Greenhouse Pest Control

Category 6d

Study Guide for Commercial Applicators

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A Guide for Commercial Applicators

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STATE AND FEDERAL LAWS
The Pesticide Applicator Core Training Manual discusses federal and state laws that govern the handling and use of pesticides. Review the core manual to understand how laws and regulations affect pesticide practices and use. These laws include federal laws such as the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Occupational Safety and Health Act (OSHA), the Endangered Species Act, and the Federal Migratory Bird Treaty Act. Pesticide technicians should keep up-to-date copies of the laws and review their contents periodically. Copies of these laws can be obtained from the Ohio Department of Agriculture.

FEDERAL LAWS
FIFRA
This is the basic federal law administered by the Environmental Protection Agency (EPA) that regulates pesticides (their use, handling, storage, transportation, sale, disposal, etc.). The Ohio Department of Agriculture (ODA) has a cooperative agreement with the EPA to enforce some provisions of FIFRA in Ohio. Some of the provisions of FIFRA are that the EPA must register all pesticides before they can be sold or used. The pesticides must be classified as either *"general use"* or *"restricted use."* General-use pesticides are those that can be purchased without restriction. Restricted-use pesticides are those that can be used only by or under the direct supervision of a certified applicator. FIFRA also stipulates that persons who misuse pesticides (in a way that is "inconsistent with the pesticide labeling") are subject to penalties.

OSHA
The U.S. Department of Labor (DOL) administers OSHA. OSHA governs the record-keeping and reporting requirements of all work-related deaths, injuries, and illnesses of businesses with 10 or more workers.

Endangered Species Act

This act requires the U.S. EPA to ensure that endangered or threatened plant and animal species are protected from pesticides. This act requires each pesticide label to limit its use in areas where these species could be harmed. Category 6d applicators must consider the possibility that the pesticides they apply may affect endangered or threatened species. The Ohio Department of Natural Resources (ODNR) Wildlife and Fisheries Management divisions maintain the federal and state endangered or threatened species lists. Ohio applicators that want to be sure they are complying with the act must take the initiative and consult with the ODNR to be sure that there are no endangered or threatened species in their area. One of the goals of pest management is to protect off-target plants and animals from pesticides, whether they are endangered or not.

THE STATE LAW

The Pesticide Law

The Ohio Pesticide Law is the law that governs the pesticide applications in the state of Ohio. The Ohio Department of Agriculture is the state agency that regulates this law and the pesticide applicators that are licensed by the state. If you have any questions or concerns, please contact the Ohio Department of Agriculture, Pesticide Regulation Section at 614-728-6987.

DEFINITION OF CATEGORY

The Definition

The definition for greenhouse pest control as stated in the law is as follows: Category **6** is "**Ornamental Pest Control**" which means the application of pesticides to ornamental plants or areas for the control of any pests except vertebrates. The subcategory **D “Greenhouse Pest Control”** means the application of pesticides to control insects, diseases, and weeds of plants grown under glass or plastic cover.

THE STATE PLAN FOR OHIO

The State Lead Agency

The state lead agency for the plan is the Ohio Department of Agriculture. The Governor assigned the responsibility of this plan to the Division of Plant Industry on March 12, 1973.

The State Plan Document

The plan is the document by which the Ohio Department of Agriculture, Pesticide Regulation Section and The Ohio State University Extension share the responsibilities for the certification and training of the Ohio pesticide commercial and private applicators. The Ohio Department of Agriculture is responsible for the testing and licensing of pesticide applicators. The Ohio State University Extension is responsible for the continuing education credits for those applicators that wish to re-certify and not re-test.

The plan sets forth the standards by which the Ohio Department of Agriculture and The Ohio State University Extension develop study materials, pesticide exams and pesticide training. These standards are called “Standards of Competency.”

Standards of Competency

Commercial applicators are required to demonstrate their knowledge and understanding of the handling and use of pesticides by means of written, closed book examinations; based on the standards of competency set forth in 40 Federal Code of Regulations (CFR) 171.4. Standards are set forth for the Core exam and for all the categories. The additional “Standards of Supervision” of non-certified applicators must be met, such as availability related to the hazard of the situation. Also needed are instructions and guidance when presence of a supervisor is not required.

General Standards

- Commercial applicators shall demonstrate practical knowledge of the principles and practices of pest control and safe use of pesticides

- A comprehension of labeling format and terminology together with an understanding of permitted uses, classification, associated warnings, precautions and other restrictions, such as reentry

- Safety factors related to handling, storage and disposal of pesticides, particularly those factors pertaining to the prevention of personal injury through accidents, misuse, symptoms of pesticide poisoning and first-aid treatment

- Adverse environmental effects, such as water or soil pollution and injury to non-target organisms

- The recognition of common types of pests, their damage symptoms, basic developmental stages and optimum periods of pesticide susceptibility

- Types of formulations of pesticides (both chemical and functional), their modes of action, persistence and compatibility with various other compounds

- Application techniques for greatest effectiveness with minimal adverse side effects

- Appropriate state or federal laws pertaining to the production, distribution, sale or use of pesticides and to the supervision of non-certified applicators

- Potential of contaminating wells, ground water and surface water by pesticides

- Areas in the state where endangered or threatened plants and animal species are to be protected from pesticides.

Specific Standards

Ornamental Plant and Shade Tree Pest Control “6” Subcategory “d” Greenhouse Pest Control: Commercial applicators shall demonstrate a practical knowledge of:

- The common insects, diseases and weed pests of greenhouse pests, with an emphasis on diagnostic characteristics and damage symptoms

- The common pesticides registered for use against these pests, their functional classifications and modes of action

- Rates, methods and timing of applications

- Methods to prevent or minimize pesticide damage to plants, humans and non-target areas

- Physiological disorder of plants resembling pest injury or herbicide damage

- Other pertinent information necessary for safe and adequate application of pesticides

PESTICIDE LICENSE INFORMATION

Application Process

The application and fee are only valid for the licensing year noted on the application and cannot be extended to the next licensing year once it is submitted. If all requirements are not met within the license year listed on the application, the application and fee are voided and the fee is non refundable. License fees cannot be transferred from one company to another. When a first time applicant submits the application and fee, study material will be sent to assist in preparation for the examinations. Categories are listed on the application.

Exams

Examination requirements are: the General-Core examination which covers the law, regulations, safety, disposal and related topics, and an examination for each category in which you need to be certified and licensed. The categorical examinations are specific to what area you will be applying the insecticide, herbicide, fungicide, etc. All examinations consist of multiple choice, photo identification and true/false questions. The exams are not open book exams. Exam results are mailed two-three weeks after the test date; they are not given over the phone. If you fail the exams, you must wait at least five days to retest. If you need to retest there is no additional fee required. Exams are only valid for one year from the date you pass the exam. Within that year if you do not meet the other qualifications for a license to be issued, the exams expire and you will need to retest. There is a Pesticide Applicator New School for new applicants conducted by The Ohio State University that is held every year in late February or early March. Their website is: http://pested.osu.edu This site also offers other licensing information: test sites, recertification sites and study material.

Please call the Pesticide Regulation Section at (614) 728-6987 or 1-800-282-1955 to schedule your appointment to take the exams or register online at www:ohioagriculture.gov. The application is only valid for the licensing year in which you have applied. (The year is listed on the application.) If you do not meet requirements within the year that you have applied, then a new application and fee will be required, and no refund is given. Ohio Dept. of Agriculture website: www.ohioagriculture.gov - look under "Pesticides."

Commercial Renewal and Recertification Information

Once you have passed the applicable exams for the license and a license has been issued, you are certified for three years. The license must be renewed continuously every year in order to keep the three-year certification valid. You need to renew the license every year (at the end of September), which consists of submitting a renewal application and fee. You need to recertify every three years (the recertification due date is printed on your license) by retesting or attending recertification programs. Your recertification is based on the first year you obtained your license, which is based on the license year you passed exams and met all other requirements. Once you have been issued a license, you may begin obtaining your recertification credits at any time during the three-year recertification cycle. You must obtain the following requirements for recertification: **TOTAL MINIMUM OF FIVE HOURS OF TRAINING CONSISTING OF 1 HOUR OF CORE TRAINING AND ½ HOUR IN EACH CATEGORY YOU ARE LICENSED – HOWEVER, IT MUST BE A TOTAL MINIMUM OF FIVE HOURS.** If you have met your category requirements you must still make sure you meet the time requirement by attending approved classes whether they are in your licensed category or not.

If you do not meet the recertification requirements of 1-hour minimum in Core, at least ½ hour in your licensed category or categories with a total minimum time of 5 hours before the recertification expiration date listed on your license, then you must retest.

Chapter 1
Study Questions

1. FIFRA is the state law that governs pesticide applicators in Ohio:

   A. True
   B. False *

2. The Ohio pesticide law is the document that sets forth the standards of competency for pesticide applicators:

   A. True
   B. False *

3. The general standards are the standards that set forth the competency for the specific categories:

   A. True
   B. False *

CHAPTER 2
THE GREENHOUSE

Learning Objectives

1. What a greenhouse is
2. Why greenhouses are used
3. Benefits of this study guide

(Figure 1.1) The Greenhouse

THE STRUCTURE

A greenhouse is a structure that is under glass or plastic. This structure may or may not be heated depending upon what is grown inside. Many of the plants that are grown in most greenhouses start out as seeds or plugs (small plants). A variety of plants are grown in greenhouses such as flowers, vegetables, herbs and other ornamental plants.

WHY GREENHOUSES ARE USED

Throughout much of the year, a greenhouse exists as an "oasis" of green. Greenhouse crops know no winter, nor do they undergo prolonged droughts. Many growers get a head start on the growing season with the use of greenhouses. Therefore, the flowers, vegetables, herbs and other ornamental plants that the garden centers sell are ready for consumers when they are ready to buy and plant in the spring. The greenhouse is a very favorable place for the existence, multiplication and spread of insects, mites and disease-causing agents. It is almost impossible to grow a commercially acceptable greenhouse crop without a program of health management that involves effective pest and disease prevention and control.

STUDY GUIDE

This study guide will provide you, the soon to be commercial applicator, with the latest information available on the control of insects, diseases and weed control on greenhouse crops. To receive the fullest benefit from this publication, first prepare yourself for the types of problems you may encounter. Second, be aware that new information exists that provides increased capabilities in the control of pest problems. Many of these capabilities involve newly labeled pesticides, new cultivars or types of plants, and new cultural procedures that increase greenhouse sanitation and reduce crop stresses.

A few minutes spent now reading this publication will aid you greatly in being prepared and able to pass the commercial greenhouse exam. There are several keys to success, and most will be discussed in the following pages of this manual.

The Commercial Greenhouse 6d exam questions were taken from the contents of this manual. This manual is all you need to study to answer the questions on the exam.

Chapter 2
Study Questions

1. A greenhouse is a structure that is under plastic or cloth.

   A. True
   B. False *

2. Greenhouses are used because the environment can be controlled in the cold weather.

   A. True *
   B. False

3. Many plants can be grown in a greenhouse including flowers, herbs and vegetables.

   A. True *
   B. False

Chapter 3
GREENHOUSE IPM

Learning Objectives
1. Greenhouse IPM
2. Cultural methods
3. Mechanical methods
4. Biological methods
5. Chemical methods
6. Crop Scouting and Trapping

GREENHOUSE IPM (INTEGRATED PEST MANAGEMENT)
Some major challenges to greenhouse production and profitability are insects, diseases and weeds. IPM is a very important management tool of these pests. The goal of IPM is to manage and control these pests in an economical and ecological way.

IPM involves the integration of cultural, physical, biological and chemical practices to grow crops with the least amount of pesticide use as possible. Monitoring, sampling, and record keeping could be a determining factor when control measures are needed. These tools should be used to keep pests below an economically damaging threshold. Pest management, not eradication, is a goal of IPM.

IPM is adaptable to all greenhouse-grown crops and involves specific techniques to manage pests. These techniques are:

Monitoring or scouting programs
- Individual plant inspection
- Colored sticky cards
- Indicator plants

Accurate pest identification is the first step in the pest management program. It is crucial to know the major pests that are likely to appear, where to look for them, and how to identify them. It is also very important to understand their life cycles and their interaction with other pests in the greenhouse.

Record keeping to identify trends and direction for your pest management program

Exclusion techniques to prevent pests from entering the production area
- Insect screens to exclude pests from entering through doors and ventilation systems

Cultural practices to prevent problems
- Soil testing
- Sanitation

Biological control, living organisms used to reduce the incidence of pest organisms

Chemical control
- Proper choice of pesticides
- Proper timing of pesticide application
- Proper application procedure
- Insect growth regulators (IGR's), insecticides that interfere with the normal insect development of the molting process

CROP SCOUTING AND TRAPPING
A crop-scouting program to detect early pest infestations includes sticky trap cards and a visual inspection. This should be completed at least weekly. If a pest infestation is detected, sticky trap cards and a visual should be conducted more often. Also, regular scouting should be done to measure the effectiveness of the control program. A hand lens is a very useful tool to detect live pests.

Monitoring records should be kept to show trends of pests, control and to allow for identification of pest trends. If plant symptoms appear, the grower can quickly see what measures were used and the effects on the crop and environment.

CULTURAL METHODS

Cultural controls are horticultural practices that disrupt or reduce pest populations. Effective cultural techniques include sanitation, resistant crop varieties, fallow periods, and modification of watering practices.

Sticky Ribbons

Sticky ribbons are long sticky insect strips that are hung throughout the greenhouse. Unlike sticky traps used for monitoring, the primary use of sticky ribbons is to reduce the numbers of flying insect pests by simply catching them.

Sanitation

The goal of sanitation is to eliminate all possible sources of pest contamination. Weeds inside and near the outside of the greenhouse can harbor pests. It is best to pull the weeds inside the greenhouse rather than spray them, because insects may survive the spray and migrate onto the greenhouse crops. Bag all the weeds and dispose of them outside of the greenhouse.

A 10-30 foot vegetation-free zone around the outside perimeter of the greenhouse, especially near the vents and opening, can decrease pests. The vegetation-free zone can be provided by mulch, gravel or other barriers and eliminate the need for herbicide use.

Plant debris from previous crops can also be a source of both immature and adult pests. Clean up all debris from prior crops and dispose of infested plants. The greenhouse should be thoroughly cleaned and left empty for at least one week, prior to beginning the next crop. This enables removal of all pest stages and starves any remaining adults. Closing the greenhouse when it is empty in the summer will increase the temperature and help kill any pests that are left.

Inside the greenhouse, a clean stock program should be in place. This includes temporary quarantine and thorough inspection of all plants upon arrival from other greenhouses, and regular monitoring of stock plants used for propagation. If a separate section of the greenhouse cannot be dedicated to this purpose, flag or tag all incoming plants to be able to track them if necessary. All new plant material should be thoroughly inspected for the presence of pests to ensure that no infested plants are introduced into the greenhouse. Greenhouse workers should avoid wearing yellow or blue clothing, because many pests are attracted to these colors and may hitch a ride on the fabric from one greenhouse to the next. Additionally, if possible, workers need to enter clean areas first, before moving to infested areas.

Crop Resistance

Crop varieties may have some or total resistance to a pest. If the number of pests on a variety is reduced but not eliminated, resistance is partial. If there are no pests found on the plants, the variety is said to have total resistance.

Susceptible varieties should be placed together in the greenhouse and monitored closely. This insures early detection of pest problems.

Sometimes chemical controls work better when using resistant varieties. Biological control organisms may be more effective with resistant varieties.

Fallow Periods
Insects and mites can be an ongoing problem in a greenhouse because there is often a constant supply of plant material. This plant material provides food for the pest and for their offspring. Removal of all plant material for a sufficient period of time results in starvation of the pest. This is very true in cool, temperate areas where vents and doors can be closed for much of the year to prevent pest movement into and out of the greenhouse. During the fallow period method, the greenhouse temperature should be warm enough to prevent pests from going into hibernation. All plant material must be removed from the greenhouse during this period. Fumigation of an empty greenhouse may increase the effectiveness of this method. Sometimes the economics of crop production may override fallow periods, but the idea should be kept in mind when considering pest control options.

MECHANICAL METHODS

Mechanical methods are the use of physical means to control pests. Screens that exclude or confine pests, vacuuming, pruning and roguing (selective pulling out) are all examples of mechanical pest controls.

Screening
Insect screens physically exclude the entry of lightweight, airborne insects like aphids, whiteflies, and thrips. Although the tiny pores of the insect screens prevent entry of insects, they can also impede the flow of air. Some specialists say the area of the screen should be three times that of the area covered (door, ventilation) to facilitate sufficient air intake. To accomplish this, screen houses designed to enclose both the cooling pads and greenhouse entranceway can be installed.

Mechanical Weed Control
Greenhouse weed control cannot be over-stressed. Weeds harbor insects, mites and plant diseases. No weeds should be tolerated, remove them regularly.

Pruning and Roguing (Selective pulling)
Discarding infested or diseased plants sometimes is more cost effective than using a chemical control.

An effective way to manage some pests on plants is pruning. For example, removing the lower leaves of poinsettias, after a healthy upper canopy develops, often reduces whitefly numbers.

Roguing (selective pulling out) is also a very good method to use if you find diseased or pest infested plants because you can just simply pull them out and dispose of them properly.

BIOLOGICAL METHODS

Biological methods are the use of living organisms to control crop pests. Biological control of greenhouse insect pests can be achieved through release of bio-control agents like predatory mites, pirate bugs, soil-dwelling mites, and parasitic insects.

