



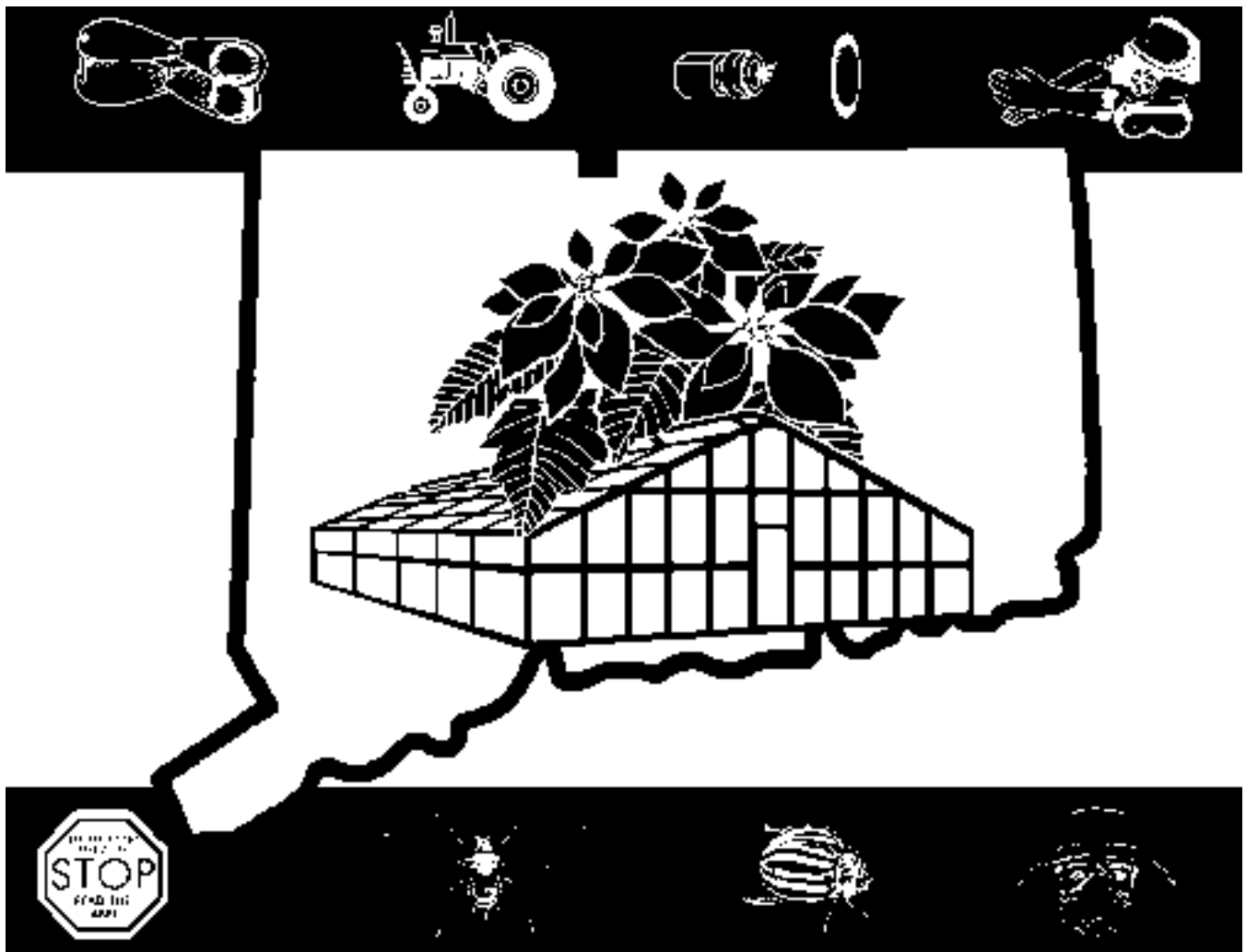
UNIVERSITY OF CONNECTICUT
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GREENHOUSE PESTICIDE MANAGEMENT

Private Pesticide Applicator Training Manual: Greenhouse



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Pesticide Applicator Training Manual: Private Greenhouse

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"Floriculture Production Guide for Commercial Growers," edited by Christine Koch, B.C. Ministry of Agriculture, Fisheries, and Food, 1994-95 ed.

"Insect and Related Pests of Flowers and Foliage Plants" edited by J. R. Baker, University of North Carolina Cooperative Extension.

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"Morphological Comparisons of Three Species of Whiteflies Found on Greenhouse-Grown Plants," Tong-Xian Liu and R. D. Oetting, University of Georgia Research Bulletin Number 412.

"Pesticide Applicator Training Manual for Private Applicators in the Greenhouse and Florist Industries," Cornell Cooperative Extension.

"Suppliers of Beneficial Organisms," Charles D. Hunter, California Environmental Protection Agency, Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1994 ed.

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PRECAUTIONS

Follow directions on chemical labels. Timing and proper sprayer calibration are as important as the product used.

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PREFACE

This manual has been edited by the Pesticide Applicator Training Program to serve as a study guide for private pesticide applicators whose primary production is greenhouse crops. It explains how to apply pesticides safely and effectively and how these applications may affect you, your family, your neighbors and your customers. It also describes the state and federal laws that regulate pesticide use and provide for worker safety. This information will help you prepare for the state certification examination.

