead to disease problems
- Symptoms can be similar to disease and insect problems

Conditions that can cause plant problems.

- Light, temperature, humidity
- Poor air circulation
- High output from greenhouse vents
- Clogged irrigation nozzles or drip tubes
- Herbicide spray drift
- Greenhouse shading: too much or too little
- Breakdown of heating or cooling unit; temperature regulation problems or production of ethylene
- Contaminated groundwater source; i.e., herbicides in groundwater

Cultural?
- symptoms can be similar to pest problems due to improper growing practices

Conditions that cause plant problems.

- Improper fertilizer injector calibration
- Close spacing of plants
- Rough handling of plants
- Over, under and uneven watering practices
- Poor soil drainage due to heavy soil mix
- Improper planting depth

6. Make a diagnosis.

By using your detective skills you should be able to determine the cause of the problem.

7. Make a recommendation.

Recommend a control measure to the greenhouse grower. The recommendation can be a chemical application, use of biological controls, a greenhouse equipment purchase, or a change in cultural practices. Follow through to make sure the action taken is effective.

Biocontrol Ideas

The use of beneficial insects and other biological controls serves a dual role in high school IPM. First, it provides experiential learning situations for students. They gain an understanding and appreciation of the biology and ecology involved in horticultural production. Second, the use of biological controls provides a pesticide-free means of preventive or curative pest control.

While a teacher will need to research and assess the growing situation, target pest, host-specificity of a biological control, the following page lists common biological control regimes in horticultural IPM. Be sure to contact your local extension as well as biological control companies for more detailed and species-specific information.

Aphid
- Parasitic wasps (*Aphidius, Aphelinus*)
- Predatory midges
- Lacewings
- *Beauveria bassiana*

Caterpillar
- *Bacillus thuringiensis (Bt)* or *Saccharopolyspora spinosa*

Fungus Gnat
- *Bacillus thuringiensisisraelensis (Bti)* or *Steinernema feltiae*
- *Hypoaspis miles* (predatory mite)
- Beneficial nematodes

Spider Mite
- Predatory mite
- Midges

Thrips
- Minute pirate bug
- Predatory mites such as *Neoseiulus cucumeris* or *Amblyseius degenerans*
- *Saccharopolyspora spinosa*

Whitefly
- Ladybird beetle
- Parasitic wasps such as *Eretmocerus* and *Encarsia spp.*

University of Maryland Extension worked with a local Howard County greenhouse to assess the efficacy of banker plants (a means of maintaining a beneficial population before the target pest population becomes established). http://ipmnet.umd.edu/research/docs/BankerPlantsforAphids-UMD.pdf

Greenhouse Biological Control Suppliers

Koppert Biological Systems
Howell, MI 48843
1502 Old US-23
Tel: +1 810-632-8750
Fax: +1 810-632-8770
www.koppert.com

IPM Laboratories, Inc.
Locke, New York
ph. 315.497.2063
fax. 315.497.3129
http://www.ipmlabs.com/home.php

ARBICO Organics
P.O. Box 8910
Tucson, AZ, 85738-0910
1-520-825-9785
http://www.arbico-organics.com/

Becker Underwood Corporate Headquarters
801 Dayton Avenue
Ames, IA 50010 USA
800-232-5907
http://www.beckerunderwood.com/en/home

BioLogic Company
P.O. Box 177
Willow Hill, Pa. 17271
Phone (717)349-2789
www.biologicco.com

Buglogical Control Systems
P.O. Box 32046
Tucsan, AZ 85751-2046
Phone/Fax: 520-298-4400
www.buglogical.com

EcoSolutions, Inc.
2948 Landmark Way
Palm Harbor FL 34684
PH 727.787.3669 FX 727.787.3669
http://www.anbp.org/products_ecosolutions.htm

Hydro-Gardens, Inc.
PO Box 25845
Colorado Springs, CO 80936
www.hydro-gardens.com

Natural Pest Controls
8864 Little Creek Drive
Orangevale, CA 95662
Phone: (916)726-0855
http://www.natural-pest-controls.com/

Rincon-Vitova Insectaries
P.O. Box 1555, Ventura, CA 93002-1555
108 Orchard Dr , Ventura, CA 93001
1-800-248-2847 Fax 805-643-6267
http://www.rinconvitova.com/index.htm

Sterling Insectary
P.O. Box 1987
Delano, CA 93216
Phone 661.792.6810
Fax 661.792.6880
http://www.sterlinginsectary.com/index.html

Syngenta Bioline Inc.,
P.O. Box 2430
Oxnard California 93034-2430 USA
Tel: +1 805 986 8265
Fax: +1 805 986 8267
http://www.syngenta-bioline.co.uk/Default.html

A more comprehensive list of natural enemy suppliers can be found on the "Natural Enemy Guidelines" Handout from the University of Florida IFAS Extension published May 2010:
http://ipm.ifas.ufl.edu/pdf/Natural_Enemy_Guidelines.pdf

The information given herein is supplied with the understanding that no discrimination is intended and no endorsement by the University of Maryland Extension is implied.