Implementing a biological control program in a greenhouse is management intensive and requires more knowledge on the part of the grower than for traditional pest control programs. Proper species identification is key before a control program using predators or parasites is initiated.

Knowing the lifespan of the beneficial species selected is important too, since fewer releases are required if sufficient numbers of parasites or predators are maintained. Some species live only a few days while others may live for a few weeks.

Their life cycles will have an affect on how often they are released.

A very important thing to keep in mind with using biological controls is that even residual insecticides can harm them.

It is very important to identify which pesticides are less harmful to beneficial organisms. Currently, there are several commercial suppliers of biological control agents.

Predators and Parasites
Predators are organisms that capture and devour their prey. The ladybird beetle is the most common greenhouse predator. This predator can eat up to 50 aphids a day. Other important insect predators include:

- Lacewings that feed on aphids, scales, mealybugs, thrips, mites and insect eggs;

- The larvae of syrphid flies (also called "flower flies") consume aphids and small ants;

- Predatory mites that feed on different types of phytophagous mites, including the all-too-common two-spotted spider mite; and

- Predatory nematodes such as *Steinernema carpocapsae,* sold as BioSafe or Vector that feed on certain soil inhabiting pests like fungus gnat larvae.

Parasitic insects that lay their eggs on or in the body of a pest species are useful pest controls. When the eggs hatch, the immature or larval stages of the parasite develop by feeding on and killing the pest.

Parasitic insect species will usually attack only one species of pest because they are highly specialized.

Pathogens
Bacteria, fungi, viruses and nematodes are considered pathogens and disease-causing organisms. They play a very important role in regulating pest populations in the greenhouse.

There are several pathogens marketed as pest control agents. *Bacillus thuringiensis,* or BT is sold as Gnatrol, Dipel, Xentari. Gnatrol controls a variety of leaf chewing caterpillars and is also used against fungus gnats. Another pathogen is a fungus called *Verticillium lecanii.* It is sold as Vetalec or Mycotel.

CHEMICAL METHODS
A pesticide can have a different effect on an individual pest. Therefore, some pesticides will control immature forms of a pest and some will not; some will control adults and not immatures. The pesticide label has all the information needed to do an effective pesticide application. Reading the label will save you time, money and will allow you to be more efficient to control the pest.

Like anything else, pesticides can also lose their effectiveness over time. Look on the label for an expiration date or contact the manufacturer if you have a question about the shelf life of a pesticide.

Multiple problems can occur when pesticides are misused or overused. Be sure to read the label and follow all the directions because "THE LABEL IS THE LAW."

Delivery
The delivery method of a pesticide may affect how well a pesticide works. The application is most successful when:

- The correct amount of pesticide is used
- The correct equipment is used
- The droplet size is correct
- The coverage is correct
- The particle distribution is good

Resistance to Pesticides
A major concern for most greenhouse owners is arthropod pests' resistance to pesticides. Numerous factors have lead to resistance of pesticides. These include pest biology, the intensity of past and present chemical use, aspects of the greenhouse setting, and commercial production practices.

A combination of IPM methods used along with pesticides will reduce the occurrence of pesticide resistance. In addition, when doing multiple applications during the season, it is very important to rotate products with different mode of action. You can learn more from the IRAC web site (http://www.plantprotection.org/irac/)

Insecticides
The word "Insecticide" was first used about 130 years ago. Primitive insecticides have been in use for several thousands of years. Several categories of insecticides exist:

- Inorganic
- Organochlorines
- Organophosphates
- Carbamates
- Pyrethroids
- Botanicals
- Neonicotinoids
- Insect Growth Regulators
- Miscellaneous

Inorganic – Inorganic minerals such as heavy metals and arsenical compounds have been used as insecticides, although they are usually toxic to a wide range of organisms, and in general, are not specific in their action.

Organochlorines – Advances in the 1930's with synthetic organic chemistry caused the rapid development of OC molecules. Their use is now increasingly restricted.

Organophosphates – This group varies widely in its insecticidal activity and mammalian toxicity. Mode of action is the inhibition of the enzyme Cholinesterase – crucial for normal nervous impulse transmission.

Carbamates – Synthetic versions made available in the early 50's, Carbamates are generally quick acting with relatively low mammalian toxicity, although exceptions do exist.

Pyrethroids - Pyrethrins are natural insecticides produced by certain species of the chrysanthemum plant. The flowers of the plant are harvested shortly after blooming. They are either dried and powdered or the oils within the flowers are extracted with solvents. The resulting pyrethrin containing dusts and extracts usually have an active ingredient content of about 30%.

These active insecticidal components are collectively known as pyrethrins. Two pyrethrins are most prominent, pyrethrin-I and pyrethrin-II. The pyrethrins have another four different active ingredients, Cinerin I and II and Jasmolin I and II. Pyrethrin compounds have been used primarily to control human lice, mosquitoes, cockroaches, beetles and flies. Some "pyrethrin dusts," used to control insects in horticultural crops, are only 0.3% to 0.5% pyrethrins, and are used at rates of up to 50 lb/A. Other pyrethrin compounds may be used in grain storage and in poultry pens and on dogs and cats to control lice and fleas.

The natural pyrethrins are contact poisons which quickly penetrate the nerve system of the insect. A few minutes after application, the insect cannot move or fly away. But, a "knockdown dose" does not mean a killing dose. The natural pyrethrins are swiftly detoxified by enzymes in the insect. Thus, some pests will recover. To delay the enzyme action so a lethal dose is assured, organophosphates, carbamates, or synergists may be added to the pyrethrins.

Semisynthetic derivatives of the chrysanthemumic acids have been developed as insecticides. These are called pyrethroids and tend to be more effective than natural pyrethrins while they are less toxic to mammals. One common synthetic pyrethroid is allethrin.

Botanicals – Insecticides of vegetable origin. Many are still used today. This class of molecules includes Pyrethrin, Nicotine and Derris.

Neonicotinoids – These compounds are fairly new neurotoxins. They are modeled from naturally occurring nicotine compounds. They act on the insect central nervous system causing irreversible blockage of post-synaptic acetylcholine receptors.

Insect Growth Regulators

Insect growth regulators (IGRs) are another less toxic pesticide control option for pests. IGRs typically kill insects by disrupting their development. They have a very complex mode of action that precludes insects from rapidly developing resistance. IGR’s can work in several ways:

- they can mimic juvenile hormones, so that insects never enter the reproductive stage of development
- they can interfere with the production of chitin, which makes up the shell of most insects
- they can interfere with the molting process

IGR’s usually work through ingestion, so good spray coverage is essential. They generally do not affect non-target species such as humans, birds, fish or other vertebrates. There are minimal re-entry restrictions for most IGR’s. Use of IGR’s is generally prohibited by organic certification organizations because the products are synthetic.

IGR’s can sometimes be used in conjunction with biological control efforts and may provide growers with a “safety net” should beneficial controls fail to keep the pests below economically damaging levels.

Miscellaneous – Biologicals, Fumigants, and types of insecticides are classified in this section.

Miticides

Miticides are pesticides for the control of mite populations on greenhouse crops. There are many different products on the market today for this type of problem.

Fungicides

Fungicides are pesticides for the control of fungus. They are also used for disease control that is caused by fungus. There are many different products on the market today for this type of problem.

Biorational Pesticides

Biorational or Biopesticides are known as the least-toxic pesticides used in greenhouses. When the use of a pesticide is necessary, materials should be selected that are least harmful to the predators and parasites released into the greenhouse.

Insecticidal soap, horticultural oils and the bacterium Bacillus thuringiensis are examples of insecticides that can be safely integrated into a biological control program. The advantages of biopesticides over conventional chemicals are their selectivity to targeted pest, lower toxicity to beneficial insects and greenhouse workers and shorter re-entry intervals (REI).

Herbicides
Herbicides are pesticides that are used for the control of or to kill unwanted plants. Herbicides can affect only part or the whole plant. They may work by contact or be processed by the plant internally. Some herbicides work on the plant when it is still in germination, while some work best when it is completely grown.

Chapter 3
Study Questions

1. Greenhouse IPM is the practice of using cultural, mechanical, biological and chemical pest controls.

   A. True*
   B. False

2. Carbamate insecticides inhibit the enzyme Cholinesterase.

   A. True
   B. False *

3. Miticides are used to kill fungus and bacteria in the greenhouse.

   A. True
   B. False *

Chapter 4
THE GREENHOUSE AND WATER QUALITY

Learning Objectives

1. What contaminants are
2. The potential for contamination
3. How to prevent contamination

(Figure 4.1) Ohio stream

Recently, there have been significant quantities of agriculture chemicals found in the drinking water in many parts of the United States. Groundwater and surface water polluted from agriculture sources is a problem that needs immediate attention. Regulations are being developed to protect water supplies from contamination. These laws could have a significant impact on the greenhouse industry. The amount of water pollution caused by greenhouses is not fully known but the potential must be taken seriously.

POTENTIAL CONTAMINANTS

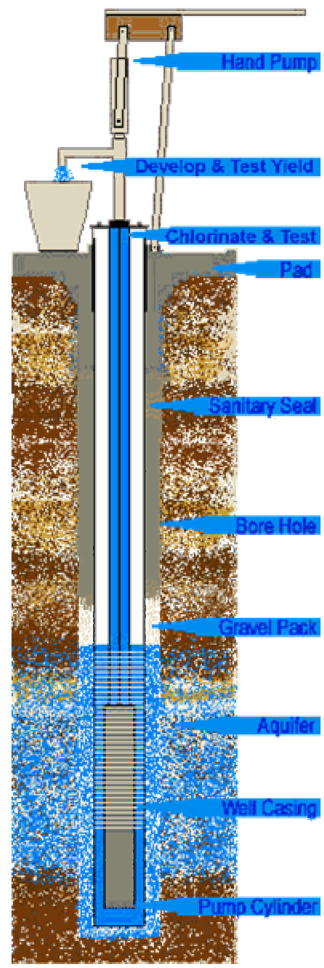
The most important threats to groundwater and surface water are pesticides and fertilizers used in greenhouse operations.

Pesticides having high leaching potentials, high surface loss potentials, or which are persistent in soil are of the greatest concern. The method of application, pesticide formulation, soil type, and microbial activity in the soil are some other factors that affect how much chemical may reach the ground water.

Fertilizers are a significant pollution threat because of their high solubility and the frequent elements are potential pollutants as well.

Runoff is a significant pollution threat to surface water; the pesticides and fertilizers can get into water sheds and affect miles of streams, creeks and some rivers.

YOUR WATER SUPPLY



(Figure 4.2) Water Well

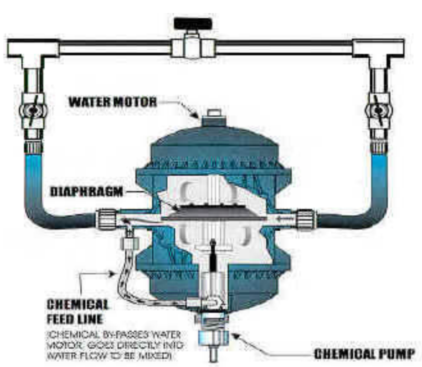
One of the most sensitive areas to contaminate would be the immediate water source that enters your operation. This may be a private wellhead or water lines that carry public water. The goal is to prevent the contamination of the water or the soil close to the wellhead. Wells provide a direct entry point for pollutants to the groundwater. Pesticide and fertilizer mixing and storage should take place away from the wellhead to reduce the chance of contamination. This is important for shallow wells and those in sandy soils.

Back flow preventers should be installed when chemicals are injected into the irrigation water regardless of source. Many localities require these devices by law. Water lines or hoses used to fill tanks during mixing should never be immersed in the solution because back siphoning may occur. An "air-break" between the water source and the chemical solution is as effective as a back flow preventer under these circumstances. Making these modifications will help protect your workers, neighbors, family and yourself from contaminated drinking water.

ACTION PLANS

Long-Term Action Plans

Long-term action plans should have the complete elimination of leaching and runoff of pesticides and fertilizers as its goal.



(Figure 4.3) Chemical pump

Recirculating Subirrigation Systems

Recirculation subirrigation systems (ebb and flow, flooded floors, troughs) do the job well, but are too much of an investment for most growers. However, these systems should be part of a 5 to 10 year plan. They should be seriously considered by anyone planning new construction. It may be possible to design and construct "homemade" low cost systems; at least trials should be made. Fears of disease infestations and the occurrence of excess soluble salts should not prevent the adoption of these systems. Growers who are using these systems easily and routinely handle both of these problems.

Short-Term Action Plans

Short-term action plans can be developed and implemented quickly. Try to reduce the use of pesticides that have high leaching potentials or move easily on the surface. Adopting an IPM program will also help. The evaluation of the level of pest infestations and proper timing of pesticide applications are important steps in reducing pesticide use.

(Figure 4.4) Drip Irrigation

Drip Irrigation

Drip irrigation systems eliminate runoff of water missing the pot during overhead irrigation. Also, the volume of water applied to the pot can be controlled. Simply by turning the system off when the pot capacity is reached can eliminate leaching from pots. Dr. Heiner Leith and co-workers at the University of California Davis described a new way of controlling drip systems (GrowerTalks; September 1990). It consists of a tensiometer placed in the growing medium to sense moisture tension (level) and a small computer programmed to turn the system on or off when present moisture tensions are reached. Using this system in a commercial greenhouse, Dr. Leith was able to reduce run off from potted chrysanthemums and poinsettias to nearly zero! Perhaps a commercial adaptation of this system will be available soon.

Water Trays and Saucers
Water trays and saucers, depending on their shape and spacing on the bench, can reduce runoff and leaching by containing the water draining from pots and holding the water that misses the pots during watering. They are cheap and reusable. Water that collects in them should be given time to evaporate or be absorbed by the plant before any more irrigation is performed. Avoid disease problems by proper spacing, do not place plants close together.

Controlled-release Fertilizers
Controlled-release fertilizers can help reduce fertilizer leaching when used properly. A single large application after planting has little benefit in controlling nutrient leaching as large quantities are released at a time when plants do not need it.

A better approach is to split the single application into smaller multiple ones during the growing season. This technique reduces the leachate of fertilizers. Also, multiple applications during the growing season provide constant nutrition for the plants as well.

Final Thoughts
Here are some final ideas on protecting groundwater and surface water from contamination. Review your past soil test to see what amounts are in the soil. Try to use less fertilizer and pesticide products. Reduce the amount of water that misses the pots. Let the water and chemical in the trays or saucers evaporate before watering again.

All of these practices will help protect your water supply.

Chapter 4
Study Questions

1. Polluted ground water by pesticides has been found recently in the United States.

   A. True *
   B. False

2. One large application of fertilizer will reduce leaching.

   A. True
   B. False *

3. A back flow preventer needs to be installed on a water source to prevent contamination.

   A. True *
   B. False

Chapter 5
DISINFECTING THE GREENHOUSE

Learning Objectives
1. The benefits
2. Algae management
3. Types of disinfectants

GREENHOUSE DISINFECTION
The first steps that growers can take in the fall for the spring growing season are sanitation and disinfection of the greenhouse. Whether the pest problem is diseases or insects, disinfection and sanitation make these pest problems easier to prevent.

(Figure 5.1) Greenhouse ready for disinfecting

Begin with a clean greenhouse. Walkways should be free of soil, organic matter and weeds. Benches, preferably made of wire, should be disinfected. Pots, flats and trays must be new or disinfected. Hose ends should always be kept off the floor. The growing media should be kept in a clean covered area. No plant material should be held in the media mixing area.

(Figure 5.2) Pots

Contaminated pots or debris should not be allowed to accumulate near the growing area. All of these practices will help prevent diseases and pests from becoming problems in the spring. The next thing to do is to disinfect your growing and plant handling areas.

(**Figure 5.3) Table**

Benefits to Disinfecting the Greenhouse
Infectious microbes and algae accumulate over the course of a growing season. Disinfecting your growing and handling areas with chemicals labeled for that purpose could protect them from infectious microbes and pathogens. Disinfecting should be done routinely, however, timing does not always permit it. Between crop cycles is the greatest opportunity for these procedures to occur, when greenhouses are totally empty.

Most diseases are controlled, to some degree, by the use of disinfectants. For example, Botrytis grows on plant debris. Spores from this fungus become airborne. Disinfectants will kill these spores. Dust particles from fallen growing medium or pots can contain bacteria, Rhizoctonia, or Pythium. Disinfectants will also control this potential problem. In addition to plant pathogens, disinfectants are useful for managing algae.

Algae Management

The growth of algae on walks, water pipes, and equipment, on or under benches, and in pots is an ongoing problem for most growers. Algae form a covering that cannot be penetrated by water; therefore, proper wetting of the plants cannot be achieved. Also, algae can clog irrigation, misting lines and emitters causing damage and costly repairs. It is a food source for some insect pests like shore flies. It can also be a liability risk for workers or customers because of slippery conditions of the walkways in the greenhouse. These things may seem impossible to eliminate but with some changes, the algae life cycle can be interrupted for a period of time.

Algae need sunlight to grow for only a few hours each day. If sunlight can be minimized, then the growth period for algae will be shorter. Exclude light by using hoses, covers, tanks or water distribution pipes that are opaque or not transparent. Use black tubing in irrigation lines and cover fertilizer tanks.

Train employees on proper watering practices. Over watering of crops with constant moisture frequently leads to algae buildup on the surface of the growing crop. Allow surface of crop to dry out between watering.

Surface water from lakes and shallow wells may be high in nutrients that will contribute to algae growth. Use water from deep wells or municipal supplies whenever possible.