Use this manual with your state Core Manual. That volume contains a glossary of pesticide related terms. It also has a section on mathematical conversions and calculations that will be useful when calibrating equipment and determining the proper quantities of pesticides to apply.

In order to become certified, you must pass two tests: one based on the information in the Core Manual and another based on this manual. Both the Core Manual and "Greenhouse Pesticide Management" are self-study guides. You control the pace of your learning. After reading each section, try to answer the review questions. These questions are similar to those found on the certification exams. Correct answers are found at the end of the manual. If you have difficulty with a certain area, go back and review that topic. Allow yourself adequate time to read and understand the material before you take the exams.

After completing the exam, keep this manual as a general reference on pest identification and management strategies. It is impossible to include pesticide recommendations in this type of manual due to new chemicals, label changes, and regulatory actions. Those pesticides that are mentioned are only examples and should not be considered either endorsements or recommendations. For specific pesticide recommendations see the latest edition of the "New England Greenhouse Floricultural Recommendations, A Management Guide for Insects, Diseases, Weeds and Growth Regulators" available through Cooperative Extension.

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SECTION 1

GREENHOUSE OPERATION AND PESTICIDE REGULATION

Several government agencies regulate the pesticides used in greenhouse production in order to protect both the environment and the health of workers and customers. This section introduces the principal laws regulating pesticides manufacture and use. Requirements for certification and licensing of applicators are provided, including:

- Who must be certified,
- Why applicators must be certified,
- What knowledge is required for certification,
- How to become certified and licensed, and
- How to maintain certification and licensing.

GREENHOUSE PRODUCTION



Greenhouse operation is an important part of Connecticut's economy and way of life. Many flowers that grace window boxes in summer or fresh vegetables gathered from gardens started in greenhouses during cold spring months.

There are 525 commercial greenhouses in Connecticut covering 8 million square feet of production area. Many are small, seasonal operations that provide only supplemental income for growers but many have growing areas greater than 10,000 square feet. The production of bedding plants is a major crop for greenhouse operators of all sizes. The annual sales of bedding plants from Connecticut's greenhouses is \$130 million. Larger

producers may also grow potted flowering and foliage plants, cut flowers, and vegetable crops.

The controlled greenhouse environment provides a level of management not possible in field-grown crops. Most factors that affect plant growth, such as soil fertility and available moisture, are easily monitored and adjusted to promote vigorous, healthy plants. Greenhouses also provide ideal conditions for the spread of some diseases and insects, making pest control an essential part of production.

Crop production and public welfare

Although profit is the primary goal for greenhouse crop production, there are other considerations that demand attention. Greenhouse producers are increasingly asked to ensure the safety of their production activities. Public expectations include:

- Offering products that present no health risks to consumers,
- Providing for worker protection, and
- Avoiding environmental contamination from pesticide use.

Putting these goals into practice demonstrates awareness and concern for public welfare. It is difficult or impossible, however, to control the effects of management practices that fall into the following categories:

- Distant effects - such as a consumer purchasing plants from a retail outlet rather than the production greenhouse;
- Delayed effects - such as a greenhouse employee who becomes ill long after pesticide exposure;
- Invisible effects - such as pesticides leaching through soil and contaminating groundwater.

Most state and federal pesticide regulations are enacted to protect human health and our environment. Knowing and complying with these laws not only minimizes pesticide problems, but may actually increase profitability and improve public opinion. Therefore, com-

pliance with the law is fundamentally important to greenhouse production.

Developing a crop management plan

Successful marketing depends on the production of quality plants free from signs of pests and disease. Developing a crop management plan *before* the beginning of a growing cycle will help meet this goal. These plans include how to control insect infestation and plant disease and give growers the opportunity to consider both benefits and risks of the available practices before actually using them. An effective management plan not only reduces the environmental risks associated with pesticide use but saves time and money.

Good crop management limits the need for pesticides by encouraging the growth of vigorous, healthy plants. Some of the factors that promote plant growth and discourage pest problems are:

- Keeping the greenhouse and all systems in good repair,
- Selecting crops suitable for the growing conditions provided,
- Selecting varieties with pest resistance, when available,
- Maintaining good environmental conditions in the greenhouse,
- Proper timing of planting and other production activities, and
- Using alternative pest management techniques including cultural, mechanical and biological control.

Although this manual provides information on the proper use of pesticides when they are required, it cannot provide complete information on greenhouse operation. Many references are available covering greenhouse construction and crop production. A few are listed in Appendix A. The current edition of *New England Floricultural Crop Pest Management and Growth Regulation Guide* is available through the University of Connecticut, Communications and Information Technology, 1376 Storrs Road, Storrs, CT 06269-4035, (860) 486-3336. This guide is updated biennially and provides information on products and application rates that are Federally registered for greenhouse use. For information about products registered for use in greenhouses contact your county or university Cooperative Extension office (see Appendix A) or the Department of Environmental Protection (DEP), Pesticide Management Division (860) 424-3369.

Alternative controls

In certain crops, biological controls may substantially reduce pesticide use. An example uses the tiny parasitic wasp, *Encarsia formosa*, to attack greenhouse whitefly. This technique may be slower but ultimately as effective as any pesticide application. Other alternatives include cultural controls, such as wider plant spacing to inhibit fungal disease, and mechanical controls like roguing (removing) diseased plants. Even for growers who use only chemical control, alternative application equipment is available that reduces the required amount of active ingredient. In addition, choosing specific pesticides to control specific pest growth stages will reduce pesticide use.