Multimedia Resources for the Classroom

School Gardens and Gardening Tips

http://www.youtube.com/user/UMDHGIC#p/u/0/TQQFsz3aCs4

The HGIC YouTube Channel contains excellent instructive videos on a variety of gardening topics.

From Seed to Flower

http://www.teachersdomain.org/resource/tdc02.sci.life.colt.plantsgrow/

The growth and development of a plant is one of the most spectacular events in nature. Yet, because it happens so slowly, over the course of days or weeks, it is difficult to observe in real time. This video segment depicts plant growth in time-lapse format, allowing the viewer to observe in just a few seconds some of the most important life stages of a plant, from germination to the formation of a flower, and several phases in between. Footage from *NOVA:* "The Shape of Things."

A Story of plant pathology: past to present.

http://www.btny.purdue.edu/outreach/PlantPathStory/

F.H. Tait. Contact information for CD including worksheets, teacher's guide, and answer key: Gail Ruhl ruhlg@purdue.edu English and Spanish versions available.

Rain Gardens

http://www.teachersdomain.org/resource/watsol.sci.ess.water.raingdn/

This video shows how a rain garden at Bernheim Arboretum and Research Forest near Louisville, Kentucky slows down the flow of water from the forest's parking lot and helps prevent soil erosion. Since soil erosion is one of the causes of non-point-source water pollution, rain gardens help protect the water supply. The video defines "site flow," which is the movement of water across a site, and identifies several plants that thrive in the wet conditions of a rain garden.

All in the family

http://www.teachersdomain.org/resource/tdc02.sci.life.evo.allinthefamily/

Are you, your cat, and your lunch related? Since all organisms descended from a single bacterial ancestor, the answer is yes. Of course, some of us are more closely related than others, depending on where in the "family tree" or common ancestor resides. In this *Evolution* Web feature, you'll learn how to assemble accurate evolutionary trees by comparing features of living organisms. Be prepared for some surprises.

American Chestnut Tree

http://www.teachersdomain.org/resource/ket08.sci.life.gen.kettree/

See the devastating impact of blight on the American chestnut tree in this annotated slideshow adapted from KET's *Electronic Field Trip to the Forest*. Learn the scientific processes scientists use to identify the remaining trees, document their locations, and cross-pollinate them with other varieties of chestnut trees to create hybrids that are blight-resistant.

Biological Invaders

http://www.teachersdomain.org/resource/tdc02.sci.life.eco.bioinvaders/

Modern transportation is a major threat to many of the world's native species — invasive organisms stow away in ballast water on ships, cargo, and airplane wheel wells. This video segment from *Evolution:* "Extinction!" features Hawaiʻi's efforts to prevent the brown tree snake from emigrating from Guam. Domingo Cravalho and Lester Kaichi of the Department of Agriculture are featured, and scientist David Burney comments.

Duckweed

http://www.teachersdomain.org/resource/tdc02.sci.life.eco.duckweed/

These images illustrate the above-surface of the water and under-surface anatomy of duckweed *(Lemna spp.)* as well as the typical environment in which these fast-growing plants -- the smallest flowering plants in the world -- are found.

Other Resources:

Horticultural Society of Maryland
http://www.mdhorticulture.org/resources.htm
Lists gardens and arboretums to visit in the state of Maryland.

Discover Entomology Brochure
http://www.entsoc.org/PDF/resources/education/discover.pdf
Entomological Society of America

School IPM Curriculum
http://www.entfdn.org/documents/SchoolIPMCurricula073109v2.pdf
Compiled by the IPM Institute of North America

National Museum of Natural History (Smithsonian Institute)
http://www.mnh.si.edu/

Lab
Entomology activities available at: http://www.entfdn.org/scienceprojects.php

Microscope Access:
Bugscope
http://bugscope.beckman.illinois.edu/
Free service for classrooms

IPM Resources

This resources list includes a variety of books, fact sheets, magazines, and websites that are applicable to greenhouse production and pest management. It is by no means a complete list. The cooperative extension websites for each land grant university have publication sections with a wealth of information on commercial horticulture topics.