GREENHOUSE DISINFECTANTS

There are several different types of disinfectants that are currently used in the greenhouse for plant pathogen and algae control. They are chlorine bleach, quaternary ammonium compounds such as Greenshields, Physan 20 and Triathlon, and hydrogen peroxide such as Zero Tol. Although it is not a disinfectant, growers can use alcohol to disinfect propagation tools.

Chlorine bleach – Chlorine is an effective sanitizer and has been used for many years by growers. Note that the half-life (time required for 50 percent reduction in strength) of a chlorine solution is only two hours. After two hours, only one half as much chlorine is present than was first used. You should prepare chlorine solutions fresh just before each use to ensure its effectiveness. The concentration is usually one part of household bleach to nine parts of water, giving a final strength of 0.5 percent. Chlorine is corrosive and repeated use may be harmful to some plastics or metals. Objects sanitized with chlorine require 30 minutes of soaking and then should be rinsed with water. Bleach should be used in a well-ventilated area. Bleach can also be phytotoxic to some plants.

Quaternary ammonium chloride salts – Q-salts currently available for greenhouse use include Greenshield, Physan 20, and Triathlon. Q-salts are stable and work well when used according to the label instructions. Q-salts are labeled for fungal, bacterial, viral plant pathogens, and algae. They can be applied to floors, walls, benches, tools, pots and flats as disinfectants. Physan 20 is also labeled for use on seeds, cut flowers and plants. Carefully read the labels for the use directions, pests and crops information.

Q-salts are not protectants. They eliminate certain pathogens, but have little lasting effect. Contact with any organic material will inactivate them. Clean objects to remove organic matter before the application of Q-salts. The products tend to foam a bit when they are active. When the foaming stops, it is a sign they are no longer effective. No rinsing with water is needed.

Hydrogen Dioxide (Zero Tol) – kills bacteria, fungus, algae and their spores immediately on contact. It is labeled for use on greenhouse surfaces, equipment, benches, pots, trays, and tools and is also labeled for use on plants. Zero Tol is currently acceptable for use by organic growers. Recommendations state that all surfaces should be wetted thoroughly before treatment. Several precautions are noted on the label. Zero Tol has a strong oxidizing action and should not be mixed with any other pesticides or fertilizers. When applied directly to plants, phytotoxcity may be of concern, for some plants, especially if applied above labeled rates or if plants are under stress. Zero Tol may also be applied through an irrigation system. Zero Tol concentrate is corrosive and causes eye and skin damage or irritation. Carefully read and follow label precautions.

(Figure 5.4) Tools

Alcohol (70 percent) – is a very effective sanitizer that acts almost immediately upon contact. It is not practical as a soaking material because of its flammability. However, it can be used as a dip or swipe treatment on knives or cutting tools. No rinsing with water is needed.

Chapter 5
Study Questions

1. The first steps a grower can take between production cycles to control pest problems is to sanitize and disinfect the greenhouse.

   A. True *
   B. False

2. Algae form a covering on plant soils that water cannot penetrate.

   A. True *
   B. False

3. Alcohol can be used, as a dip or swipe disinfectant treatment for knives or cutting tools but is not practical as a soaking material because it is flammable.

   A. True *
   B. False

Chapter 6
SUCCESSFUL GREENHOUSE PEST CONTROL

Learning Objectives
1. Early detection and diagnosis of pests
2. Preventive management
3. Greenhouse environment manipulation
4. Greenhouse sanitation
5. Soil sanitation

EARLY DETECTION AND DIAGNOSIS

Pests get into greenhouses in many ways. During the summer, open vents and doors offer ready access. Moths are attracted by lights at night and enter if vents are open. Some pests are brought in on plants that are exchanged between growers. Poor quality cutting material that is brought in or salvaged at the end of summer is commonly a source of pest problems. Finally, pests come in with soil, mulching material or equipment from outdoors.

If a pest is detected before it has an opportunity to spread or build up, a good control can be achieved. Early action depends on correct identification of the problem.

The true cause of a problem may be simple, such as seeing the pest on the plants (e.g., aphid or powdery mildew infestations). In some cases, the pests may be invisible to the unaided eye. This is the case when dealing with disease-causing agents. You must learn to recognize the symptoms or the damage done by the pests.

Even symptoms may not be totally revealing. Some symptoms are very general and can result from a number of causes (e.g., stunting of growth from root rotting organisms). The life cycles of the pests and the environmental conditions in these cases, will aid you in making a correct diagnosis of the problem.

The other condition of early detection and diagnosis is frequent and thorough inspection of your crops. A vital tool for this process is a hand lens. You and your key employees should carry one at all times. Weekly crop inspections are a good idea. Do not forget to check the lower foliage of densely growing crops. Inspectors often miss the undersides of leaves.

(Figure 6.1) The rose mildew was detected through routine crop inspections.

Finally, everyone in the greenhouse should be trained in knowing when a crop is doing well or not. If something is not right, good communication should exist. The person first spotting the problem should get the word to the right people without delay.

PREVENTIVE HEALTH MANAGEMENT

Those who follow good detection and diagnostic procedures without a slip will find that eradication generally works well. When IPM procedures along with chemical methods are used promptly, there are usually good results.

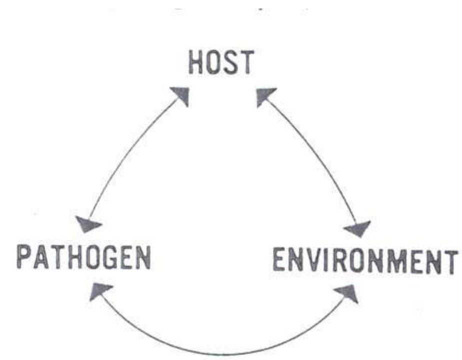
Very few of us manage our greenhouses without an occasional mistake. These errors are why you must think about "insurance programs" or preventive control programs. These programs are simply the routine practices of applying pesticides or carrying out other operations that control pests before they appear at damaging levels.

Preventive health management is especially important when fighting plant diseases. Many disease-causing agents can spread and build to epidemic size before you can detect them. By this time, it is too late to cure the infected portions of the crop.

Preventive health management involves much more than "needless" application of chemicals. Providing the best growing conditions does a lot toward preventing pest problems and manages plant stress. Keeping the plant under the best growing conditions takes advantage of any natural resistance it might have against insects or disease. Controlling the greenhouse environment so it does not favor pests aids greatly as well. Good greenhouse sanitation does much to keep crops free of pests. All of these elements of preventive health management are important to the greenhouse grower.

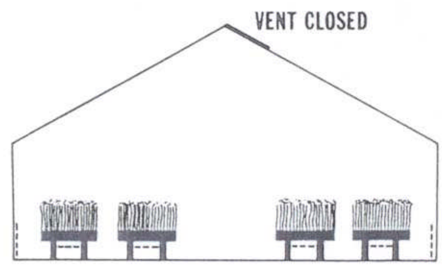
ENVIRONMENTAL MANIPULATION

The cause of a pest infestation is caused by a triangle of factors: a host, a pathogen or pest, and an environment that favors their contact. Such a favorable environment may be one that also favors or does not favor the host. Environments that favor development of pests or pathogens in most cases are those that stress the host in one-way or another. Therefore, you can often control a disease or pest in the greenhouse by changing the environment to one that does not fit into the causal triangle.



(Figure 6.3) Triangle of Factors

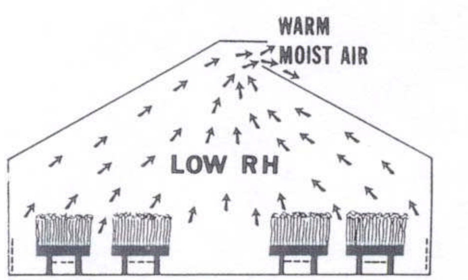
Botrytis leaf blight is an excellent example. This fungus will not bear spores, or previously formed spores will not germinate and infect a host plant unless there is a long period of leaf wetness. During the fall, winter, or spring, a sunny day may raise the greenhouse temperature to 80° F or so.



(Figure 6.4) Relative humidity rises as trapped air-cools at sundown.

You may be concerned with saving the heat trapped in the greenhouse, so you do not vent. As the air in the house cools, the relative humidity goes way up and stays there all night (Figure 6.4). This is especially true if you have watered late in the day. The high humidity can cause dampness or dew on the leaves that favors *Botrytis*.

This situation can be prevented by environmental manipulations. At sundown, change the air in the greenhouse by briefly venting or turning on exhaust fans. This drives the 80° F air out, taking the moisture out with it (Figure 6.5). The outside air you bring in is heated lowering the relative humidity and preventing *Botrytis*-caused disease. You have to pay a little more for heating but you have controlled a costly disease in doing so.



(Figure 6.5) Venting and heating at sundown which drives moist air out.

The greenhouse environment can also dramatically affect insect and mite populations. The daily manipulation of air temperature and humidity for plant pathogen control probably does not have a drastic effect on insects or mites that are more responsive to longer-term fluctuations in air and soil temperatures.

Most growers are aware that many insects and mites seem to be more numerous during warm weather months. Much of this is because the air temperature and sunlight conditions are just right for maximum reproduction and shorter generation times to occur among the major pest populations. For example, spider mites have an egg to adult cycle of about 20 days at 64° F. This same cycle only takes seven days at 81° F. Similarly, leafminers (*Liriomyza* spp.) go from egg to adult in 50 days at 58° F. This same cycle only takes 13 days at 86° F. These same trends can be found for nearly every insect or mite species. Temperatures may also become too high for insect survival and reproduction, but these temperatures are usually bad for crops in the greenhouse.

Other important factors in development of diseases caused by insects and mites include cropping practices, cultivars, growing product and plant nutrition. All of these can play a role with temperature or relative humidity. Be conscious of the relationship between temperatures, relative humidity, and pest or pathogen development, and adjust your control program accordingly. Keep in mind this discussion on environmental manipulation as you read the following sections. You will see that many health management recommendations are based on this principal. They will be easier to understand if you remember they are merely ways to prevent problems by removing the favorable environment from the triangle of the causes of infectious diseases or pest infestations.

GREENHOUSE SANITATION

Sanitation is one of the most important means of managing plant health and controlling disease. Sanitation is cleaning up sources of pests, microbes or pathogens. Sanitation includes controlling weeds, steaming or fumigating soil, sweeping up plant debris and disinfecting equipment and greenhouse surfaces from time to time. (Figure 6.6)

(Figure 6.6) Greenhouse Sanitation

Many root-rotting organisms survive in damp spots where water is permitted to stand. Good sanitation involves eliminating damp or poorly drained areas under benches or on the aisles. Practice placing the end of the watering hose in a holder off the ground. This will prevent it from resting in a damp spot and becoming contaminated.

Be certain that equipment, reused pots, walkways, bench tops, etc., are properly freed of microbes. Most growers wash or spray items with chemical disinfectants.

SOIL SANITATION AND PASTEURIZATION

If you are growing crops in beds or using soil in potting mixes, you might want to sanitize with steam, steam air, other types of heat or with fumigants. When using steam, 180° F for 30 minutes is required for sufficient killing of microbes, insects, nematodes and weed seed. The greatest disadvantage of steam sterilization is that it is hard to reach the desired temperature throughout the soil mass for the required time. The soil batch or bed may be hot enough in general, but there may be a corner that is not. The additional steaming that must be done to heat the entire bed or batch tends to make the procedure expensive and time consuming. You are actually over steaming the majority of the soil mass.
An important aspect of steam sterilization is monitoring the temperature. Keep your long stemmed thermometer handy, and use it. Make no assumptions as to the thoroughness of the job.

Many greenhouse growers and nurserymen have been turning to the fumigation of potting soil mixes as an energy efficient method for good soil sanitation. (Figure 6.7)

(Figure 6.7) Soil Fumigation

Read and follow all the label instructions before performing any soil fumigations. The label has all the information needed to do proper soil fumigation.

Many greenhouse growers, to sanitize batches of potting soils, are using electric soil pasteurizers. They can provide an economical and effective means of carrying out the task. Because the process is time consuming, most growers will electrically heat the soil at night. The night use of electricity can also provide savings in energy expense as well. Most of the devices on the market are sufficiently insulated to hold heat for enough time once it reaches 180° F. A simple thermostatic cut off and a gradual cooling down period are effective. Electric soil pasteurizers come in various sizes, up to two yards of capacity.

Chapter 6
Study Questions

1. Pests can enter the greenhouse many ways, through open doors and vents is one way.

   A. True *
   B. False

2. Greenhouse sanitation is one way to control plant health and disease.

   A. True *
   B. False

3. Greenhouse growers use fumigation to make sure soil is free of insects and diseases.

   A. True *
   B. False

Chapter 7
COMMON GREENHOUSE INSECTS AND MITES

LEARNING OBJECTIVES
1. The common greenhouse insects
2. Their life cycles
3. How they damage crops
4. Their controls

APHIDS
Identification
Aphids are small (1/16-1/8 inch long), soft bodied insects. They are called plant lice or ant cows. Every plant has at least one aphid species that attacks it. These small insects are masters of reproduction. They are often found in great number on stems or leaves. Some species even feed on the roots of plants. They range in color from green to brown, red, black or purple. Some species may even have different color forms in the same colony. Most have the soft exoskeleton exposed, but some species produce waxy, cotton-like strands that cover the body. These are often called wooly aphids.

Aphids are identified by their sucking mouthparts, long, thin legs, long antennae, pear-shaped body and pair of tube-like structures (called cornicles) arising from the rear of the abdomen. A hand lens may be needed to see the short cornicles of some species. These cornicles apparently are the ducts of glands that produce alarm odors. Aphids may be winged or wingless and colonies often have both forms.

Aphids excrete a sugary liquid called honeydew. This honeydew drips onto plant foliage or other structures and provides a suitable place for black sooty molds to grow. Ants often tend to care for aphids in return for the honeydew. Therefore, if ants are running over a plant, look carefully for aphids.


(Figure 7.1) Aphid

Life Cycles and habits
Aphids belong to a group of insects with simple life cycles. They go from egg to nymph to adult. Some aphid species have very complex life histories. They can be grouped into two types:

1. Those with single hosts and asexual reproduction

2. Those with alternating hosts and alternating asexual and sexual reproduction

Aphids with simple life histories live on one plant species or a group of related plants. The females give live birth (ovoviviparous) to tiny female nymphs that start sucking sap immediately. They shed their skin several times. Then the nymphs reach adulthood and soon produce new aphids. A complete cycle may only take 10-14 days depending on temperature and other factors. As the colonies grow, winged forms may be produced that seek out additional host plants. Some of these species may lay eggs, asexually, in the fall that allow them to overwinter.

The next group again lives on one plant or group of plants, but alternates from the spring asexual form of reproduction to fall sexual cycle. Generally, these aphids overwinter in the egg stage. The egg hatches in the spring into a female called the "stem mother." This female gives live birth to female aphids. Asexual reproduction continues with wingless or winged forms being produced. Late in the summer or fall, the asexual reproducing females produce sexual male and females. These sexual forms mate and lay eggs for overwintering.

The most complicated aphid life cycles include not only alternation from asexual to sexual reproduction but also a switch of host plants. The spring and summer asexual forms live on one host but fly to an alternate plant for the production of the sexual forms. The sexual forms, after mating, return to the spring host plant to lay eggs.

The important thing to remember about aphids is that they are tremendous reproducers, and with their ability to fly, tend to constantly reinfest plants.

Types of Damage

Each plant reacts differently to aphid attacks. Some plants show no response to aphids while other plants produce distorted (twisted, curled or swollen) leaves or stems (Figure 7.2). Occasionally, aphids may actually kill leaves or small shoots. Since aphids may move from one plant to another, they may transmit plant diseases that contaminate the sucking mouthparts. Some aphid species are important vectors of plant diseases.

Probably the most common disturbance caused by aphids is their never-ending production of honeydew. This sweet liquid drips onto plant foliage and stems and is soon covered with black sooty mold. Greenhouse tables, walkways etc., can become covered with the honeydew and sooty mold. This attracts other pests like ants, flies, and wasps.

(Figure 7.2) Aphid damage of mum

Control Tactics

There are a number of ways to control aphids in the greenhouse. They include plant resistance, biological and chemical controls.

Biological control involves the use of predators and parasites to control the pests. Lady beetles, green lacewings, hoverflies and parasitic wasps commonly do a good job of aphid control. This is only if they are not killed with insecticide or if ants are not allowed to tend the aphid colonies. Some effective species of biological control agents are commercially available. Examples include parasites such as *Aphidius ervi* and *Aphidius colemani* and predators such as *Aphidoletes aphidimyza* and *Chrysoperla rufilabris.*

Chemical controls are divided into three types "Soft," Contact and Systemic. Soft pesticides are horticultural oils and insecticidal soaps that provide good control. Thorough coverage is needed since these products have contact activity only.

Contact Insecticides. There are a number of these registered for aphid control. Since aphids are often placed under considerable pesticide pressure in greenhouses, they may be resistant to certain categories of insecticides. Therefore, if you do not obtain reasonable control, consider rotation of another insecticide with a different mode of action. Contact insecticides currently registered for aphid control include:

Product Name	Active Ingredient
Orthene	acephate
Talstar	bifenthrin
Mesurol	methiocarb
Enstar	kinoprene
Malathion	malathion
Endeavor	pymethrozine
Azatin	azadirachtin
Thionex*	endosulfan
Mavrik*	fluvalinate

(*)= Restricted Use

Systemic Insecticides. Several of these are useful in aphid control. Aphids have sucking mouthparts and are very prone to pesticides located in the plant vascular system. Some of the systemic insecticides also have contact activity. Systemic insecticides injected or applied to the ground are less harmful to beneficial insects. Systemic insecticides include:

Product Name	Active Ingredient
Marathon, Admire	imidacloprid
Flagship	thiametoxam

FUNGUS GNATS
Identification
Adult fungus gnats are about 1/8 to 1/10 inch (2.5 mm) long, grayish to black, slender, mosquito-like, and delicate with long legs, long antennae and one pair of wings. Identification can be made by the vein patterns in the wings. Dark winged fungus gnat adults have eyes that meet above the base of the antennae. Eggs are hardly visible, oval, smooth, shiny white and semi-transparent. Larvae or maggots are legless, thread-like, white, shiny black headed, up to 1/4 inch (5.5 mm) long and transparent. Food in the gut can be seen through the body wall. Pupae occur in silk-like cocoons in the soil.