Using a variety of techniques that maximize the affect of pesticides and maintain crop quality is called INTEGRATED PEST MANAGEMENT (IPM). The general principles of IPM should be incorporated into crop management plans. IPM promotes wise pest control using a combination of cultural, mechanical, biological and chemical methods. Federal and state agencies, grower organizations and private consultants cooperate in supporting IPM programs. Contact your county Cooperative Extension office or the Extension Specialists at UNH for the most recent information on these programs. A general introduction to IPM practices is provided in Section 4.

CHEMICAL PEST CONTROLS



Pest control has changed a good deal over the last 50 years. Early methods relied on labor-intensive cultural practices. The few chemicals available were dangerous to use and often ineffective. Beginning in the 1940s, development of synthetic chemical pesticides provided hope of ending pest problems once and for all. However, this hope was short lived. Soon after widespread, intensive use of these new compounds, certain

insects and diseases developed resistance to their effect. Continued application of these products provided little control but substantially increased production costs and resistance problems.

Chemical pesticides may also lead to environmental damage although the effects may go unobserved for years. Following widespread use of pesticides during the 1950s, it became apparent that some of them caused serious harm to nontarget organisms such as birds, fish and beneficial insects. Chemicals that persisted in the environment, like DDT, were particularly harmful. Now products registered for pest control are regularly reviewed in an effort to reduce undesirable effects.

Pesticides and public safety



Pesticides and public safety is an increasingly important consumer issue. In recent years, concern over pesticide residues on consumer products and groundwater contamination has received national attention. Proper selection and use of pesticides will generally prevent residues from exceeding federal limits. This is especially important for businesses that allow customers into greenhouses when marketing crops. Pesticides must be carefully chosen and applied to avoid unacceptable residues on all crops at the time they are sold. Remember that certain types of plants may actually retain chemical residues.

Groundwater quality is a growing concern throughout the country. As a pesticide applicator you should know that groundwater contamination may be caused by pesticide spills, incorrect applications or improper disposal methods. Even correctly applied chemicals used over long periods may leach through the soil and enter groundwater. This can easily occur in many of the types of soils that are found throughout Connecticut.

Pesticides are poisons designed to kill a narrow selection of living organisms. In addition to controlling these target pests, pesticides may also, unfortunately, injure or kill nontarget plants and animals, including humans. This is true of synthetic pesticides as well as

compounds derived from natural sources. Pesticide injury may result from:

- Direct contact with pesticides during handling or application;
- Indirect contact from residues following an application; or
- Indirect contact through contaminated natural resources, such as treated soils or polluted water.

The persons most likely to be harmed by exposure to pest control chemicals are the applicators themselves during pesticide use. However, the chemicals currently registered should not cause adverse effects when used according to label directions. Specific regulations have been developed to protect the health of applicators and farm workers. These include procedures that must be followed when handling, mixing and applying pesticides.

Careful choice of products and timely applications help reduce the risks associated with pesticide use. Applicators should be aware of these personal and environmental hazards and limit risks by handling all products according to label directions. **Information provided on labels is the primary means of regulating pesticides.**

PESTICIDE REGULATION



The EPA has the authority to regulate the pesticide industry under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). This law permits the control of all aspects of pesticide use, from production through the disposal of empty containers. In Connecticut chemical use is supervised by the Connecticut Department of Environmental Protection.

General information on federal and state laws covering the use and storage of pesticides is found in your State Pesticide Applicator Training (Core) Manual. Many of these laws help greenhouse operators develop low risk and effective application programs. For example, record keeping requirements make it possible to com-

pare results over several seasons and provide useful evidence in the event of legal action. Every pesticide applicator is responsible for knowing and complying with all appropriate pesticide laws.

certification programs are offered by the University of Connecticut Cooperative Extension Service (CES), the DEP, growers' organizations and other sources.

Classification of pesticide products

Toxicological studies performed by chemical companies during product development determine the classification of each pesticide. The EPA classifies pesticides as either GENERAL USE or RESTRICTED USE. Anyone applying general use or restricted use pesticides, which include certain products used in greenhouse production, must meet the standards set by the EPA and the DEP. Anyone applying restricted use pesticides must be licensed, or under the direct supervision of someone who is licensed. In Connecticut, a third class, PERMITTED USE pesticides, is recognized which requires a special permit for each use. The DEP requires certification and licensing of persons using restricted use pesticides and those making commercial applications of any pesticide.

Applicator Certification

Pesticide applicators who become certified must successfully demonstrate the competency requirements specified by state law. A *private* applicator is an individual who uses or supervises the use of any pesticides, whether classified as general use or state restricted use, for purposes of producing any agricultural commodity on property owned or rented by them or their employer or, if applied without compensation other than trading of personal services between producers of agricultural commodities, on the property of another person. Ask your Cooperative Extension for more information.

The DEP uses written exams to determine the qualifications of persons seeking certification as private applicators for greenhouse applications. The Greenhouse Pesticide Management Manual, when used with the Core Manual, provides the technical information needed to prepare for the private applicator exams. Sample questions at the end of each section are similar to those on the written exams. Be sure to know and understand the answers to these questions before taking the written exams.