BOOKS
Ball Red Book, Volumes I and II
16th or 17th Editions

Ball Identification Guide to Greenhouse Pests and Beneficials
Stanton Gill, University of Maryland, and John Sanderson, Cornell University
Ball Publishing 1998

Plant Protection: Managing Greenhouse Insect and Mite Pests
Raymond A. Cloyd
Ball Publishing 2007

Biocontrol in Protected Culture
Roy G. Van Driesche, Kevin M. Heinz, and Michael P. Parella.
Ball Publishing 2004

Nutrient Deficiencies of Bedding Plants
James L. Gibson, Dharmalingam S. Pitchay, Amy L. Williams-Rhodes, Brian E. Wipker, Paul V. Nelson, and John M. Dole.
Ball Publishing 2007

> *Ball Publishing*
> *PO Box 9*
> *Batavia, IL 60510*
> *888-888-0013*
> *http://www.ballbookshelf.com*

MAGAZINES
Greenhouse Grower
Meister Publishing Company
37733 Euclid Avenue
Willoughby, OH 44094-5992
Phone: 440-942-2000
Fax: 440-975-3447
info@meisternet.com
www.greenhousegrower.com

GrowerTalks
Ball Publishing
335 N. River Street
Post Office Box 9
Batavia, IL 60510-0009
Phone: 630-208-9080
Fax : 630-208-9350
info@ballpublishing.com
http://www.ballpublishing.com/growertalks/default.aspx

Greenhouse Management
GIE Media
4020 Kinross Lakes Pkwy
Richfield, OH 44286
800/456-0707
http://www.greenhousemanagementonline.com/Default.aspx

WEB-BASED PUBLICATIONS AND RESOURCES

University of Maryland Extension
Many publications are available online. The following site includes information on how to order publications http://extension.umd.edu/publications/Category.cfm?ID=C

EB 363 Total Crop Management for Greenhouse Production with an emphasis on Integrated Pest Management. Stanton A. Gill, Debby Smith-Fiola, Karen Rane, Andrew Ristvey, Chuck Schuster, Joyce Latimer, Brian Whipker, Will Healy, Gerald Brust, Kate Everts, Megan McConnell, David Ross, and Mark VanGessel. <http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm>.

FS 762 Thrips Management in Greenhouses
Stanton Gill, Ethel Dutky, Michael Raupp, John Davidson, and Sueo Nakaraha (USDA)
http://extension.umd.edu/publications/PDFs/FS762.pdf

FS 777 Whitefly (Homoptera-Aleyrodidae) Control in Greenhouses
Stanton Gill and Paula Shrewsbury

FS 838 Plant-parasitic nematodes in Maryland.
Sandra Sardanelli and Gerald E. Brust
http://extension.umd.edu/publications/PDFs/fs825.pdf

FS 593 Starting a Greenhouse Business
Will Healy, James Hanson, and Stanton Gill
http://extension.umd.edu/publications/PDFs/FS593.pdf

EB 351 Greenhouse Heating, Circulation, and Ventilation Systems

IPM for Commercial Horticulture

http://ipmnet.umd.edu/greenhouse/grnhs_pubs.htm

Insects (aphids, brown marmorated stink bug, whitefly, sunflower moths, thrips)

http://ipmnet.umd.edu/research/index.htm

Greenhouse Research: aphid, foliar nematode, beneficial wasps and whitefly

http://ipmnet.umd.edu/cutflower/cut_pubs.htm

FS-686: Producing Annual Sunflowers as Cut Flowers
FS-687: Production of Hybrid Lilies as Cut Flowers
FS-684: Production of Celosia as cut flowers
FS-6837: Production of Tulips as Cut Flowers

Environmental Horticulture

http://environmentalhorticulture.umd.edu/#Divider.