Fungus gnats *Sciara* spp. become a pest in greenhouses when adults emerge in large numbers from potted plants containing damp soil rich in humus. The adults are mosquito-like insects that are attracted to lights and are often first noticed at windows. Larvae or maggots that feed in high organic matter soil can injure the roots of bedding plants. African violets, carnations, cyclamens, geraniums, and poinsettias are among some of the plants where fungus gnats can cause problems. Plant symptoms may appear as sudden wilting, loss of vigor, poor growth, yellowing and foliage loss. Some are serious pests in mushroom houses. Fungus gnats inhabit large fungi or dead plant materials and are harmless to humans and animals.

(Figure 7.3) Fungus Gnat

Life Cycles and Habits
Fungus gnats reproduce in moist, shaded areas in decaying organic matter such as leaf litter. The life cycle takes about four weeks, with continuous reproduction in homes or greenhouses where warm temperatures are maintained. Broods overlap, with all life stages present during the breeding season.

Types of Damage
Larvae not only feed on fungi and decaying organic matter, but on living plant tissue, particularly root hairs and small feeder roots. Brown scars may appear on the chewed roots. The underground parts of the stem may be injured and root hairs eaten off. Damage occurs most often in greenhouses or plant beds.

Adults live about 7 to 10 days and deposit eggs on the moist soil surface or in soil cracks. Females lay up to 100 to 300 eggs in batches of 2 to 30 each in decaying organic matter. Eggs hatch in 4 to 6 days; larvae feed for 12 to 14 days. The pupal stage is about 5 to 6 days. There are many overlapping generations throughout the year. They might help spreading diseases such as *Pythium* rot in young seedlings.

Control Tactics
Inspect plants carefully before purchase for signs of insect infestation. Always use sterile potting soil to prevent introduction of fungus gnats. A common practice is the use of soil-less media. Over watering, water leaks and poor drainage may result in buildup of fungus gnats. Allowing the soil to dry as much as possible, without injuring the plants, is an effective way to kill many maggots. Inspect plants carefully and discard if heavily infested and unable to save. Remove all old plant material and debris in and around the facility or home. Practice good sanitation. Electrocution-light flytraps will attract and kill many adults at night. However, this technique alone will not control populations of this insect.

Use yellow sticky cards (traps) for adult fungus gnat detection. Place traps just above the plants at a frequency of one per 500 to 1,000 square feet. Replace when covered with insects (ideally every 1-2 weeks if economically possible.) Check traps 2 to 3 times each week.

Adult fungus gnats are killed easily with pyrethrin sprays or aerosols labeled for "gnats" or "flying insects." Repeat applications several times if necessary. Commercial mushroom growers may get control with Dimilin (Difluobenzuron) whereas commercial greenhouse growers can use *Bacillus Thuringiensis* Berliner var. israelensis (Gnatrol, Vectobac). Other products that can be used to control fungus gnats are:

Trade Name	**Active Ingredient**
Ultra Fine Oil	paraffinic oil
Orthene	acephate
Astro	permethrin
Talstar	bifenthrin
Decathlon	cyfluthrin
Marathon	imidacloprid
Flagship	thiametoxam
Precision	fenoxycarb
Distance	pyriproxyfen
Enstar II	kinoprene
Gnatrol	*Bacillus thruingiensis* Israelensis
Adept	diflubenzuron
Citation	cyromazine
Azatin XL	azadirachtin

LEAFMINERS
Identification
Leafminers, mainly *Liriomyza trifolii* sp. are larvae of small black and yellow flies. The adult Leafminers *Liriomyza.* sp are tiny yellow and black flies about 2 mm in length.

The larvae are glossy yellow in color and are about 4 mm long.

(Figure 7.4) Adult Leafminer

Life Cycles and Habits

The life cycle duration depends on temperature, host plant and possibly day length. The generalized cycle is as follows: each female can lay up to several hundred eggs, which are placed individually and can take from 4-5 days to hatch. Larvae feed inside (in between upper and lower surface) the leaf for four to six days before becoming a pupa. The larvae usually leave the leaf and pupate off the plant, often dropping to the ground to do so. Pupation may also take place in leaf mines or on leaf surfaces. Adults emerge in seven to 40 days depending on the species and environmental factors.

Leafminers can survive transport of cuttings as eggs, larvae or pupae stage. Some infestations may result from shipment of contaminated plant material. Be especially careful when receiving shipments of plants or cuttings of known leafminer-susceptible crops.

Types of Damage

Foliar and fruit damage can be extensive when populations of leafminers are high. Because the larvae generally do not cross-existing mines, the later stages of feeding result in characteristically serpentine patterns.

(Figure 7.5) Leafminer larva feeding on chrysanthemum leaf

(Figure 7.6) Leafminer damage on chrysanthemum

Control Tactics

Several parasites for leafminers have been recorded in Hawaii, they include: (*Chrysonotomyia punctiventrus)* Crawford, *(Ganaspidium hunteri)* Crawford, *(Opius dissitus)* Muesebeck, *(Chrysocharis parksi)* Carwford, *(Hemitarsenus semialbiclavus)* Girault, *(Diglyypus begini)* Ashmed, *(Diglyphus intermedius)* Girault, *(Cothonapsis pacifica)* Yoshimoto, and *(Haliticoptera circulus)* Walker.C. *(punctiventris), (H. cirulus)* and *(G. hunteri)* have been found to be major parasites (Lynch, 1986; Johnson 1987).

Commercially available biological control agents include: *Dacnusa sibirica* and *Diglyphus isea.*

Insecticides for control of leafminers:

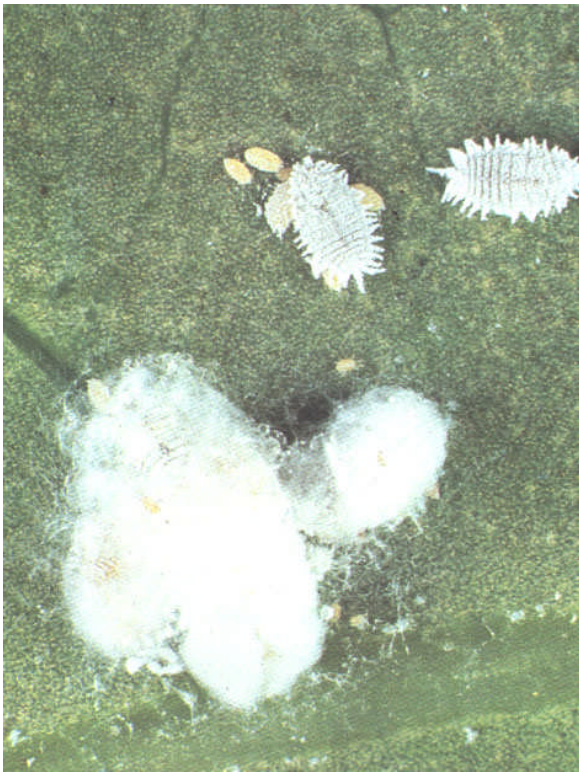
Product Name	**Active Ingredient**
Ultra Fine Oil	paraffinic oil
Orthene	acephate
Scimitar	lambda cyhalothrin
Astro	permethrin
Talstar	bifenthrin
Marathon	imidacloprid
Conserve	spinosad
Avid	abamectin
Precision	fenoxycarb
Adept	diflubenzuron
Pedestal	novaluron
Citation	cyromazine
Azatin XL	azadirachtin
Malathion	malathion

MEALYBUGS

Identification

Mealybugs are small, sluggish insects, about 1/8 inch long (Figure 7.7). They have short spines on the body margin and a white waxy covering. There are many species of mealybugs that may occur on greenhouse floral crops. Probably the most common is the citrus mealybug, *Planococcus citri.*

One of the most common ways for a mealybug infestation to develop is by moving infected plants into the greenhouse. Thorough inspection of any incoming plant material will help reduce the chance of an infestation getting started.


(Figure 7.7) Mealybug

Life Cycles and Habits
Each female may lay 500 eggs during her lifespan. Eggs hatch in about seven days. The tiny nymphs migrate over the plant and soon begin sucking sap. Breeding is constant in the greenhouses. The usual life cycle lasts from six to eight weeks.

Types of Damage
Mealybugs have piercing-sucking mouthparts. They reduce plant energy by removing plant sap. Also, black sooty mold grows on honeydew excreted by these insects.

Some mealy bugs, called root mealybugs, feed below ground on roots and may stunt plant growth if infestations are high.


(Figure 7.8) Mealybug and Scale Damage on Palms

Control Tactics
There are numerous parasitic wasps that attack the citrus mealybug and several predatory beetles. A number of them is described by Mahr et al (2001). Pathogenic fungi also attack these pests.

Some insecticides that can be used against mealybugs are:

Product Name	Active Ingredient
M-Pede	potassium salts of fatty acids
BotaniGard	Beauveria
Aria	flonicamid
Orthene	acephate
Astro	permethrin
Talstar	bifenthrin
Tame	fenpropathrin
Tristar	acetamiprid
Marathon	imidacloprid
Flagship	thiametoxam
Enstar II	kinoprene
Preclude	fenoxycarb
Azatin XL	azadirachtin
Distance	pyriproxyfen

SCALES
Identification
There are several species of scale insects that can occur on greenhouse plants. Scales are usually very small. By the time an infestation is detected, control is very difficult.

(Figure 7.9) Scales

Life Cycle and Habits
A female can produce more than 1,000 eggs. These eggs are covered under a hard shell. The eggs hatch into tiny crawlers that move on the plant looking for feeding sites. When they have found a site they settle and begin feeding, continuing the life cycle. The length of life cycle varies with each species. It could range from one to eight or more generations per year.

Types of Damage
Like mealybugs, aphids and whiteflies, scale insects excrete honeydew (Figure 7.8). Also, infestations often occur when contaminated plants are brought into the greenhouse. A large infestation of scales can cause leaves to turn yellow, get stunted and die. Scales also produce honeydew, which serves as food for black sooty mold that grows on the leaves below the infestation area.

Control Tactics
The most susceptible stage in the scale insects life cycle is the crawler or young scale. Unfortunately, most species emerge as crawlers over a period of time and require more than one spray.

Some insecticides used against scales:

Product Name	**Active Ingredient**
Triact 70	neem oil extract
Ultra Fine Oil	paraffinic oil
DuraGuard	chlorpyrifos
Orthene	acephate
Attain TR	bifenthrin
Marathon	imidacloprid
Flagship 25 WG	thiametoxam
Precision	fenoxycarb
Distance	pyriproxyfen
Enstar II	kinoprene
Ornazin	azadirachtin

THRIPS

These plant-feeding pests are attracted to potted plants with excess water in their drainage pans. They hitchhike indoors on cut flowers, occur near swimming pools, ornamental waterfalls and grassy areas, etc. Thrips are very small (less than 1/8 inch), and are responsible for entomophobia or delusionary parasitoses.

Identification
Adult thrips are very active and usually less than 1/8 inch long, tan-to-dark brown bodied with four very thin, veinless, featherlike wings. The wing margins are fringed with close-set long hairs. Wings are laid back over the body while at rest. The head has compound eyes and less noticeable, simple eyes. Mouthparts are rasping-sucking. Nymphs are creamy white and wingless. Eggs are laid on the tissues of plants or inserted into plants. Magnification is required for best identification. A simple technique to detect the presence of thrips is to gently blow air near flower or flower buds (from exhalations). Thrips become more active when the CO_2 concentration is high, thus making them easier to be detected.

(Figure 7.12) Thrips

Life Cycle and Habits

Thrips are serious pests on vegetables (especially onions) and flowers (chrysanthemum, gladiolus, iris). Both nymphs and adults cause plant injury. They cause damage by rasping the bud, flower and leaf tissues of the host plants, and then sucking the exuding sap. This produces distorted and discolored flowers or buds and gray or silvery, speckled areas on the leaves. Gladiolus thrips also feed on the corms in storage, causing russeted areas and lowering vigor, which retards growth and makes the flowers smaller.

After successful mating, eggs are laid on plants with the young developing to maturity in about two or more weeks. The number of generations produced each year depends on the thrips species, temperature and other climatic factors. Most species produce many generations in a season. Females may lay fertilized or unfertilized eggs, the latter developing into males only (reproduction without a male is known as parthenogenesis).

The thrips exhibit gradual metamorphosis having four or more nymphal instars. Both nymphs and adults overwinter concealed in grass stems or other plant debris with continuous activity in warmer climates.

Types of Damage

Leaf scars and specks of black feces are a good way of diagnosing the presence of Western Flower Thrips (WFT) on plants. Depending on the host species, feeding injuries occur on fruit, flowers, flower buds, leaves, and leaf buds (Childers and Achor 1995). In some host species, WFT feeding causes flower or leaf buds to abort or emerging leaves to become distorted. Feeding does not always result in immediately visible damage because many flowering species do not show injury until flower buds open. When WFT feed on flowers, symptoms include streaks and discoloration of the petals—with dark flowers showing light streaks and light flowers showing dark streaks (Pfleger et al. 1995).

(Figure 7.13) Thrips damage of petunia

Control Tactics

Try to locate the source of infestation. Many greenhouses may have the habitat and food source for a thrips population. Check for host plants such as potted plants, vegetables, flowers, fruit trees, etc. Thrips may feed between the leaves well down toward the plant base where it is difficult to see. Collect specimens in vials of rubbing alcohol for accurate species identification.

To reduce and eliminate a thrips infestation, remove excess water around plants and vacuum up thrips if possible. Discard infested plants or treat with insecticides labeled for the host plant. Surface applications may aid in control efforts. Review labels before selection and application of any pesticide. Several species of lady beetles and minute pirate bugs are thrips predators available commercially. Some pesticides that are registered for the control of thrips are:

Product Name	Active Ingredient
M-Pede	potassium salts of fatty acids
BotaniGard	Beauveria
Mesurol	methiocarb
Orthene	acephate
Talstar	bifenthrin
Decathlon	cyfluthrin
Mavrik Aquaflow	fluvalinate
Pyreth-It	pyrethrins + PBO
Conserve	spinosad
Precision	fenoxycarb
Pedestal	novaluron
Azatin XL	azadirachtin
Aria	flonicamid
Tristar	acetamiprid
Marathon	imidacloprid
Avid	abamectin
Phaser	endosulfan

WHITEFLIES

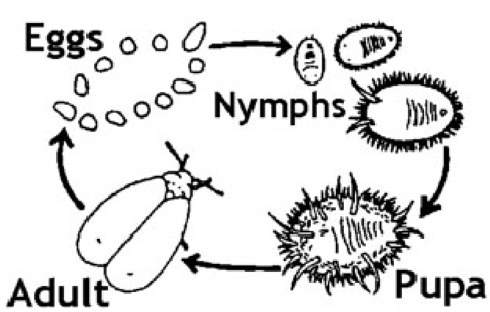
Identification

The most common and perhaps most difficult to control insect pests in greenhouses are whiteflies. The common species of whiteflies found in the greenhouse are the greenhouse whitefly (*Trialeurodes vaporariorum*), and the silverleaf whitefly (Bemisia argentifolii). They attack a wide range of plants including bedding plants, cotton, strawberries, vegetables, and poinsettias. In addition to attacking many different crops, whiteflies are difficult to control. The immature stages are small and difficult to detect. Growers often buy plants and are not aware of the whitefly infestation. Once inside a greenhouse, whiteflies develop and when adults emerge, they quickly become distributed over an entire crop or move to other available host plants. In addition, chemical control programs directed at the pest often have limited success. Two life stages, the egg and pupa, are very difficult to control using insecticides. Control procedures are also complicated because these insects live on the underside of foliage, making them difficult to reach with chemical sprays.

Life Cycle and Habits

To the untrained eye all whiteflies may look alike. It is important to recognize each species and to know their life cycle to develop the most effective control program. All whiteflies develop from the egg through four nymphal instars before becoming adults.

Eggs are deposited on the undersides of leaves and are often found in a circular or crescent-shaped pattern. The "crawler" hatches from the egg, moves a short distance and then settles and begins feeding. The remainder of the nymphal development is spent in this sedentary condition. The adult whitefly emerges from the pupal case and has the capability of flying to other host plants to lay eggs and begin the cycle again. Fourth instar nymphs (called pupae) and adults are most frequently used to distinguish one species from another.



(Figure 7.14) Whitefly Life Cycle

Adult GHWF are slightly less than 1/8 inch long. When they first emerge they are pale green or yellow, but quickly expand its wings which are covered by a waxy coating. They hold their wings over the body. The wings are held almost parallel to the leaf surface. GHWF pupae from the side view appear cake-shaped with perpendicular sides. Pupae have a fringe of short hairs or setae around the top edge and several long wax filaments projecting from the top surface. Silverleaf whitefly (SWF) adults can be distinguished from GHWF because of the way they place their wings when resting and by the form of the last instar. Adult SWF wings are held on an angle and the fourth instar nymph is flat with very short unapparent hairs.