Certification for private applicators is for up to a five-year period, during which time twelve (12) recertification credits must be accumulated. Participating in recertification sessions is also a means of keeping up-to-date with the changes that affect greenhouse production. Re-

SECTION 1- REVIEW QUESTIONS
Greenhouse Operation and Pesticide Regulation

1. Crop management plans give growers the opportunity to consider both benefits and risks of available practices before actually using them.

_____ True _____ False

2. Which factors promote plant growth and discourage pest problems?

- a. Selecting pest resistant plant varieties
- b. Maintaining good environmental conditions in the greenhouse
- c. Using cultural, mechanical and biological controls
- d. All of these

3. The New England Floricultural Crop Pest Management and Growth Regulation Guide provides information on crop management products and application rates.

_____ True _____ False

4. List three non-chemical pest control alternatives.

- a.
- b.
- c.

5. Integrated Pest Management (IPM) involves using a variety of pest control techniques that maximize the effect of pesticides and maintain crop quality.

_____ True _____ False

6. Widespread, intensive use of synthetic pesticides in the 1940's and 50's led to insect and disease resistance to these controls.

_____ True _____ False

7. Groundwater contamination may be caused by:

- a. Pesticide spills
- b. Incorrect application of pesticides
- c. Correct application of pesticides
- d. All of these

8. Pesticide injury could result from contact with treated potting soil.

_____ True _____ False

SECTION 2

WORKER AND CONSUMER SAFETY ISSUES

APPLICATOR SAFETY

Greenhouse pesticide use requires strict attention to safety measures. Two aspects of the greenhouse environment directly affect the safety of pesticide applicators:

(1) Frequent application - Greenhouses produce plants year-round confined in a warm, sheltered area. These ideal conditions can attract pest populations and create the need for frequent pest control.

(2) Enclosed design - Greenhouses enclose space and carefully regulate air flow. During typical pesticide applications, all ventilation within the house is stopped. This minimal air movement hinders pesticide dispersal and harmful levels may concentrate within greenhouse air.

Pesticide applicators should know these points and understand how they increase risk. At this point it will be helpful to review your Core Manual for a discussion of pesticide exposure and personal protective clothing and equipment.

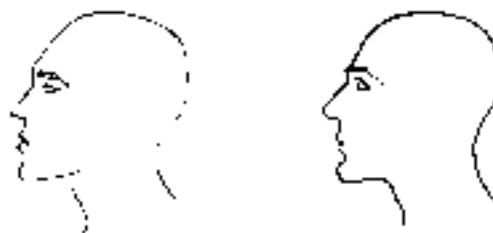
Inhalation exposure and protection



Pesticide application in an enclosed greenhouse is very different from treatments in the open air. In the greenhouse, pesticides not only dissipate slowly, but, without wind or air turbulence, they may actually concentrate to dangerous levels.

Because continuous pesticide exposure through inhalation is a major risk, a respirator is required whenever a pesticide applicator or handler is in the greenhouse during treatment. Remember, even though amounts are small or the pesticides are only slightly toxic, repeated contact with pesticides increases the risk of overexposure. Review the section on respirators in your Core Manual.

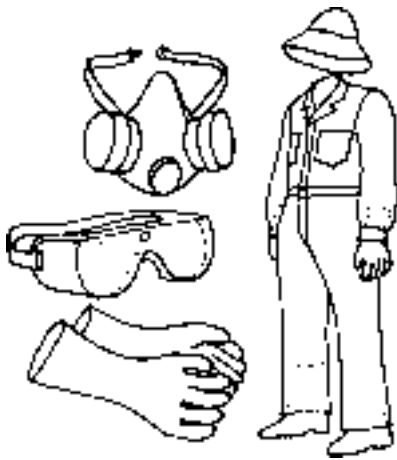
Dermal exposure and protection



During control treatments, applicators can accumulate considerable skin (dermal) and eye (ocular) contact with pesticides. Contact occurs when applicators brush against plants and other treated surfaces, or by walking through the pesticide mist which tends to linger in the still air, or from falling spray droplets and dripping overhead baskets.

Examples of clothing requirements found on pesticide labels include:

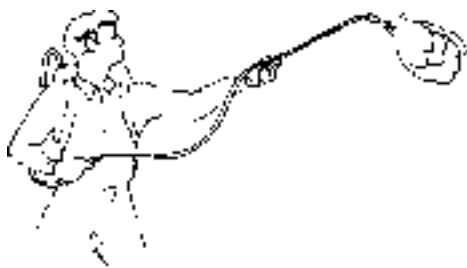
- Personal protective equipment must be worn every time an applicator applies pesticides inside a greenhouse. Read the pesticide label for specific instructions.
- The eyes must be covered either with chemical splash goggles or a full face respirator.
- The head and neck must be protected. Use chemical-resistant rain hats, or washable hard hats and hooded chemical resistant spray suits.



- Cover the arms, body and legs with a chemical resistant suit. Do not use cotton coveralls. They do not provide adequate protection for greenhouse applicators.
- Wear unlined, chemical-resistant boots that cover the ankles.
- Wear chemical-resistant gloves.
- Clean all personal protective equipment after each use and store in a clean uncontaminated area.
- Launder garments, including undergarments at the end of each work day. Because most materials will accumulate pesticide residues over time, you should replace gloves, boots and suits periodically.