HGIC Publications.

http://www.hgic.umd.edu/content/onlinepublications.cfm

Plant Diagnostic Laboratory.

http://www.plantclinic.umd.edu/

Plant Nematology Resources.

http://nematology.umd.edu/

Regional Soil Test Labs.

http://www.hgic.umd.edu/_media/documents/RegionalSoilTestLabsCharthg110b.pdf

North Carolina State University

NC State has a wide range of publications available online on producing greenhouse crops with a strong emphasis on fertility management and identifying nutrient problems.
http://www.ces.ncsu.edu/depts/hort/floriculture/

Rutger's University

Northeast Greenhouse IPM Notes
http://www.rce.rutgers.edu/pubs/greenhouseipmnotes/

Greenhouse and Nursery Publications
http://www.rce.rutgers.edu/pubs/subcategory.asp?cat=3&sub=20

Natural Resource, Agriculture and Engineering Service offers publications focusing on greenhouse structures and environmental management.
http://www.nraes.org/

Virginia Tech

http://www.hort.vt.edu/floriculture/publication.html

Penn State

Pennsylvania IPM

http://extension.psu.edu/ipm/program/greenhouse

http://extension.psu.edu/ipm/schools/educators/curriculum

Northeast IPM

Comprehensive listing of IPM publications made available through Northeast IPM

http://www.northeastipm.org/ipm_resources_all.cfm

Maine

Compiled listing of high school curriculum and lesson plans related to IPM and horticulture.

http://www.maine.gov/agriculture/pesticides/school-ipm-curriculum/Extension%20Pages/highschool_home.htm

ADDITIONAL SITES

CDMS-Crop Data Management Systems – Pesticide labels online

http://www.cdms.net

Maryland Department of Agriculture Pesticide Database Searches

http://www.kellysolutions.com/md/searchbyproductname.asp

Cornell University

"Biological Control – A Guide to Natural Enemies in North America"

Editors: C.R. Weeden, A.M. Shelton, Y. Li, and M.P. Hoffmann

http://www.nysaes.cornell.edu/ent/biocontrol/

Paul Ecke Ranch and The Flower Fields

http://www.Ecke.com

Maryland Department of Agriculture-Plant Industries and Pest Management

Links to Pesticide Regulation, Plant Protection, and Weed Control

http://www.mda.state.md.us/plants-pests/

Maryland Department of Agriculture

Integrated Pest Management (IPM) in Schools

http://www.mda.state.md.us/plants-pests/pesticide_regulation/index.php

University of Massachusetts Floral Facts

http://www.umass.edu/umext/floriculture/

Some common sources for pest monitoring supplies

Company	Address	Sticky Cards	Hand Lenses	Portable Microscopes	Flags/Tape	Traps	EC and pH Meters	Disease Test Kits
Aerokure Intl, Inc. http://www.aerokure.com	PO Box 22 Sherbrooke, Quebec J1H5H5	X				X		
Agdia, Inc. http://www.agdia.com	30380 County Road 6 Elkhart, Indiana 46514							X
BioQuip Products http://www.bioquip.com	2321 Gladwick Street Rancho Dominguiz, CA 90220		X	X		X		
Contech Enterprises Inc. www.contech-inc.com	Unit 115, 19 Dallas Rd. Victoria, BC V8V 5A6 Canada	X				X		
Carolina Biological Supply Company http://www.carolina.com	2700 York Road Burlington, NC 27215		X	X			X	
Forestry Suppliers, Inc. www.forestry-suppliers.com	205 West Ranking St, PO Box 8397 Jackson, MS 39284			X	X		X	
Gempler's www.gemplers.com	PO Box 270 Mt. Horeb, WI 53572	X	X	X	X	X	X	
Griffin Greenhouse and Nursery Supplies www.griffins.com	33 Hess Road Leola, PA 17540				X		X	
Hanna Instruments, Inc. www.hannainst.com	584 Park East Drive Woonsocket, RI 02895				X		X	
Hydro-Gardens, Inc. www.hydro-gardens.com	PO Box 25845 Colorado Springs, CO 80936	X	X	X		X		

Company	Address	Sticky Cards	Hand Lenses	Portable Microscopes	Flags/Tape	Traps	EC and pH Meters	Disease Test Kits
IPM Laboratories, Inc. www.ipmlabs.com	980 Main Street Locke, NY 13092-0300	X	X					
K.C. Schaefer Supply Co., Inc. www.kcschaefer.com	2655 Springwood Road York, PA 17402		X					
MacKenzie Nursery Supply, Inc. www.mnsinc.cc	3891 Shepard Road Perry, Ohio 44081		X					
Markson Lab Sales www.markson.com	PO Box 3616 Honolulu, HI 96811			X			X	
Maryland Plants and Supplies www.mdplantsandsupplies.com	9103-G Yellow Brick Rd. Baltimore, MD 21237	X					X	
Neogen Corporation www.neogen.com	620 Lesher Place Lansing, MI 48912							X
Penn State Seed Co www.pennstateseed.com	224 Maple Avenue Bird in Hand, PA 17505	X	X					X
Pest Management Supply Co. www.pestmanagementsupply.com	PO Box 938 Amherst, MA 01004					X		
Trece, Inc. www.trece.com	PO Box 6278 Salinas, CA 93912						X	
Whitmire Research Labs www.wmmg.com	3568 Tree Court Industrial Blvd. St. Louis, MO 63122	X					X	