(Figure 7.15) Silverleaf Whitefly Adult

Adult GHWF and SWF have life spans of 1 to 2 months and can produce 30-500 eggs. Egg laying begins 1-3 days after emerging from the pupa and occurs during daylight. Females usually lay the white to yellow eggs in a circular or crescent-shaped pattern. The first instar nymph, or crawler, hatches from the egg within 7-10 days. The crawler moves a short distance, inserts its siphoning type mouthparts into the plant and begins to feed. Within approximately one week or less, the crawler settles and remains stationary for the second, third and fourth instars. The second and third instar nymphs also feed on sap and are pale-green and scale-like in appearance. Fourth instar nymphs feed initially, then feeding ceases before the adult begins to form internally. Thus, fourth instar nymphs are considered pupae. After about 6 days, adults emerge from the pupal case. The entire life cycle may be completed in 32 days at temperatures of 65-75 degrees F. However, the exact duration of the life cycle varies depending on temperature and type of host plant. GHWF reproduce most effectively at temperatures averaging 75 degrees F, while SWF reproduces most effectively between 78 and 86 degrees F.

Types of Damage

The whitefly injures the plant by consuming large quantities of sap, which it obtains with its sucking mouthparts. Further injury is caused by sooty mold fungus that grows over fruit and foliage in the copious amount of honeydew excreted by the whitefly. This black fungus may cover the leaves so completely that it interferes with the proper physiological activities of the plants. Heavily infested plants become weak.

(Figure 7.16) Whitefly Damage on Poinsettia

Control Tactics
A good control program for whitefly begins prior to the arrival of a susceptible crop. Following are some specific practices that should begin before the crop arrives and continue until the crop is delivered.

Exclusion - Make sure entry points to the greenhouse are properly fitted with screening that excludes whitefly from entering. In a large greenhouse range, consider using screening within the greenhouse to isolate certain areas and prevent potential spread of whitefly from one age crop to another or between different crops.

Sanitation - The first objective is to eliminate all possible sources of residual whitefly infestations. Totally eliminate all weeds and plant debris inside and immediately outside the greenhouse. They can harbor immature or adult whiteflies. Collect the weeds and debris in covered containers or seal them in plastic bags. Infested plant debris stored in open containers may continue to produce adult whitefly that may quickly migrate back onto crops inside the greenhouse.

Cultural Practices - If possible, allow the growing range to stand empty for one week prior to planting a new crop. If no host plants or weeds are present, one week provides sufficient time for adult whiteflies to starve. This ensures that you start with a whitefly free house. If it is not feasible to empty the greenhouse, scout the area thoroughly. If infested plants are found, discard them or remove leaves with eggs and nymphs. Then, move the infested plants to another area. Apply an insecticide treatment to remaining plants to eliminate any adults that may be present.

Scout and Monitor - When plants arrive, before putting them in the greenhouse, examine each one. Continue to scout and monitor the crop frequently for the presence of whitefly. Look for nymphs, pupae and eggs as well as the adults. Do not place infested plant material next to clean plants.

Once or twice a week systematically examine each greenhouse for developing whitefly populations. Examine the greenhouse in the same manner each trip. Look at the crop and note differences in color, size, or vigor of plants in each area. Next, select and closely examine several plants from each bench (10 plants per 1000 square feet should provide an adequate sample). Begin at the top of each plant and work to the bottom. Examine both the upper and lower surfaces of each leaf for the presence of whitefly eggs, nymphs, or adults. Commonly, whiteflies tend to oviposit in younger leaf material. The underside of the lower leaves need to be examined more closely for immature whiteflies. A small hand lens is an invaluable tool that can be used to find whiteflies. If whiteflies are found, it may be useful to mark the leaf on the plant so that it can serve as an indicator plant for future monitoring trips. Indicator plants are useful in monitoring life cycle development as well as the efficacy of insecticide application.

Use yellow sticky traps throughout the crop as a tool to detect whitefly populations early. For best results in trapping whiteflies, hang one to four yellow sticky cards per 1000 square feet level with the crop canopy. The adults are attracted to the yellow and will stick to the adhesive surface of the card. Check each card during every scouting trip and note the number of whiteflies found. Develop a monitoring system so that you can keep a record of where whiteflies have been found and if the number of whiteflies trapped in each area is increasing or decreasing. Monitor whiteflies and replace traps as frequently as needed, but at least on a weekly basis. It is difficult to detect a population change on a sticky card that has an accumulation of insects.

Whiteflies have natural enemies that help keep their populations under control. In fact, several predators and parasites of whiteflies are commercially available for release into infested greenhouses or interiorscapes. Studies on fungal pathogens indicate some success in controlling the GHWF. Reliable programs, based solely on biological agents, have not been developed in the U.S. Biological agents have been successfully used to control whiteflies in areas such as interiorscapes where total elimination of whiteflies is not necessary. In commercial greenhouse production, biological control agents are best used in conjunction with properly timed insecticide applications. Currently, there are different insecticides that can be successfully combined with the use of biological control agents.

Encarsia formosa, a small wasp that parasitizes whiteflies, is considered the primary natural enemy of GHWF. The wasp lays an egg inside a whitefly nymph and the developing wasp eventually kills the whitefly. Furthermore, the adult wasp destroys additional whiteflies by probing her ovipositor into second stage nymphs and feeding on the whiteflies' excreted body fluids. *Encarsia* populations prefer temperatures above 72 degrees F for development. When temperatures are cooler, the whiteflies can reproduce faster than the parasite, so control of the whitefly population is not achieved. Other parasitoids such as *Eretmocerus eremicus* are available for the control of SWF.

A second beneficial organism, *Delphastus pusillus*, has a ravenous appetite for whitefly eggs, nymphs and adults. Studies indicate successful control of GHWF has been achieved with the release of this small black lady beetle at a rate of 1 beetle per 15-50 square feet.

Prior to using a beneficial organism inside the greenhouse, consider the history of pesticide use inside the facility. Predators and parasites can be very sensitive to pesticides used in the past and even small quantities of pesticides that persist on foliage can be lethal to predators and parasites.

Chemical Controls - When choosing a pesticide to control whitefly, the first step is to identify the whitefly species and the life stages present. Select an insecticide from Table 1 that is effective against the most prevalent stages. Remember that pupae and eggs of the whitefly are difficult to kill. Watch the population closely and apply the insecticide when first stage nymphs or adults have emerged. Proper application of the insecticide is also a key component to a successful control program. It is necessary to deliver the insecticide to the undersides of leaves to achieve good control. Many greenhouse crops mature, into a dense canopy of foliage. This dense canopy interferes with pesticide delivery and applications. It is necessary to control whiteflies prior to the formation of this canopy or to space plants so they can be treated adequately. Since biological control agents seek their prey, they can reach places where it is difficult to deliver pesticides. Therefore, an appropriate combination of biological control agents and pesticides might provide the best control under these situations

When making any pesticide treatment, the method of application is dependent on the formulation of pesticide used. Read and follow all application procedures carefully. All plant surfaces need to be thoroughly covered, especially the lower leaf surfaces, where whiteflies feed and reproduce. Because whitefly populations can develop resistance to pesticides, it is best to rotate products used in a control program. To avoid the development of resistance, switch among products from different chemical classes (Table 1 lists products by the chemical classes, i.e. pyrethroids, organophosphates, insect growth regulators, etc). Avoid making more than two consecutive applications of any product classified as an organophosphate, carbamate or chlorinated hydrocarbon insecticide before switching chemical classes. Avoid the use of pyrethroid insecticides for more than one application before rotating to a product from a different chemical class. Insect growth regulators can be applied with greater frequency than organophosphate, carbamate, chlorinated hydrocarbon or pyrethroid insecticides. Imidacloprid (Marathon) is a systemic insecticide that can be applied as a granular or drench and will give residual control for eight to nine weeks. Therefore, it is best to apply the soil medium treatment two weeks after planting rooted cuttings or when the roots first reach the edge of the pot.

Trade and brand names are used only for information. The Ohio Department of Agriculture does not guarantee or warrant the standard of any product mentioned; neither does the use of a trade or brand name imply approval of any product to the exclusion of others that also may be suitable.

Acknowledgement: The authors thank Tong-Xian Liu for drawings of whiteflies used in this publication.

Chemical Class/Common Name (MOA)*	Brand/Formulation	Life Stages Affected	Impact on Natural Enemies
Chlorinated Hydrocarbon:			
Endosulfan	Thiodan 2EC, 3EC, 50WP	Adult	Harmful
Organophosphate (1):			
Dichlorvos	Fulex DDVP	Nymph, adult	Harmful
Acephate	Orthene TT&O, Acephate Pro 75	Nymph, adult	Harmful
Chlorpyrifos and cyfluthrin	Duraplex TR	Nymph, adult	Harmful
Pyrethroid and pyrethrum (3):			
Bifenthrin	Talstar 10WP	Nymph, adult	Harmful
Cyfluthrin	Tempo 2E*; Decathlon 20WP	Nymph, adult	Harmful
Fenpropathrin	Tame 2.4EC	Nymph, adult	Harmful
Fluvalinate	Mavrik 2F*	Nymph, adult	Harmful
Permethrin	Pounce, Astro	Nymph, adult	Harmful
Pyrethrum	Pyrenon; PT 1100; PT 1600A*	Nymph, adult	Harmful
Lambda-cyhalothrin	Scimitar 10WP	Nymph, adult	Harmful
Neonicotinoids (4):			
Imidacloprid	Admire, Marathon 1%G, Marathon II	Nymph, adult	Harmless if used as drench
Thiametoxam	Flagship 25 WG	Nymph, adult	Harmless if used as drench
Acetamiprid	Tristar 70 WSP	Adult	Harmful
Insect Growth Regulators (7):			
Kinoprene	Enstar II, Enstar 5E*	Egg, nymph, pupa, adult	Slightly toxic to parasitoids
Fenoxycarb	Preclude, Precision	Egg, nymph, pupa	Slightly toxic to parasitoids
Pyriproxyfen	Distance	Egg, nymph	Slightly toxic to parasitoids
Pyridine azomethine (9):			
Pymetrozine	Endeavor 50 WG	Nymph, adult	Harmless
Benzoylurea IGR(15):			
Diflubenzuron	Adept	Nymph	Harmless to parasitoids
Novaluron	Pedestal	Nymph	Harmless to adults
Biopesticide IGR (18):			
Azadirachtin	Azatin XL, Ornazin 3% EC	Nymph	Slightly toxic
Pyridazinon (21):			
Pyridaben	Sammite 75SP	Nymph, adult	
Miscellaneous:			
Insecticidal soap	M-Pede	Nymph, pupa	
Horticultural oil	Sunspray Ultrafine: Saf-T-Side	Nymph, pupa	

MITES

Twospotted Spider Mite

There are several species of spider mites that invade greenhouse, nursery and ornamental plants. The most troublesome of these is the Twospotted spider mite *Tetranychus urticae* Koch.

(Figure 7.17) Twospotted spider mites and eggs

Identification

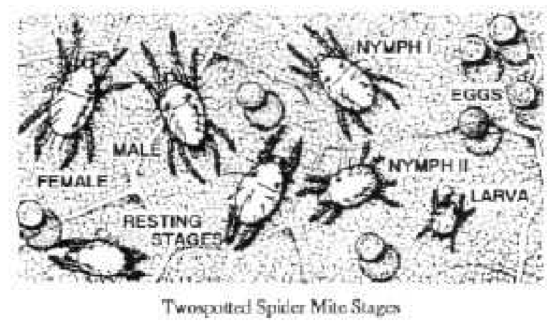
The eggs are spherical, clear to pale green in color, and shiny. They are usually found on the underside of the leaves where adult feeding occurs. They are attached to the leaves in the webbing spun by the adults.

The first instar is a six-legged stage called a larva and is similar in shape and color to the adult.

The adult is an eight-legged mite, ranging in color from green to brown. The male is smaller than the female, and has a narrower, pointed abdomen. Both sexes have sparse spines and two dark pigmented areas on the back. These pigmented areas are food particles that can be seen through the body wall.

Life Cycle and Habits

This non-insect pest goes through four stages of development: egg, larva, nymph, and adult.

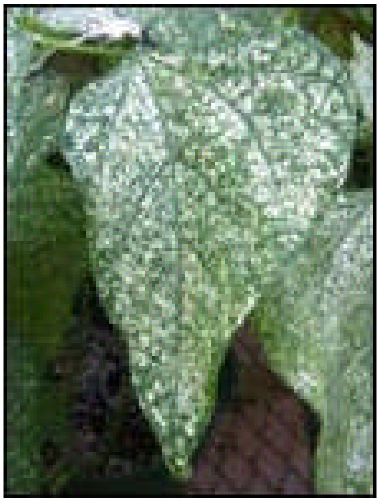


(Figure 7.18) Twospotted spider mite Life Cycle

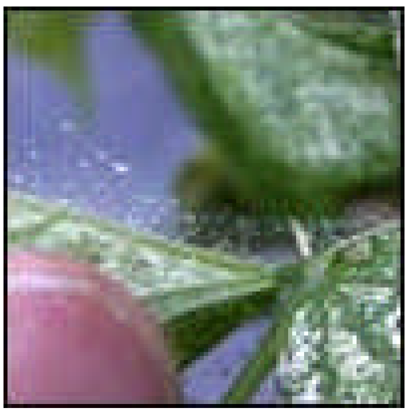
The Twospotted spider mite is quite small with the adult female averaging 0.5 mm in length. Eggs hatch in 3-19 days, depending on temperatures. After hatching, the six-legged larva will start to feed on the leaves at once. Later it will change into the eight –legged stage. The adult stage will begin in about 19 days. Constant feeding occurs during this time. There are several continuous generations per year in greenhouses.

Types of Damage

Twospotted spider mites have tiny mouthparts modified for piercing individual plant cells and removing the contents. This results in tiny yellow or white speckles. When many of these feeding spots occur near each other, the foliage takes on a yellow or bronzed cast. Once the foliage of a plant becomes bronzed, it often drops prematurely.



(Figure 7.19) Spider Mite Stippling



(Figure 7.20) Spider Mite Webbing

Control Tactics
Early detection of spider mites, before damage is noticed, is important. Taking a piece of white paper or cardboard and striking some plant foliage on it can detect the tiny spider mites. When scouting, it is always helpful to use a hand lens to detect this pest. The mites can be seen walking slowly on the paper. If 10 or more mites per sample are common, controls may be needed.

Option 1: Cultural Control - Quarantine and Inspection. The Twospotted spider mite is often introduced on infested bedding plants. When purchasing new plants, carefully inspect the lower leaf surface for any signs of mite activity. New greenhouse plants should be quarantined from other plants until you are sure that no mites are present.

Option 2: Biological Control – Predators. There are numerous insects (lacewings and lady beetles) that prey on spider mites. However, the most commonly sold predators are other types of mites. Predatory mites (usually *Phytoseiulus* spp., *Amblyseius* spp. or *Metaseiulus* spp.) can be purchased and released onto infested plants. Be sure to check listings to determine which species is appropriate. Some species are host specific and each predator works better under different weather conditions. If predators are used, do not apply pesticides that will kill them.

Option 3: Chemical Control - "Soft Pesticides." Most spider mites can be controlled with insecticidal oils and soaps. The oils, both horticultural oil and dormant oil, can be used. Horticultural oils can be used on perennial and woody ornamentals during the summer at the 1 to 2 percent rate. Higher rates of horticultural oil (3 to 4 percent) or dormant oil are useful for killing mite eggs and dormant adults in the fall and spring. The insecticidal soaps are useful in the warm season. Remember that mites are very tiny and soaps and oils work by contact only. Therefore, thorough coverage of the plant is necessary for good control.

Option 4: Chemical Control – Miticides. Spider mites are usually not killed by regular insecticides, so be sure to check the pesticide label to see if "miticide" is present. Pesticides claiming "for mite suppression" are usually weak miticides and will not perform well. Some pesticides are listed below:

Product Name	**Active Ingredient**
M-Pede	potassium salts of fatty acids
Ultra Fine Oil	paraffinic oil

Mesurol 75-W	methiocarb *
DuraGuard ME	chlorpyrifos*
Floramite	bifenazate
Talstar	bifenthrin *
Mavrik Aquaflow	fluvalinate
Pyrethrum TR	pyrethrins
Attain TR	bifenthrin
Conserve SC	spinosad
Avid 0.15 EC	abamectin
Preclude TR	fenoxycarb
Hexygon DF	hexythiazox
Ovation SC	clofentezine
TetraSan 5 WDG	etoxazole
Pylon	chlorfenapyr
Akari 5SC	fenpyroximate
Sanmite	pyridaben

Some of these products are restricted use pesticides available only to licensed applicators. Always read the label for up-to-date information.

Cyclamen Mites
Stenotarsonemus pallidus (Banks). Cyclamen mites like to feed on colorful flowering plants.

Identification
These mites are tiny animals, less than 0.3 millimeters long. Colorless or brown tinted and waxy looking, they have four pairs of legs. The fourth pair of the female is slender with a long hair extending from the tip. The fourth pair of legs of the males ends in a strong claw. The elliptical egg is 0.1 millimeter long and smooth.

(Figure 7.21) Cyclamen Mite and egg

Life Cycle and Habits
Cyclamen mite is a cool weather mite. Delphinium is injured from early spring to early summer and again in late summer. Injury is seldom caused in the high heat of mid to late summer.