In addition to personal protective equipment, there are a few application practices that will reduce the risk of accidental poisoning:

- Many labels require that you take down hanging plants for treatment, do not spray over your head if it can be avoided.
- Do not use highly toxic pesticides (like aldicarb) for hanging baskets.



- If you must apply over your head, treat plants in the aisle next to you, rather than the plants directly over your head. This way you are to the side of the application.
- Apply the pesticide while backing away from the application.
- Be informed of available pest management alternatives, and use the least toxic method.

WORKER PROTECTION STANDARDS FOR GREENHOUSES



The EPA Worker Protection Standard (WPS) regulates activities of greenhouse employers, pesticide handlers and other workers to reduce the possibility of pesticide exposure. Requirements of the WPS have been in place since January 1, 1995. These requirements are summarized here. For more information, contact your Cooperative Extension or the DEP.

GREENHOUSE is defined as any operation that produces agricultural plants indoors in an area that is enclosed with nonporous covering and that is large enough to allow a person to enter. Examples include polyhouses, mushroom houses and caves, and rhubarb houses, as well as traditional greenhouses. Malls, atriums, conservatories, arboretums, and office buildings that grow or maintain plants primarily for decorative or environmental benefits are *not* included.

AGRICULTURAL EMPLOYER is defined as anyone who employs or contracts for the services of workers (including themselves and members of their families) for any type of compensation to perform tasks related to the production of agricultural plants or, who owns or operates an agricultural establishment that uses such workers.

PESTICIDE HANDLER is defined as anyone who: (1) is employed (including self-employed) for any type of compensation by an agricultural establishment or a commercial pesticide handling establishment that uses pesticides in the production of agricultural plants on a farm, forest, nursery, or greenhouse, and (2) is doing any of the following tasks:

- mixing, loading, transferring, or applying pesticides,
- handling opened containers of pesticides,
- acting as a flagger,
- cleaning, handling, adjusting, or repairing the parts of mixing, loading, or application equipment that may contain pesticide residues,
- assisting with the application of pesticides, including incorporating the pesticide into the soil after the application has occurred,
- entering a greenhouse or other enclosed area after application and before the inhalation exposure level listed on the product labeling has been reached or one of the WPS ventilation criteria has been met to:
 - operate ventilation equipment
 - adjust or remove coverings, such as tarps, used in fumigation, or
 - check air concentration levels,
- performing tasks as a crop advisor:
 - during any pesticide application,
 - before any inhalation exposure level or ventilation criteria listed in the labeling has been reached or one of the WPS ventilation criteria has been met,
 - during any restricted-entry interval,
- disposing of pesticides or pesticide containers

Handlers working with fumigants must be in constant visual or voice communication with another trained handler who monitors the application.

WORKER is defined as anyone who: (1) is employed (including self-employed) for any type of compensation and (2) is doing tasks, such as harvesting, weeding, or watering, relating to the production of agricultural plants on a farm, forest, nursery, or greenhouse. This term does NOT include persons who are employed by a commercial establishment to perform tasks such as crop advisors.

All employers must establish an information area at a central location that displays the EPA WPS safety poster and complete medical emergency information. Facts about all pesticide applications must be posted from just before they are made until 30 days after the restricted-entry interval (REI) ends. Greenhouse entry restrictions for workers and handlers depend on the type of pesticides and application methods used - see chart on following page.

Employers must provide handlers with a decontamination site consisting of adequate clean water to wash the entire body, soap, disposable, single-use towels and one clean change of clothes. At least three gallons of clean water should be supplied for each handler. Workers must also have access to a similar decontamination site except that a change of clothes is not required.

Employers must provide pesticide safety training for handlers and workers every five years unless they are already licensed applicators. Training may only be done by a certified applicator, a person designated by the state pesticide lead agency, a person who has completed a train-the-trainer class, or, in the case of workers, a trained handler. Training must be given in a language understandable to the employees. These requirements may vary from state to state.

Employers must provide handlers with, at least, the amount of personal protective equipment (PPE) required on the pesticide label. Employers must ensure that protective clothing and equipment is clean and intact, fits properly, and is in good operating condition. Employers must also ensure protective clothing and equipment is used correctly. No handler may wear or take pesticide-contaminated personal protective equipment away from the job site or employer's facility.