University of Maryland Extension Contacts

Research and Education Centers

Central Maryland Research and Education Center (CMREC)
Headquarters Building
11975-A Homewood Road
Ellicott City, MD 21042
301.596.9330
http://ipmnet.umd.edu/
http://ipmnet.umd.edu/greenhouse/grnhsandcutalerts/index.htm

Western Maryland Research & Education Center
18330 Keedysville Road
Keedysville, MD 21756-1104
301.432.2767

Lower Eastern Shore Research and Education Center
27664 Nanticoke Road
Salisbury, MD 21801-8437
410.742.1178

Wye Research and Education Center
P.O. Box 169
124 Wye Narrows Drive
Queenstown, MD 21658
410.827.8056

County Offices

Allegany County
One Commerce Drive
Cumberland, MD 21502
301.724.3320
http://allegany.umd.edu/

Anne Arundel County
7320 Ritchie Highway, Suite 210
Glen Burnie, Maryland 21061
410.222.6755
http://annearundel.umd.edu/

Baltimore County
1114 Shawan Road, Suite 2
Cockeysville, MD 21030
410.771.1761
http://baltimorecounty.umd.edu/

Baltimore City
6615 Reisterstown Rd, Suite 201
Baltimore, Maryland 21215
410.856.1850
http://baltimore.umd.edu/

Calvert County
Community Resources Building
30 Duke Street, Room 103
P.O.Box 486
Prince Frederick, MD 20678
410.535.3662; 301.855.1150 (DC Line)
http://calvert.umd.edu/

Caroline County
207 S. Third Street
Denton, MD 21629
410.479.4030
http://caroline.umd.edu/

Carroll County
700 Agriculture Center Dr
Westminster, MD 21157
410.386.2760
http://carroll.umd.edu/

Cecil County
200 Chesapeake Blvd., Suite 1500
Elkton, MD 21921
410.996.5280
http://cecil.umd.edu

Dorchester County
501 Court Lane, Room 208
P.O. Box 299
Cambridge, MD 21613
410.228.8800
http://dorchester.umd.edu/

Frederick County
330 Montevue Lane
Frederick, MD 21702
Phone: 301-600-1594
301.600.1672
http://frederick.umd.edu

Garrett County
1916 Maryland Highway, Suite A
Mt. Lake Park, MD 21550
301.334.6960
http://garrett.umd.edu

Harford County
P.O. Box 663
2335 Rock Spring Road
Forest Hill, MD 21050
410. 638.3255
http://harford.umd.edu

Howard County
3300 N Ridge Road, Suite 240
Ellicott City, MD 21043
410.313.2707
http://howard.umd.edu

Kent County
709 Morgnec Road, Suite 202
Chestertown, MD
410.778.1661
http://kent.umd.edu

Montgomery County
18410 Muncaster Road
Derwood, MD 20855
301.590.9638
http://montgomery.umd.edu

Prince George's County
6707 Groveton Drive
Clinton, MD 20735
301.868.9366
http://princegeorges.umd.edu

Queen Anne's County
505 Railroad Avenue, Suite 4
Centreville, Maryland 21617
410.758.0166
http://queenannes.umd.edu

St. Mary's County
21580 Peabody Street
Leonardtown MD 20650
301. 475.4482
http://stmarys.umd.edu

Somerset County
Howard B. Anderson Building, Princess Anne Industrial Park
30730 Park Drive
Princess Anne, Maryland 21853
410.651.1350
http://somerset.umd.edu

Talbot County
Talbot Commerce Park
28577 Marys Court, Suite 1
Easton, Maryland
410.822.1244
http://talbot.umd.edu

Washington County
7303 Sharpsburg Pike
Boonsboro, MD 21713
301.791.1404
http://washington.umd.edu

Wicomico County
28647 Old Quantico Rd
Salisbury, MD 21801
410.749.6141
http://wicomico.umd.edu