Each female deposits about 90 eggs over several weeks, five or six per day. Eighty percent or so are females. The eggs hatch in a week and the larva is active for a week, then molts to the eight-legged nymph.

The nymphal stage is a quiescent one of about 3 days before molting to the adult. The life cycle from egg to adult can be completed in 2 weeks. All stages may be found on the host foliage at one time.

Types of Damage
Cyclamen mites prefer to feed in buds and young leaves. Leaves curl inward and develop a puckered appearance. Pit-like depressions can also form. Leaves may become brittle or appear streaked. Flowers can become shriveled and discolored. Sometimes, flower buds may not open at all.

Cyclamen mites have a broad host range and can feed on African violets, cyclamen, dahlia, gloxinia, ivy, snapdragons, vinca, chrysanthemum, geranium, fuchsia, begonia and petunia. Outdoors, the cyclamen mite can attack delphinium, aconite, chrysanthemum, verbena, strawberry and viola. Damage to delphinium is particularly severe, as flower stalks become twisted and buds turn black and do not open.

(Figure 7.22) Cyclmen Mite Damage to New Guinea Impatiens.

SLUGS

Identification

Slugs are simply snails (mollusks) without shells. These slimy creatures live in and on the ground and have big appetites for a wide variety of plants. Young seedling plants are eaten as well as mature plants. They frequently cause damage to glasshouse (greenhouse) and nursery plants, and may be especially injurious in mushroom houses. Slugs may be found when the ground thaws in the spring until it freezes in the fall. Wet conditions are ideal for slug development.

Life Cycle and Habits

Probably the best description of a slug is that it is a snail without a shell. They vary in size depending upon the species and measure from 1/4 to seven inches long. They secrete a characteristic slime (mucus) that they leave behind as they move around. These slime trails are silvery in appearance upon drying and is a common diagnostic characteristic used to identify the presence of slugs. The color of slugs also varies with species, ranging from a dark black-brown to an orange color.

(Figure 7.10) Slug

The most common slugs found in Ohio landscapes are the gray garden slug, the leopard slug, and the dusky slug. The gray garden slug is the most common and is generally a mottled gray to black in color. It is usually less than one inch long. The leopard slug is the largest, commonly reaching four to five inches in length. It has characteristic black spots on its upper surface. The dusky slug is intermediate in size, being one to three inches long, and can range from a gray to a bright orange in color.

All slugs lay eggs. Each species requires a different length of time for the development of its eggs and the maturing of its young. The number of eggs laid at one time by one slug may be up to 100, but average 20 to 30. Young adult slugs apparently lay fewer eggs than older ones.

The eggs appear as perfectly round gelatinous spheres filled with a watery substance. They range in size from 1/8 to 1/4-inch in diameter. They are usually colorless, often reflecting the color of their surroundings, but they may become cloudy just before hatching. Baby slugs resemble adults but are smaller and may not be as fully colored.

Though slug eggs may be found outdoors during any month of the year, most of the eggs are laid in the spring and early summer. Most species overwinter as adults or nearly mature young. In the spring, eggs are laid in moist areas and the new slugs normally reach maturity by fall. During periods of particularly warm and wet climatic conditions, the rate at which the slugs develop may allow for eggs to be laid in mid-summer, thus making possible a second generation. Mating usually takes place from August until mid-October and eggs can be laid from 30 to 40 days after a successful mating.

Eggs are generally laid on or near the soil surface. They are usually deposited in places of concealment, such as underneath mulch, dead leaves, rocks, flowerpots, trash, and boards. Mostly preferred are spots where the nature of the cover keeps the surroundings relatively cool and moist.

The minimum temperature that an egg needs to develop varies with the species of the slug. The general range is 32 to 42 degrees F. With lower temperatures eggs may require as long as 100 days to develop. In higher temperatures eggs require less time, developing in ten days to three weeks.

As soon as slugs hatch, they are active and begin to crawl or feed if the temperature and humidity are right. They are mainly nocturnal and remain motionless and concealed until nightfall provides suitable conditions for activity.

The rate of growth of immature slugs depends mostly on the type and amount of food available. Dry conditions usually result in a loss of weight that is regained rapidly when moist conditions return. In greenhouses, many adult slugs may live for more than one year.

Types of Damage
Snails and slugs feed on a variety of living plants as well as on decaying plant matter. On plants they chew irregular holes with smooth edges in leaves and flowers and can clip succulent plant parts. They can also chew fruit and young plant bark. Because they prefer succulent foliage or flowers, they are primarily pests of seedlings and herbaceous plants, but they are also serious pests of ripening fruits, such as strawberries, cabbage and tomatoes, that are close to the ground.

(Figure 7.11) Slug Plant Damage

Control Tactics
Formal slug control recommendations were first made during the last decade of the 19th century. Home remedies were probably used even earlier. Flat boards, cabbage leaves, rocks, wet newspaper, etc. are sometimes placed in the problem area for slugs to use as shelter. These slugs are then collected and destroyed. Protective barrier rings of coal tar, soot, ash, lime and other caustic substances were old suggestions and occasionally are used today.

Trapping - The use of beer, near-beer or any fermenting food (such as a mixture of sugar, yeast and water) put in cups in the ground is a technique that often results in large collections of drowned slugs. This method is helpful but still leaves a lot to be desired. In fact, commercial slug baiting stations can be purchased for the same purpose.

Commercial Slug Baits and Pesticides- Slug baits are probably the most consistent and efficient method of slug control. Several commercially available baits or pellets are available which contain a molluscicide. A molluscicide is a poison that kills snails and slugs. Since these poisons may be toxic to pets, fish and humans, carefully use the products as directed on the labels. Some of these are Ambush or Pounce (permethrin), Distance (Pyriproxyfen), Aphid-Mite Attack, Insecticidal Soap, M-Pede (soaps, pesticidal) Conserve (spinosad).

Chapter 7
Study Questions

1. Aphids secrete a liquid called honeydew.

   A. True *
   B. False

2. Spider Mites cause stippling on plants.

   A. True *
   B. False

3. When using pesticides to control whiteflies in the greenhouse you must first identify the species and life cycle.

   A. True *
   B. False

Chapter 8
COMMON GREENHOUSE DISEASES

Learning Objectives
1. What causes diseases
2. What types of diseases there are
3. How to control diseases
4. What to do when a disease is found
5. How to keep the greenhouse disease free

COMMON DISEASE PESTS
The following information contained in this chapter is by no means complete. There are so many diseases of ornamental and flowering plants we cannot provide information on all of them. It is however, the most common greenhouse disease pest to date.

DISEASES CAUSED BY BACTERIA
Bacteria are a varied group of single-celled microbes. These microbes can cause many diseases of greenhouse crops.

(Figure 8.1) Leaf spot

LEAF SPOT AND STEM ROT
This is one of the most serious diseases affecting geraniums. This disease is also known as "bacterial blight." This disease affects the common geranium, the horseshoe geranium and the ivy geranium. Under warm humid conditions, losses may be as high as 100 percent depending on the cultivar. This disease is hard to manage because cool temperatures mask disease symptoms. Plants that seem healthy may later show symptoms when conditions favorable for the bacteria occur.

Causes
This disease is caused by Xanthomonas *campestris* pv. *pelargonii* (hereafter called *X. pelargonii).* The bacteria attack leaves and stems of seedlings, cuttings and mature plants.

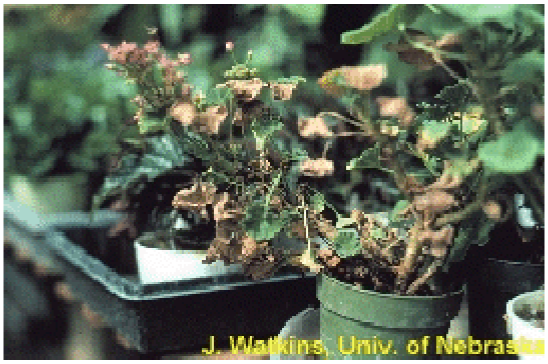
X. *pelargonii* is commonly introduced into the plantings by cuttings taken from infected plants. There is also some evidence that suggest the pathogen might be seed transmitted. The bacteria can spread through the rooting system to healthy cuttings if plants are being rooted close together and they have a high moisture level. The pathogen is often spread by contaminated tools and by physical contact between infected and healthy leaves.

The greenhouse whitefly *Trialeurodes Vaporaior* and other insects can serve as vectors (carriers of the bacteria). Bacteria can enter the plant wherever wounds occur. Once X. *pelargonii* is inside the host, it spreads through the vascular system producing the stem rot and leaf symptoms. Plants under cool dry conditions may seem healthy because the disease is kept in check. When temperatures become elevated, signs of the disease appear.

Portions of diseased plants carry the bacteria to the soil. X. *pelargonii* can survive in decaying tissue for extended periods of time. Contaminated soil can serve as a source of infection. Because the bacterial can easily enter the plant through cutting wounds or damaged roots, nearly every plant in contaminated soil will probably develop the disease. This disease spreads quickly through the greenhouse when the moisture levels are high and the temperatures are between 70 F and 80 F. Also excessive nitrogen and phosphorus fertilization and low levels of calcium may promote disease development.

Symptoms and Damage
Plants infected with X. *pelargonii* show two clearly different leaf symptoms. Spots may develop on the under surfaces of infected leaves. They are small, round and water soaked at first. However, they develop into large sunken areas in a few days. Borders of the lesions may be round or angular depending on the variety of geranium attacked. The spots could in time reach a diameter of 1/8 to 3/16-inch. The spots then will turn dark and become hard and dry. Infected leaves may drop from the plant shortly after they die or remain soft and wilted but attached to the stem for several days. Bacteria can enter the stem through the stalk of the infected leaves. The bacteria can spread to other portions of the plant, resulting in more leaf infections. If bacteria reach the upper part of the plant, stem rots may develop. These infections frequently result in the death of the plant. Stem rot is often seen at the point where diseased leaves are attached to the stem.

The second common symptom, wilting of the leaf margins, occurs in nearly every variety of geraniums. These wilted areas quickly die, become dry, and form large, angular dead regions enclosed by leaf veins. These leaves also quickly drop from the plant. Similar symptoms could be caused by other plant pathogens or certain nutrient deficiencies, but spotting and leaf margin wilt is diagnostic of X. *pelargonii* infections.



(Figure 8.2) Stem rot

Growers commonly call stem rot “black rot.” The vascular system of infected stems darkens and finally becomes shriveled and a dull dark brown to black in color. This commonly occurs two to four weeks after infection. As the bacteria rots through the stem, infected tissue becomes, dry, black and shriveled. If the stem is cut at the advancing edge of the rot, yellow bacterial ooze often appears on the cut surfaces. Plants may possess several blackened branches in addition to the main stem. Infected branches usually become completely defoliated except for small clusters of leaves at the tips. Blackening may also progress down the stem and affect the roots. However, rotting of root tissue rarely occurs. Some infected plants may seem to recover and produce branches that appear to be healthy but this new growth nearly always becomes infected and dies.

Infected cuttings typically fail to root. Instead they develop rot that gradually moves up the stem. Leaf wilt and leaf spotting may be evident. The rotted stem eventually becomes shriveled as with *Pythium*. The rot produced by *Pythium splendens* (blackleg) is black, moist, and shiny while X. *pelargonii* produces a dull black rot that appears quite dry. The bacterial stem rot develops much more slowly and may take as long as a month to kill a plant. Pythium may kill a geranium cutting within a week. A distinguishing characteristic of X. *pelargonii* stem rot, slimy bacterial ooze exuded from a cut stem, is never associated with Pythium blackleg.

Control Tactics

Very few commercially grown geranium varieties show resistance to X. *pelargonii*. Some resistant cultivars have been identified as carriers of the disease without any symptoms. These resistant varieties can infect a clean crop. The pathogen is easily spread and there is no effective chemical control. Exclusion and sanitation are the most practical means of controlling the disease. A comprehensive control program for leaf spot and stem rot of geranium would include the following:

1. Start nursery and hobby stock from seed. Cuttings taken from these plants should be removed from the upper branches. Plants must be grown in sterilized flats or pots using fumigated or pasteurized potting mixture.

2. Take geranium cuttings by breaking rather than cutting with tools. This is the most important means of controlling the disease in commercial production. If a blade is used, it should be dipped in 70 percent alcohol and flamed between source plants. Cuttings should never be treated with liquid dips!

3. Root cuttings in individual pots containing steam sterilized soil, if possible. This reduces the spreading of disease through the roots. If flats are used, cuttings should be adequately spaced to prevent foliage contact between plants.

4. Avoid damaging roots when rooted cuttings are transplanted.

5. Observe strict sanitation procedures when handling plants and cuttings. Hands should be washed with soap and water before and after contacting plant tissue. Benches holding plants should be washed with bleach and water or any other disinfectant. Allow benches to air dry. Benches should not be located in areas where other geraniums are grown.

6. Avoid over-watering and wetting the leaves. If possible, do not use over-head sprinklers. If possible, each pot should be watered at soil level.

7. Do not over-fertilize. High nitrogen and phosphorus fertilizer should be limited or avoided. Higher levels of calcium and potassium can be used.

8. Control whiteflies and other insects that are vectors or carriers for diseases.

Ralstonia *solancearum*

Ralstonia *solanacearum* race 3 biovar 2 is a bacterial pathogen not known to occur in the U.S. It causes a wilt disease in several important agricultural crops such as potatoes, tomatoes, peppers and eggplant. The disease it causes is known as Southern wilt, bacterial wilt, and brown rot of potato. This pathogen was detected early in 2003 in some U.S. greenhouses that received imported geranium plants, and was subsequently eradicated.

USDA, APHIS Plant Protection and Quarantine, in cooperation with State plant health regulatory authorities placed holds on plant material (i.e. geraniums) at various nurseries around the country suspected of harboring the pest until confirmatory testing was performed to determine which geranium shipments contained infected material. An "action plan" was assembled and distributed to our field offices. The plan provided guidance to federal and state regulatory officials who were taking actions to stop this pest from moving and eradicate it from facilities.

Since that time, APHIS began requiring that all geraniums imported from countries with Ralstonia solanacearum race 3 biovar 2, must be certified as tested and found free of the bacterium and meeting production facility sanitation requirements. For more information, look for the document, "Minimum Sanitation Protocols for Offshore Geranium Cutting," to be posted to the aphis.usda.gov website. Additionally, a program review and planning meeting was sponsored by PPQ in Riverdale, Maryland in June of 2003. A record of that meeting appears on this website.

(Figure 8.3) Ralstonia damage of geranium

Causes

Bacteria cause Ralstonia. It can be transmitted through soil, contaminated irrigation water, equipment, or personnel. For example, it may be spread by transplanting and propagating infected plants, taking cuttings without disinfecting grafting knives between plants, pinching buds of plants, and especially by sub-irrigating geraniums. The pathogen does not spread from plant-to-plant through the splashing of water, casual contact, or aerially. Spread can be controlled in greenhouses by the application of sound sanitation practices.

(Figure 8.4) Ralstonia root damage of geranium

Symptoms and Damage

Wilting symptoms in geraniums caused by Ralstonia species are similar to wilting symptoms caused by other pathogens such as Xanthomonas *campestris* pv. *pelargonii*, the agent of bacterial blight. The primary geranium symptom of infection by R. *solanacearum* race 3 biovar 2, is wilting of leaves and/or abnormal yellowing of lower leaves, while Xanthomonas *campestris* pv. *pelargonii* can also produce leaf spots. Bacterial streaming may be seen if stem sections from Ralstonia infected, symptomatic plants are placed into water. If infected with Ralstonia, vascular discoloration of the stem is common, and roots may sometimes turn brown. However, with Xanthomonas *campestris* pv. *pelargonii*, vascular discoloration is less pronounced or absent, and roots remain white.

Control Tactics

Because Ralstonia usually does not occur in the United States, little is known about its control.

The culture and sanitation approaches to disease control are the best way to manage this pest. Make sure all cuttings are free of the bacteria. Make sure all potting medium is sterile. Make sure all utensils used are clean and disinfected.

If you suspect you have a Ralstonia problem, take the plants in question to a place in the greenhouse where they cannot contaminate the crop. Then contact the APHIS/USDA and let them know you think you have a problem with Ralstonia.

DISEASES CAUSED BY VIRUSES

Viruses are pathogens that live and multiply only within living cells of the host. The symptoms they cause are diverse. Sometimes growth abnormalities will appear. Virus-induced diseases of greenhouse grown floral crops result in substantial economic losses to growers every year. There are a variety of viruses that can infect floral crops, most of which are moved from plant to plant by insects. The type of symptom they induce in the plant can identify most virus diseases; however, positive identification needs to be done in cooperation with a plant diagnostic clinic. The five most important viruses infecting floral crops are discussed in this section.

Symptoms associated with floral crop viruses vary substantially with the virus and the particular host that is affected. The same virus can cause different symptoms in different hosts. Symptoms such as mosaic, ringspot, necrotic spot, leaf blistering and deformation are all symptoms associated with floral plant viruses. Other symptoms of the more general type can also be associated with virus infection. These include yellowing, stunting, and wilting. This general group of symptoms sometimes complicates the diagnostic process, as they are also symptoms associated with other types of floral crop pathogens.

IMPATIENS NECROTIC SPOT VIRUS (INSV)

Until recently, tomato spotted wilt virus was considered to have two strains; the impatiens strain and the lettuce strain (also known as the common strain). The impatiens strain was recently found to be different from tomato spotted wilt virus and has been renamed Impatiens necrotic spot virus (INSV). The impatiens strain is more commonly found in greenhouses than the lettuce strain. Both strains may occur in greenhouses as well as in vegetables but it is usually the lettuce strain that is found in vegetables. Tuberous dahlias also appear to be a common host of the lettuce strain. The two different viruses can cause different symptoms in tobacco but it is not yet clear if they cause different symptoms in other plants. The host ranges of the two viruses overlap but it is not known to what extent.