◆ Special Application Restrictions in Greenhouses

<p style="text-align: center;">COLUMN A</p> <p style="text-align: center;">When a Pesticide Is Applied:</p>	<p style="text-align: center;">COLUMN B</p> <p style="text-align: center;">Workers and Other Persons Are Prohibited in:</p>	<p style="text-align: center;">COLUMN C</p> <p style="text-align: center;">Until:</p>	<p style="text-align: center;">COLUMN D</p> <p style="text-align: center;">After the Expiration of Time in COLUMN C Until the Restricted-Entry Interval Expires, the Entry-Restricted Area Is:</p>
<p>1. As a fumigant.</p> <p>2. As a</p> <ul style="list-style-type: none"> • Smoke, or • Mist, or • Fog, or • Aerosol. <p>3. Under circumstances (other than in 1 or 2) for which the pesticide labeling requires the applicator to wear a respirator.</p> <p>4. Other than in 1, 2, or 3, but</p> <ul style="list-style-type: none"> • From a height of greater than 12 in from the planting medium, or • As a fine spray, or • Using a spray pressure greater than 40 pounds per square inch <p>5. In any other manner</p>	<p>Entire greenhouse plus any adjacent structure that cannot be sealed off from the treated area.</p> <p>Entire enclosed area.</p> <p>Entire enclosed area.</p> <p>Pesticide-treated area plus 25 feet in all directions within the entire enclosed area.</p> <p>Pesticide-treated area</p>	<p>The ventilation criteria on the previous pages are met.</p> <p>The ventilation criteria on the previous pages are met.</p> <p>The ventilation criteria on the previous pages are met.</p> <p>Application is complete.</p> <p>Application is complete.</p>	<p>No entry restrictions other than in column C are met.</p> <p>Entire enclosed area is the treated area.</p> <p>Pesticide-treated area.</p> <p>Pesticide-treated area.</p> <p>Pesticide-treated area.</p>

WPS Questions and Answers for Greenhouse Operators

Q: I'm treating only a few benches in my greenhouse with a hand sprayer. Do I need to post signs? If so, where do I post them?

A: All pesticide applications in greenhouses must be posted with one or more WPS warning signs. Because only a few benches were treated with a non-powered hand sprayer, you have a choice about sign placement. Warning signs can be placed on the entrance to the greenhouse. This would prohibit workers from the entire greenhouse. Warning signs can also be placed on the corners of benches or in aisles, designating a smaller area within the greenhouse in which workers are prohibited. In some situations small warning signs may even be placed in individual pots to warn workers about pesticide applications. Each employer must determine what is acceptable for their situation based on total area treated in the greenhouse and anticipated worker tasks

Q: I am treating several benches in a large greenhouse with a pesticide which requires me to wear a respirator. The restricted entry interval (REI) is 12 hours. When can workers go in and work with plants on the other benches?

A: When a pesticide is applied which requires the applicator to wear a respirator, workers, customers and members of the public, must stay out of the *entire enclosed area* of the greenhouse until ventilation criteria are met. Suitable ventilation is accomplished in one of several ways in a greenhouse:

- 10 air exchanges, or
- 2 hours of ventilation using fans or other mechanical ventilating systems, or
- 4 hours of ventilation using vents, windows or other passive ventilation, or
- 11 hours with no ventilation followed by 1 hour of mechanical ventilation, or
- 11 hours with no ventilation followed by 2 hours of passive ventilation, or
- 24 hours with no ventilation.

If ventilation is accomplished before the expiration of the REI, workers *only* are prohibited from contacting plants on the treated benches for the duration of the REI. If ventilation takes longer than the REI, then workers are free to work with all plants once criteria are met.

Q: When I applied a pesticide this morning in my greenhouse, the weather forecast was for a cloudy, cool day. The clouds have cleared and the sun is out. I'm worried that I will lose my plants if I don't water them, but the restricted entry interval is 12 hours. What can I do?

A: Entry to a greenhouse during the REI to water plants is normally prohibited, however, there are some exceptions for this type of emergency situation. First, workers may enter after any ventilation criteria have been met to water plants providing they have *no contact* with anything treated with pesticide. For example, workers could easily water seedlings in starter trays without contacting the treated matter. Workers are also allowed to enter to operate or move watering equipment under the *limited contact exception*. This exception provides for those unforeseen tasks which cannot be delayed without significant economic loss. An employer is required to provide a number of protections to workers under this exception including personal protective equipment and special training. Worker time in the area under restricted entry is also limited.

Q: I recently purchased some pesticides without WPS requirements on the label. Do I need to comply?

A: All agricultural pesticides now in the marketplace must bear WPS labeling. If you have recently purchased a product to use in your greenhouse which does not contain WPS language, then check the product label and make sure it has directions for use in a greenhouse. All pesticides used in greenhouses must specifically mention "greenhouse" on the label. Home and garden pesticide products should not be used in greenhouses because they neither mention greenhouses on the label nor contain WPS language.



Worker Protection Warning Signs

In September 1995, EPA proposed to allow growers to substitute another language for the Spanish portion of the warning sign and to allow the use of a small size sign in nurseries and greenhouses where use of the standard (14"x16") sign interfered with operations and the clear identification of a treated area. EPA considered the comments received from growers, farmworker groups, state agencies, and private citizens and amended the rule, in June 1996, to allow other languages to improve the effectiveness of the signs in warning workers whose predominant language is not Spanish and to permit smaller signs in greenhouses and nurseries. The English/Spanish warning sign is pictured below.



Summary of the Final Rule Amendment

- Allows substitution of the language commonly spoken and read by workers for the Spanish portion of the warning sign. The sign must be in the format required by the WPS and be visible and legible. Use of alternative languages is optional and continued use of English/Spanish sign is always acceptable.
- Allows use of smaller signs provided minimum letter size and posting distances are observed. In nurseries and greenhouses, small signs may be used any time. A small sign may be used on farms and forests if the treated area is too small to accommodate the standard sign.
- Language substitution on the sign allows agricultural employers to tailor the sign to accommodate a work force whose predominant language is neither English nor Spanish. Allowing smaller signs in nurseries and greenhouses will facilitate posting of treated areas. The posting and lettering requirements for the smaller signs will result in sign sizes of approximately 7 inches by 8 inches and 4½ inches by 5 inches.

Sign Size and Posting Minimum Requirements

	Circle graphic height	DANGER & PELIGRO lettering height	Other lettering height	Posting Distance
7"X 8"	3"	$\frac{7}{8}$ "	$\frac{1}{2}$ "	50 feet
4 $\frac{1}{2}$ "X 5"	1 $\frac{1}{2}$ "	$\frac{7}{16}$ "	$\frac{1}{4}$ "	25 feet

OSHA Hazard Communication Standard and the Worker's Right to Know Law

These companion federal and state laws are often referred to as the WORKER'S RIGHT-TO-KNOW laws. They require employers to inform employees of any chemical hazards they may be exposed to while performing their work. In Connecticut, the Director CONN-OSHA or the Connecticut Department of Labor is responsible for administering and enforcing these regulations. For more information call (860) 566-4550.

Businesses comply with these regulations when they implement the following practices:

- Develop a written hazard communication program stating how they comply with the law.
- Inventory all hazardous materials.
- Obtain Material Safety Data Sheets (MSDS) on all hazardous materials or products used in the workplace (MSDS sheets are available upon request from pesticide suppliers).
- Provide employees access to all MSDSs.
- Attach warning labels for any secondary containers that hold hazardous materials.
- Provide a written policy on how the company will comply with the law, and allow employee access to the policy.
- Report information concerning chemicals used, and other information as requested, to the BLS.
- Provide annual training sessions for all employees that include:
 - The location and availability of the written hazard communication program and related documents.
 - An explanation of the labeling system and the material safety data sheets.
 - Any operations in the work area where hazardous chemicals are present.
 - The physical and health hazards of the chemicals in the work area.
 - Measures employees can take to protect themselves from these hazards, including the purpose, proper use, and limitations of personal protection equipment.
 - Methods of detecting the presence or release of a hazardous chemical in the work area.
 - Emergency procedures.
 - Document all training including employee name, job title, date of training, and type of training provided.

CONSUMER PROTECTION



It is important to avoid exposing your customers to pesticides. It is equally important that the preventative measures you take and any public statements you make regarding consumer protection must be positive and honest.

Customers in the greenhouse



Is your greenhouse used for retail sales? Do customers and their children browse among your benches? Do you apply pesticides to areas where you also allow customer access? If so, then there are some important considerations and precautions you should take.

Although you and your staff routinely take precautions to avoid pesticide poisoning, your customers cannot be expected to do this. Customers think about purchases, not pesticide safety. They do not wear protective clothing and they are unaware of the routine hazards you and other trained professionals recognize. It is your job to protect your customers by warning them of potential hazards and keeping them out of treated areas.

Do not allow puddles to accumulate on floors in customer areas. Pesticide residues may run into and concentrate in such puddles. Without the proper protective boots, contaminated water may soak through customers' shoes and stockings. Beware of water dripping on customers from structures and plants hanging overhead. Customers may also be exposed to pesticide residues on benches or other structural components where they accumulate from repeated pesticide treatments.

Children in your greenhouse require extra precautions. Do not create an "attractive nuisance" by leaving pesticide containers or application equipment where children can see or reach them. In the event of an accident, you could be held liable. Keep pesticides and pesticide equipment under lock and key. Make sure children and other unauthorized people can not enter treated or contaminated areas.

It may be best to establish a totally separate display and sales area where no pesticides are applied. This system may require frequent inspection to avoid pest infestations. If pests or pest symptoms are found in the display area, affected plants should be promptly moved to a work area for treatment.

Purchased plants



Most materials labeled for use on ornamentals and other nonfood crops do not list a preharvest interval. Most pesticides list an REI on the product label, but, remember, preharvest and restricted entry intervals are not the same thing. An REI is the waiting period required before workers may reenter a treated crop without protective clothing. In contrast, a preharvest interval establishes a minimum interval between application and harvest. Once a crop is harvested, it becomes available for consumption by the general public. Restricted entry intervals protect workers, while preharvest intervals protect consumers. Preharvest intervals are set to ensure that pesticide residues on food or feed crops do not exceed tolerances set by the EPA when they are made available for public consumption. No residue tolerances have been set for ornamentals and other nonfood crops.

An equivalent to the preharvest interval does not exist for ornamental crops. Although your customers are not likely to eat the product that they purchase from you, they may place it on their dinner table, bury their nose in the blossoms, handle and admire the foliage, or place it at the bedside of a sick friend or relative. You must take precautions to prevent any chance of accidental poisoning that results from a customer's use of your product. Factors to consider include the persistence and the toxicity of the materials you apply and the time interval you allow between application and sale. Read labels and MSDS's or consult Cooperative Extension personnel to compare the toxicity and the persistence of different materials.

Customer relations



What is your response when customers ask if you use pesticides? You should consider your response carefully. The issue of pesticide residues in our environment is very important. Your customers' questions may be an opportunity to inform them that you understand their concerns and have sound policies in place to minimize pesticide hazards. You may want to anticipate the question by making a statement on your sales-label or even producing an informational brochure. Remember to always be honest and courteous in your response.