Impatiens necrotic spot virus is becoming one of the most important problems in the floriculture industry today. The virus is widespread due to the distribution of infected plant material and the increased prevalence of the insect vector which transmits the disease.

The host ranges for the viruses are extensive. More than 300 plant species are known to be susceptible. It is likely that many more new hosts will be discovered.

Causes

Both viruses are transmitted by vegetative propagation of infected plant material and by the feeding activity of certain species of thrips. In greenhouses, the most important vector is considered to be the Western flower thrips (WFT), *Frankliniella occidentalis*. The virus is associated with thrips in a persistent manner. Larvae become virus infected after feeding about 30 minutes on an infected plant. After a latent period lasting 3 to 18 days, the thrips can infect new plants after feeding for 5 to 10 minutes. The insects are able to transmit the virus for the rest of their lives. In greenhouses, the viruses can be perpetuated through successive crops and weeds resulting in losses year round.

Symptoms and Damage

The original name of the virus was derived from the symptoms (spotting followed by wilt) that develop on tomatoes. On other hosts, ringspots, purple to black lesions on leaves and stems, flower color breaking, stunting, death of terminals, and wilt may occur. The stage of growth can also influence symptom development.

(Figure 8.5) INSV of Impatiens

For many hosts, symptoms are not well known or are not described. However, in some commonly infected crops, symptoms can be diagnostic. Gloxinias infected as young plants develop necrosis of the central leaves, resulting in collapse. Older gloxinias develop necrotic ringspots on the foliage, as well as necrosis along the veins.

(Figure 8.6) INSV of Gloxinias

(Figure 8.7) INSV of Cineraria

Cineraria develops chlorotic ringspots and/or mottling on the upper leaf surface, and purple to black lesions on the veins underneath. On exacum, the virus causes tan to dark brown cankers on stems. Reiger begonias develop necrotic ringspots, mosaic, and necrosis of the leaf veins. Symptoms on impatiens and New Guinea impatiens include stunting, leaf distortion and blackened spots or rings on foliage and stems. In some cases, terminals will die and the entire plant may collapse. As with other virus diseases, infected plants may remain without symptoms for a period of time.

(Figure 8.8) INSV of New Guinea Impatiens

Control Tactics

There are no chemicals that will cure a plant of a virus infection. Chemicals are helpful in insect and weed control. That is why it is so important to practice all of the non-chemical disease management practices.

Elimination of infected plant material and Western Flower Thrips are the most important management practices. Newly acquired plant shipments should be inspected for evidence of thrips and symptoms of virus before being introduced into the greenhouse.

Symptomatic plants should be discarded or isolated and the supplier should be notified after laboratory confirmation of the disease. Since various weed species can harbor the viruses, thorough weed control is important. If possible, keep plants reproduced from vegetation plants isolated from those produced from seed. *Do not* grow vegetable transplants in the same greenhouse with susceptible ornamentals. Thrips populations should be monitored with sticky traps. Since only a small number of virus-infected thrips are necessary to start an epidemic, total eradication of Western Flower Thrips should be the goal.

CUCUMBER MOSAIC VIRUS (CMV)

Cucumber mosaic virus has the widest host range of any plant virus in the world and is a common problem in a wide variety of ornamental plants including greenhouse-grown bedding and perennial plants. The virus infects plants in hundreds of families and in some cases has the ability to go undetected unless one has a keen eye as to its sometimes-subtle symptoms.

Causes

Cucumber mosaic virus can enter a greenhouse in a variety of ways. Aphid-transmission is its primary method of moving the virus from plant to plant. These pesky insects can feed on weeds and other virus-infected hosts outside the greenhouse and then move indoors where they spread the virus from plant to plant very efficiently. Cucumber mosaic virus can also be brought into the greenhouse via virus-infected seed (in selected hosts) and cuttings. Mechanical transmission (plant to plant contact or propagation tool to plant contact) is another method of entry. However, seeds, cuttings and mechanical transmission are negligible when compared to aphid-transmission.

Symptoms and Damage

The most common symptoms associated with Cucumber mosaic virus infection are mild to severe leaf mosaic, leaf distortion, flower color-break, plant stunting, and yellowing. In some cases plants infected with Cucumber mosaic virus can appear to look "healthy" and may, depending on the environmental conditions "grow-in and grow-out" of symptoms. Cucumber mosaic virus-infected plants tend to express symptoms during the cooler times of the growing season and as the greenhouse gets hotter the symptoms may be suppressed. However, once a plant is infected, it is infected for life, symptoms or not.

Plants without symptoms can still serve as a source of the virus is fed-on by aphids or if cuttings are taken from these plants. Damage caused by Cucumber mosaic virus is dependent on the host species and the age of the plant at which infection takes place. In some hosts, Cucumber mosaic virus infection can cause severe stunting and deformation, while in a host such as geranium, the virus has little to no effect on the outward appearance of the plant. The further along in the growth stage of the host, the less likely Cucumber mosaic virus infection will be a serious problem. Plants infected in the early stages of growth and development can be severely stunted, may not set flowers and in extreme cases, the plants will die.

(Figure 8.9) Cucumber mosaic virus on geranium

Control Tactics

It should be noted that once a plant is infected with any plant virus there is **NOTHING** that can be applied to the plant that will "cure" it of the virus. There are products that will "kill" viruses on bench tops and floors; however, these products have no affect on virus-infected plants. Therefore, the best way to control Cucumber mosaic virus (as it is with all plant viruses) is to avoid virus infection to begin with (prevention). This means making sure that the seed or the propagation stock that you purchase is virus-free. Most major producers of seed and propagation material go to great lengths to make sure that the product they sell you is free from viruses. Problems arise when growers try to cut corners and purchase second-rate propagation material or cheap seed. These actions will only cost you more money in the long run. Since aphid transmission is the number one way Cucumber mosaic virus moves in, out and about the production facility, it is of utmost importance the population of these insects be kept to a minimum. Aphid populations should be monitored within the greenhouse using yellow or blue sticky cards. When aphid populations reach a critical level, the appropriate insecticides should be applied. Also, weeds growing outside of the greenhouse can harbor Cucumber mosaic virus and other viruses. Aphids can acquire these viruses when feeding on infected weeds and move the viruses into the greenhouse. Weeds should be eliminated by mowing or herbicide applications. Caution should be taken when using herbicides outside the greenhouse. Be aware that some herbicides can drift into the greenhouse and cause problems on the greenhouse crop.

TOBACCO MOSAIC VIRUS (TMV)

Recently, another very destructive virus has become a problem in solanaceous (nightshade family) crops such as petunia and Nicotiana. This virus is Tobacco mosaic virus. Tobacco mosaic virus is not a new virus. It was the first plant virus to be identified and it is the most studied of the hundreds of plant viruses known today. Tobacco mosaic virus has the potential to be very destructive particularly if it escapes early detection in the host crop. Growers need to know what types of symptoms to look for and more importantly what to do with the infected plants and the infested greenhouse after Tobacco mosaic virus has been confirmed.

Causes

Many of the commonly-grown greenhouse bedding plants are susceptible to Tobacco mosaic virus infection. Hosts such as petunia, Nicotiana, impatiens and vegetable transplants such as tomato and pepper are all highly susceptible. The primary way that this virus moves from plant to plant is by mechanical transmission. This means by physically handling infected plants with ones hands, pruning implements or watering wands, Tobacco mosaic virus can spread from plant to plant. Unlike most other viruses, insects are not of major concern when dealing with Tobacco mosaic virus.

Symptoms and Damage

One of the most common symptoms associated with Tobacco mosaic virus infection is leaf mosaic and flower break.

(Figure 8.10) Tobacco Mosaic Virus on Impatiens

Leaf mosaic is usually accompanied with leaf distortion which can range from mild distortion to severe distortion. In most cases the infected plants are stunted and may be yellow. Ringspots on the leaves that are commonly associated with INSV infection are not normally seen in plants infected with TMV.

Control Tactics

To reduce infection of plants with TMV, all tools should be washed with soap or a 10% solution of household bleach to inactivate the virus. TMV-contaminated soil should be discarded. To avoid transmitting the virus from an infected plant to healthy plants, the watering hose or watering can should not be allowed to make contact with the plants. Care should be taken to dispose of dead leaves and old plants, because dry, TMV-infected leaves can be blown around the greenhouse. The dust can infect healthy plants if they are wounded.

Inoculation of a mild strain of the virus onto young plants can protect them from the infection by more severe strains of TMV. This is a well-documented control strategy, called "cross protection," that is successfully applied in greenhouse operations. Transgenic plants also offer alternative strategies for virus control.

DISEASES CAUSED BY FUNGUS

There are a number of diseases that are caused by fungi. They have many different symptoms. Some diseases can be superficial and some can be fatal to the host.

POWDERY MILDEWS

Almost all greenhouses have plants that can become diseased with one of the powdery mildew fungi. Although the fungi that cause powdery mildew are usually different on different plants, all of the powdery mildew diseases are similar in appearance. Prompt recognition and control actions can prevent severe damage to plants from powdery mildew diseases in most cases.

(Figure 8.11) Powdery Mildew on Gerbera Daisy

Causes

A fungus that infects the plant causes powdery mildew. Most powdery mildew fungi produce airborne spores. They infect plants when temperatures are moderate (60 to 80 degrees F). They will not be present during the hottest days of the summer.

Unlike most other fungi that infect plants, powdery mildew fungi do not require free water on the plant surface in order to germinate and infect. Some powdery mildew fungi are favored by high humidity. Over crowding and shading will keep plants cool and promote higher humidity. These conditions are highly conducive to powdery mildew development.

Remember that each species of powdery mildew has a very limited host range. Infection of one plant type does not necessarily mean that others are threatened. For example, the fungus that causes powdery mildew on lilac does not spread to roses and vice versa.

Symptoms and Damage
Powdery mildews often appear as a superficial white or gray powdery growth of fungus over the surface of leaves, stems, flowers, or fruit of affected plants. These patches may enlarge until they cover the entire leaf on one or both sides. Young foliage and shoots may be particularly susceptible. Leaf curling and twisting may be noted before the fungus is noticed. Severe powdery mildew infection will result in yellowed leaves, dried and brown leaves, and disfigured shoots and flowers. Although it usually is not a fatal disease, powdery mildew may hasten plant defoliation and fall dormancy, and the infected plant may become extremely unsightly.

(Figure 8.12) Powder Mildew on Begonia

Control Tactics
The following cultural practices should be beneficial for controlling powdery mildews.

- Purchase only top-quality, disease-free plants of resistant cultivars and species from a reputable nursery, greenhouse or garden center. Horticulturists in the green industry and Extension offices should be consulted concerning the availability and performance of resistant varieties.
- Prune out diseased terminals of woody plants, such as rose and crabapple, during the normal pruning period. All dead wood should be removed and destroyed (preferably by burning). Rake up and destroy all dead leaves that might harbor the fungus.
- Maintain plants in a high vigor.
- Plant properly in well-prepared and well-drained soil where the plants will obtain all-day sun (or a minimum of 6 hours of sunlight daily).
- Space plants for good air circulation. DO NOT plant highly susceptible plants--such as phlox, rose, and zinnia--in damp, shady locations.
- Do not handle or work among the plants when the foliage is wet.

- Water thoroughly at weekly intervals during periods of drought. The soil should be moist 8 to 12 inches deep. Avoid overhead watering and sprinkling of the foliage, especially in late afternoon or evening. Use a soil soaker hose or root feeder so the foliage is not wetted.

RUSTS
Like powdery mildews, rusts are also host specific. Rusts spores are transmitted abundantly to the leaf tissue. The masses of orange to dark red spores are what show on plants when they become diseased.

GERANIUM RUST
Causes
The fungus *Puccinia pelargonii-zonalis* causes geranium rust. This fungus has a very restricted host range. This fungus only exists on living plant tissue. It cannot survive for long in the absence of the host plant. Consequently, the spores of this fungus infect geraniums. Rust pustules containing more spores then form on infected leaves, and these spores are moved around by wind and water. Eventually they cause new infections on leaves on the same plant as well as on other plants. This disease cycle continues indefinitely as long as environmental conditions are favorable.

Symptoms and Damage
Symptoms and signs of geranium rust occur mainly on the foliage. Signs may also occur on stems and leaf petioles. Initially, symptoms appear as yellow or white circular spots or lesions on upper and lower leaf surfaces. These symptoms usually appear 10-14 days after infection has occurred. A small, blister-like pustule (called a uredium) develops in the middle of the lesion on the underside of affected leaves. Mature pustules break open to expose large quantities of rusty brown spores (called urediospores). The spores are released about three weeks after infection has occurred. As the disease progresses, the number of lesions or spots per leaf increases. The ring of smaller pustules develops around the central pustule in many lesions. When the disease is severe, entire leaves wither and die and whole plants may succumb to infection.

(Figure 8.13) Rust pustule on geranium leaf

Control Tactics
Prevent rust from ever getting established in your greenhouse by carefully examining cuttings or plants before purchasing them. Greenhouse and nursery operators should question suppliers. They should ask about the propagation material. They should ask about the occurrence of rust at their production facilities, particularly those located outside the United States. Avoid purchasing plants from locations where rust occurs naturally.

The best and most effective method of managing geranium rust is to rogue (cut) out and destroy affected plants as soon as they are recognized!! By eliminating the host plant, the life cycle of the fungus is broken and the pathogen cannot survive. Diseased plants should not be placed on a compost pile because fungus spores can persist and remain infective for several months on dead geranium leaves. Keeping zonal geraniums out of the greenhouse or nursery where rust has occurred for a period of four to six months should insure that rust would not reoccur the following year.

Fungicides can be effective at preventing rust from developing in the greenhouse. Newer fungicides registered for use on geraniums and containing the active ingredients triadimefon (Bayleton, Strike) and myclobutanil (Systhane) should be most effective against geranium rust. However, these fungicides are in a class of chemicals that also has growth regulator activity and should be used sparingly on young actively growing plants. In addition, mancozeb products (e.g., Dithane, Protect) traditionally have had reasonably good activity against rust diseases on other crops. Probably the best fungicide treatment would be a combination of one of the newer fungicides and a mancozeb product. This would take advantage of two types of chemistry and should provide excellent disease management.

WATER MOLDS

These fungi have a spore stage that can spread by swimming in water. They attack a wide variety of plants, causing root, stem, and cutting rots. Usually they do not kill their host.

PYTHIUM

Pythium is a fungus-like organism. It can be found in field soil, sand and has been found in commercial non-soil potting mixtures. It can be found in the water of ponds and streams. Also, it can be in the sediments of those ponds and streams.

Causes

Pythium can be easily introduced into the greenhouse by contaminated water, tools, soils, planting media and dirty pots.

(Figure 8.14) *Pythium* root rot

Symptoms

Pythium attacks juvenile tissues such as the root tip. After gaining entrance to the root the fungus may cause a rapid, black rot of the entire primary root. It may even move up into the stem tissue. As the soil dries, new roots may be produced and the plant may recover or never show symptoms of disease.

Under wet conditions brought about by poor soil drainage or excess irrigation, more and more roots are killed. The plant may wilt, stop growing, or even collapse and die.

Bulbs of susceptible plants turn black, gradually dry out, and form a hard mummy.

Control Tactics

In the control of *Pythium* disease, emphasis is placed on providing good drainage and water management. Steam (at 140°F for 30 minutes) or chemically treat growing medium. Sanitation is important because *Pythium* spp. can survive in dust, planting medium, or soil particles on greenhouse floors and in flats and pots. Remove and discard diseased plants. Use of properly composted pine bark at 20% in potting mixed is reported to provide some control of Pythium and Phytophthora root rots; also the mycoparasite, *Gliocladium virens,* is used as a *Pythium* biocontrol agent.

PHYTOPHTHORA

A fungus causes *Phytophthora* blight. Other names applied to this disease are damping off, *Phytophthora* root rot, crown rot, stem and fruit rot. All of these names can apply since all parts of the plant are affected.

Causes

Phytophthora can be easily introduced into the greenhouse by contaminated water, tools, soils, planting media and dirty pots.

Symptoms

Phytophthora blight can attack the roots, stems, leaves, and fruit, depending upon which stage plants are infected. A grower, not knowing what to expect, might first encounter the disease at mid-season when sudden wilting and death occur as plants reach the fruiting stage. Early infected plants are quickly killed, while later-infected plants show irreversible wilt. Often a number of plants in a row or in a roughly circular pattern will show these symptoms at the same time.

Fungus-infected seedlings will damp off at the soil line, but relatively few plants die when temperatures are cool. Far more commonly, the disease will strike older plants which then exhibit early wilting. Stem lesions can occur at the soil line and at any level on the stem. Stems discolor internally, collapse, and may become woody in time. Lesions may girdle the stem, leading to wilt above the lesion, or plants may wilt and die because the fungus has invaded the top branches before the stem lesions are severe enough to cause collapse.

(Figure 8.15) *Phytophthora* crown rot

Leaves first show small dark green spots that enlarge and become bleached, as though scalded. If the plant stems are infected, an irreversible wilt of the foliage occurs.

Phytophthora is a soil-borne disease. It is more prevalent on poorly drained soils. Careful attention must be given to cultural practices, especially in greenhouses with a history of the disease. Make sure that plants can drain properly. Airflow is needed to dry soil, so plant spacing is important. Disinfecting tools, planting tables, soils and the greenhouse will help control this disease.

ROOT AND STEM ROTTING FUNGI

Many other fungi cause root and stem rots. They live in the soil and attack a wide variety of crops.

BLACK ROOT ROT

Black root rot is a common and destructive fungal disease on greenhouse floral crops. The disease is widespread, having been reported on many different plants including poinsettia, geranium, fuchsia, pansy, vincas, petunia, etc. The fungus is soil-borne and is capable of living in soils as a saprophyte (without causing disease) and surviving in soil and dust for years via tiny, thick-walled spores called chlamydospores. Plants may be infected but not show symptoms until the plant undergoes some form of stress.

Causes

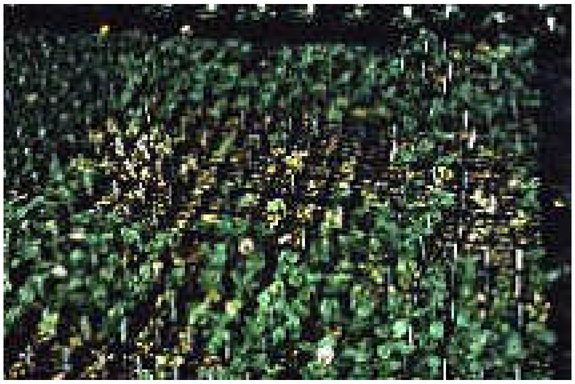
The fungus, *Thielaviopsis basicola*, causes black root rot. As mentioned earlier, the fungus is very common and widespread. It has a wide host range and affects many other hosts besides greenhouse floral crops. *Thielaviopsis* can spread between greenhouses or between crops within a greenhouse in many ways. Long distance spread between greenhouses occurs via the movement of infested (but not necessarily diseased) plant material. Many of our specialized plug producers control crop stresses so well that an infestation of their material goes undetected by all parties until the plants are stressed in shipment or transplanting.

Infested plugs are not the only way your crop can get black root rot. *Thielaviopsis* also has the potential to enter a greenhouse via wind blown dust or in growing media. Once within a greenhouse, there are many situations that can result in the pathogen becoming a long term resident. *Thielaviopsis* has a broad host range, and its saprophytic nature may allow it to continue to grow, spread and survive on many plants in the greenhouse that may appear symptomless or nearly so.

Thielaviopsis produces resistant "resting" spores on infected host tissue in tremendous numbers. These spores can be splashed about or blown about in dust in the air. They will be present on flats, pots, or trays that may be brought into a work area for reuse. In addition, the pathogen produces a second type of spore that is spread by splashing water. It may be the spread of these small spores that allows the disease to develop so quickly once it gets started. All in all, the black root rot pathogen is well suited to becoming a permanent, though unwelcome, resident in your greenhouse.

Symptoms and Damage

Black root rot is commonly confused with *Pythium* root rot. Aboveground symptoms of both diseases include yellowing, stunting and under certain conditions wilting or death of the plant. Sometimes, plants affected with black root rot may have black stem lesions at or near the soil line. A close examination of the roots will reveal different symptoms for each disease. *Pythium* usually attacks roots from the ends or tips, causing a soft, brown rotting as it progresses. Oospores of *Pythium* can be seen in the infected roots with a microscope. Black root rot begins by attacking the middle of the root and forms cankers. The black root cankers can be seen relatively easily by washing roots free of growing media and then viewing them carefully with a hand lens. A plant diagnostic lab can be consulted if you suspect black root rot. Be sure and tell them you think black root rot may be involved so that the lab will examine the roots through a microscope. If *Thielaviopsis* is there, the black, barrel-shaped spores will be easily seen. There are also methods to culture the fungus from the tissue.



(Figure 8.16) Pansies with black root rot

(Figure 8.17) Black root rot on Pansy root

(Figure 8.18) Black root rot spores

BOTRYTIS GRAY MOLD

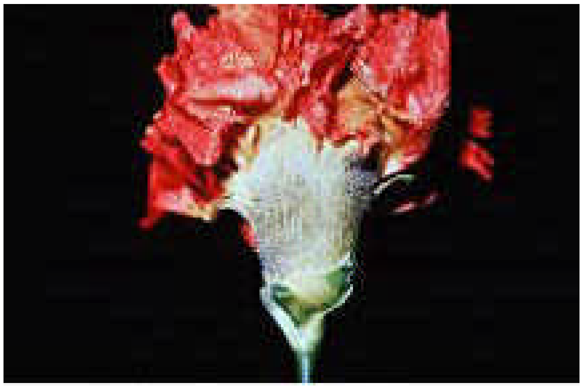
The most common disease of greenhouse floral crops is gray mold. The disease can affect almost every type or variety of floral crop grown. This disease can either be a common nuisance or an economic disaster depending on the host and the conditions under which the crop is grown. It is also one of the easiest diseases to control using non-chemical means.

Causes

The fungus *Botrytis cinerea* causes gray mold. It is a common fungus, with a very wide host range and can persist in the greenhouse year-round; as mycelium, conidia, or as sclerotia on living or dead tissue. The fungus produces a large amount of spores that move throughout the greenhouse via air currents. Under optimum environmental conditions (relative humidity at or above 85%, with little or no air circulation or with free water on the leaf surface), the spores land on the plant surface, germinate, and penetrate the host plant. The optimum temperature for spore germination is 72 to 77 degrees F (22 to 25 degrees C). Germinating spores rarely penetrate actively growing tissue directly. However, penetration of actively growing tissue can take place through wounds. Cutting stubs are particularly susceptible to gray mold infection. If left unchecked, the fungus will grow and sporulate and the newly produced spores will be the source of infection for other hosts in the greenhouse. The fungus can also be a post-harvest problem, becoming established at temperatures of 32 to 50 degrees F (0 to 10 degrees C).

Symptoms

Symptoms of gray mold vary depending on the host and the environmental conditions associated with the host. Under most conditions and with most hosts the disease is characterized by the production of leaf spots, flower blight, bud rot, stem canker, stem and crown rot, cutting rot, damping off, and in extreme cases, plant death. When conditions of high relative humidity prevail, at or above 85%, the fungus can be seen growing and sporulating on the infected tissue. Fungal growth is characterized by the presence of fluffy, gray/brown mycelium that produces a cloud of spores if disturbed. Affected tissue is soft and brown, and sometimes has a water-soaked appearance.



(Figure 8.19) Flower blight of carnation

Flower Blights and Bud Rots

Flower blight of greenhouse crops such as begonia, carnation, chrysanthemum, cyclamen, geranium, impatiens, marigold, and petunia often precedes and leads to stem rot. The fungus becomes established in the flower petals and under ideal conditions moves from the flower to the pedicel or peduncle, and eventually to the stem. Symptoms appear as tannish, irregular spots on the flower petals. Flowers can also become infected in the bud stage. The buds turn brown and appear to be water-soaked. Infected buds fail to open and may sometimes abort.

(Figure 8.20) Bud rot of geranium

Leaf Spot and/or Blight

Leaf spot often appears when infected flower petals or other plant parts fall on the leaves. The pathogen can also invade damaged tissue on leaves that have marginal or tip burn. When this happens, the affected leaf may develop a triangular-shape lesion. Other leaf spots appear water-soaked, are brown in color and have irregular margins.

(Figure 8.21) Leaf spot and stem blight

Damping-Off or Bed Rot

Damping-off of floral crops can commonly be associated with gray mold. Susceptible hosts include, cineraria, cyclamen, exacum, and snapdragon. Damping-off is prevalent when the relative humidity is high or when the growing medium is contaminated with the fungus. Infected seedlings wilt or collapse at or near the soil line.

(Figure 8.22) Damping off of seedlings

Control Tactics

If there is one practice that will go a long way toward the management of gray mold, it is controlling the environment. Maintaining an environment within the greenhouse that will not permit the fungus to grow and sporulate is essential to control. Keeping the relative humidity below 85%, as well as maintaining good air circulation and adequate plant spacing can achieve excellent control. Whenever possible, plants packed closely together should be spread apart to allow better air circulation and to reduce relative humidity within the plant canopy. Fans should be used to provide good air movement above the canopy. Plants with wounds should be either protected with a fungicide or removed from the greenhouse, as the wound is the perfect environment for the fungus to initiate the infection process.

Chapter 8
Study Questions

1. Bacteria are triple celled microbes.

   A. True
   B. False *

2. Powdery mildews are considered to be water molds.

   A. True
   B. False *

3. Black root rot is commonly confused with *Pythium* root rot.

   A. True *
   B. False

Chapter 9
COMMON GREENHOUSE WEED PESTS

Learning Objectives

1. What kind of weeds
2. Where to find them
3. What to do with them
4. How to control them

WEED MANAGEMENT INSIDE THE GREENHOUSE

Weeds are a constant problem in both retail and wholesale greenhouses. Weeds are unpleasant and harbor insects, such as whitefly, aphids and thrips. They also harbor slugs, mites and diseases. Studies have shown that chickweed, oxalis, bittercress, jewelweed, dandelion and ground ivy are hosts for impatiens necrotic spots virus (INSV), which may be vectored to susceptible host crops by thrips. Therefore, the removal of weeds from greenhouse floors is important for the purpose of pest management.

An integrated weed management program will effectively manage weed populations. This includes the use of cultural controls (prevention and sanitation), mechanical controls (hand weeding), physical barriers (fiber cloth), emptying the range and allowing weeds to dry up (solarization) and selective use of chemical control (pre and post-emergence herbicides). These methods will only remove the weeds that are present. These methods will not prevent new growth from seed, which will also be present. Even solarization rarely produces enough heat to effectively kill weed seed.

Prevention

The most important means to manage weeds is sanitation. This involves using weed block fabric to cover the floor and removing any weeds that grow in along the edges. Weed seedlings can be removed either manually or by using herbicide before weeds go to seed. It is best to leave the fabric-covered floor bare so it can be easily swept. Some growers have covered the fabric mulch with stone or other material. This creates a nice environment for weed seedlings to germinate after media had fallen onto the floor and settled in the gravel.

Using Herbicides in the Greenhouse

Very few herbicides are labeled for use in the greenhouse because of the possibility for crop injury or death. This injury may occur in a number of ways.

1. Spray drift, if fans are operating at the time of application.

2. Volatilization (herbicides changing from a liquid to a gas). Herbicide vapors can easily buildup within an enclosed greenhouse and injure susceptible plants.

Always be sure the herbicide you choose is labeled for greenhouse use. Carefully follow all label instructions and precautions. Herbicides are usually classified according to the stage of weed growth affected.

Preemergence herbicides are applied before weeds emerge and provide residual (lasting) control of weed seedlings.

Postemergence herbicides are applied after the weeds have emerged (come out). Several postemergence herbicides can be used under greenhouse benches and on the floors. Contact herbicides are best applied to small succulent seedlings. Large weeds will be burned but not killed. Some selective herbicides are best applied to actively growing grasses beneath greenhouse benches. Irrigating crops too soon after applying an herbicide can wash it off and reduce its effectiveness. Also, since most herbicides are generally non selective, they should not come into contact with crop foliage. Systemic (taken up by the weed) herbicides are best applied to actively growing weeds when temperatures are above 50 degrees F.

MANAGING WEEDS OUTSIDE THE GREENHOUSE

Managing weeds outside of the greenhouse is important to eliminate a major source of air borne weed seed to prevent perennial weeds such as bindweed from growing under the foundation and into the greenhouse. Weed control around the greenhouse will also reduce populations of flying insect pests. There are several options for controlling these weeds. One option is mowing. Mowing, when done regularly, can prevent the majority of weed seed formation. A better solution, if possible, is to maintain a weed-free barrier around the greenhouse. Some sources suggest that a 10 to 20 foot weed-free barrier around the greenhouse is adequate. Weed block fabric mulch or postemergent and soil residual herbicides may be used. While applying herbicides to weeds around the greenhouse, close windows and vents to prevent drift from entering the greenhouse.

If weeds are currently growing up close to the greenhouse and the plan is to eliminate those weeds, use a knockdown insecticide on the weeds first. This will kill flying insects and prevent them from leaving the weeds and entering the greenhouse through the vents. Then use a post emergence, nonselective herbicide to kill existing vegetation.

It is important to practice exclusion and sanitation as part of a routine integrated crop management program with the limited number of herbicides available for greenhouse use.

Chapter 9
Study Questions

1. Weeds harbor insects that are bad for the greenhouse crops.

   A. True *
   B. False

2. Studies have shown the Oxalis is a vector for (INSV).

   A. True *
   B. False

3. The most important means to manage weeds is sanitation.

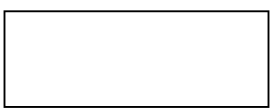
   A. True *
   B. False

Chapter 10
CALCULATIONS

Learning Objectives
You should learn about:
1. Formulas for Application
2. Types of Structures
3. Measuring an Area
4. Calculating the Amount of product to Use

FORMULAS
Here are a few formulas you will need to calculate areas:

The rectangle (4 sides)



Formula: Length X width = square feet

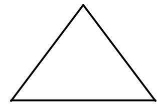
Formula: Length X width X height = cubic feet

Example 1: If the length of the rectangle is 20 ft and the width is 10 ft the equation should look like this: [20' X 10' = 200 square feet]

Example 2: If the length of the rectangle is 20 ft and the width is 10 ft and the height is 14 ft the equation should look like this: [20' X 10' = 200 sq feet X 14' = 2800 cubic feet]

The same logic would apply to a square.

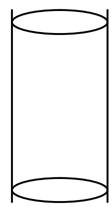
The triangle (3 sides)



Formula: ½ (base X height)

Example: If the height is 10' and the base is 20' the equation should look like this: ½ (20 X 10) = 100 cubic ft

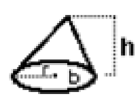
The cylinder – A continuous circular structure (use 3.14 + pi)



Formula: 3.14 X radius squared X height = Volume

If the radius is 5' and the height is 40' the equation should look like this: [3.14 X (5'X5') 40'] 3.14 X 25' X 40' = 3140 cubic feet

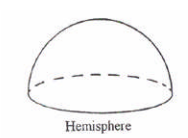
The Cone



Formula: 1/3 [3.14 X radius squared X height] = Volume

If the radius is 6' and the height is 10' the equation should look like this: [1/3 3.14 X (6x6) X 10 = volume] 1/3 3.14 X 36' X 10' = 376.8 cubic feet

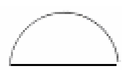
The Hemisphere



Formula – 2/3 (Ab X height)

If the average base is 12’ and the height is 8’ the equation should look like this: 2/3 [12’ X 8’] = 64 cubic feet

Semi Circle



Formula – ½ Pi R2

TYPES OF STRUCTURES

There are a variety of structures that could be treated. These structures are made up of various shapes, buildings with the shapes of squares, rectangles, and triangles. Some are storage places with the shapes of circles and cones. The formulas above will help you to find the volume of these different structures.

MEASURING AREAS

First determine how large the structure is and then calculate the volume of the structure to properly treat it. You have to determine the length, width and height of the structure and use the correct formula to calculate the area. If the structure has a roof or cover you have to determine the radius and height and use the correct formula to calculate the area. Once you have the area of the building and the roof area then you add the two figures together to get the total area.

Chapter 9
Study Questions

1. To measure the cubic ft. of a structure that is the shape of a rectangle, you use the formula L x W.

   A. True
   B. False

2. One bushel has the capacity of 1.22445 cubic ft.

   A. True
   B. False

Glossary

Algae - primitive chlorophyll-containing mainly aquatic eukaryotic organisms lacking true stems and roots and leaves
Asexual – reproduction without the union of male and female germ cells
Asexually – to reproduce without the union of male and female germ cells
Bacteria – one-celled micro-organisms which multiply by simple division, and can only be seen with a microscope
Biological – of the nature of (living matter) plants
Canopy – covering; shelter
Contaminated – defiled; polluted
Cocoon – The silky or fibrous case which the larvae of certain insects spin about themselves to shelter them during the pupa stage
Diagnosis – the process of deciding the nature of a condition by examination of the symptoms
Diagnostic – the method of diagnosis
Dormancy – state of being dormant; not actively growing
Drip Irrigation – controlled irrigation by dripping from an overhead system
Entomophobia – a morbid fear of insects
Eradication – getting rid of; destroying
Exoskeleton – a hard, external secreted supporting structure
Fatal – resulting in death
Germinate – to sprout
Groundwater – water found underground in porous rock, strata and soils
Larvae – (plural of larva) the immature form of any insect that changes structurally when it becomes an adult, usually by a complex metamorphosis
Leach – to filter down through some material
Lifespan – the longest period of time that a typical individual can be expected to live
Microbes – any bacteria that cause disease
Mollusks – invertebrate animals characterized by a soft, usually unsegmented body
Nymphs – the young of an insect with incomplete metamorphosis, differing from the adult primarily in size and structural proportions
Parasite – a plant or animal who derives advantage or sustenance from another and gives nothing in return
Pasteurization – a method of destroying disease-producing bacteria, by heating to a prescribed temperature for a specified period of time
Pathogen – a micro-organism or virus that can cause disease
Persistent – continuing to exist or endure
Predators – living by feeding upon others
Pruning – to remove dead or living parts from a plant
Pupal – an insect's non-feeding stage of development between the last larval and adult forms
Pupate – to go into the pupal stage
Residual – left over after part or most is taken away
Roguing – to remove unhealthy plants
Species – a distinct variety
Subirrigation – irrigation by a system of underground pipes
Susceptible – to receive, easily affected with
Symptom – a condition resulting from a disease or disorder and is an aid in diagnosis