SECTION 2 - REVIEW QUESTIONS

Worker and Consumer Safety Issues

1. Because of the lack of air movement, pesticide concentrations within a greenhouse can reach harmful levels.

_____ True _____ False

2. A respirator is required whenever a pesticide applicator or handler is in the greenhouse during treatment.

_____ True _____ False

3. Where might greenhouse workers come into contact with pesticides?

- a. from brushing up against plants
- b. by walking through spray mist
- c. from dripping overhead baskets
- d. all of these

4. For greenhouse applicators, cotton coveralls provide adequate protection from pesticide exposure.

_____ True _____ False

5. List three of the five application practices that reduce the risk of accidental poisoning over and above PPE.

- a.
- b.
- c.

6. Application of fumigants in the greenhouse can be done by a trained and unassisted handler so long as the required protective equipment is worn.

_____ True _____ False

7. For some greenhouse pesticide applications, workers watering plants can remain in an area being treated with pesticides.

_____ True _____ False

8. Why is it so important that customers be warned of potential pesticide hazards?

9. Which situations pose potential pesticide hazards to customers?

- a. water dripping from overhead hanging plants
- b. puddles on greenhouse floors
- c. application equipment within sight or reach of children
- d. all of these

10. How can you best avoid customer exposure to pesticides?

11. Since ornamental crops are not eaten, pesticide residues should not be of concern on those crops.

_____ True _____ False

SECTION 3

ENVIRONMENTAL PROTECTION ISSUES

Pesticide control treatments are an integral part of greenhouse crop production. When used properly, these chemicals promote the growth of healthy, pest-free plants. Improper use, however, may lead to environmental contamination. Any pesticide that drifts or is applied off-target is a potential pollutant and threatens the environment. The benefits of pesticide use are meaningless if our world becomes polluted through misuse and carelessness. It is the responsibility of the pesticide applicator to keep pesticides on target. This chapter discusses pesticide handling methods in greenhouses that minimize the threat of pollution. Refer to the Core Training Manual for a more generalized discussion of pesticide handling and environmental protection.

Federal, state and local authorities are greatly concerned about the safe use of pesticides. Current regulations control product availability, application methods and equipment. These laws are intended to protect our valuable resources including:

- Unique natural habitats,
- Rare plant and animal species,
- Surface and groundwater supplies, and
- Off-target plants and animals, people and sensitive areas.

POLLUTION FROM GREENHOUSES

The enclosed nature of greenhouses allows a good deal of control over the application and dispersal of pesticides. Newly developed delivery systems combine pesticides with irrigation water and fertilizers to give even greater regulation of chemical use. However pesticide users must still pay strict attention to environmental protection because the threat that pesticides may escape from the greenhouse still remains.

Air movement\Drift



The problem of pesticide drift is relatively easy to manage in greenhouses. Winds rarely enter to blow pesticide mist off-site. Pesticides may, however, drift from the target area into other parts of the greenhouse, or they may escape through vents and doorways.

Factors within the greenhouse that affect drift include temperature, humidity, ventilation, and heating systems. Inside a warm greenhouse, many pesticides volatilize because high temperatures promote the evaporation of spray droplets. Spray droplets that evaporate quickly are more likely to drift. On the other hand, the high humidity inside a greenhouse can suppress evaporation or drying of the spray solution, causing pesticide materials to persist.

Heating, air conditioning, and ventilation systems that move air can also move airborne spray droplets, dust particles, or vapors. Although ventilation systems may be left on to achieve better spray coverage, you may consider turning off some of these systems during pesticide applications.

Fumigants and other volatile pesticides produce vapors that are contained by the walls and other structural elements of the greenhouse, just as air is contained inside a balloon. The applied material is under pressure within

the greenhouse and will escape from any openings in the structure. Make sure that all doors, windows and vents are securely closed before fumigating or applying volatile pesticides. Escaped vapors will reduce control and pose a threat to nontarget plants, workers, and unprotected persons. Once outside the greenhouse, pesticide vapors may cause damage leading to complaints or even legal action against the applicator.

When applying herbicides to areas outside the greenhouse, remember that these chemicals are often volatile and nonselective. Herbicide vapors can move to nontarget sites and damage valuable plants. Follow label directions restricting the temperature range of proper pesticide application. Never apply pesticides when temperatures are above 85°F or when winds are blowing more than 5 mph.

Irrigation runoff/groundwater protection

Irrigation water from the greenhouse may contain fertilizer, pesticides and other agricultural chemicals that will contaminate groundwater. Properties of the pesticide, the soil and the climate all influence whether or not a particular material actually reaches groundwater. These properties are discussed in your Core Manual.

A pesticide can be both highly soluble and highly volatile at the same time. Whether it leaches into the groundwater or volatilizes into the atmosphere is determined by method of application, the ambient temperature during and after application, and moisture conditions.

Conditions which favor groundwater penetration by pesticides are sandy soils, soils low in organic matter, an acidic pH, and a high water table. Low temperatures, high rainfall, or applications of large volumes of irrigation water also favor penetration. Highly soluble or more persistent pesticides are more likely

to enter the groundwater than less soluble or less persistent pesticides. On the other hand, pesticides that are broken down by sunlight or microbial action in the soil or those that volatilize from soil or plant surfaces rarely enter groundwater. Always check the pesticide label for specific warnings or instructions regarding groundwater protection. Information about the properties of specific pesticides which may influence groundwater contamination can be obtained from your Core Manual supplemental booklets.

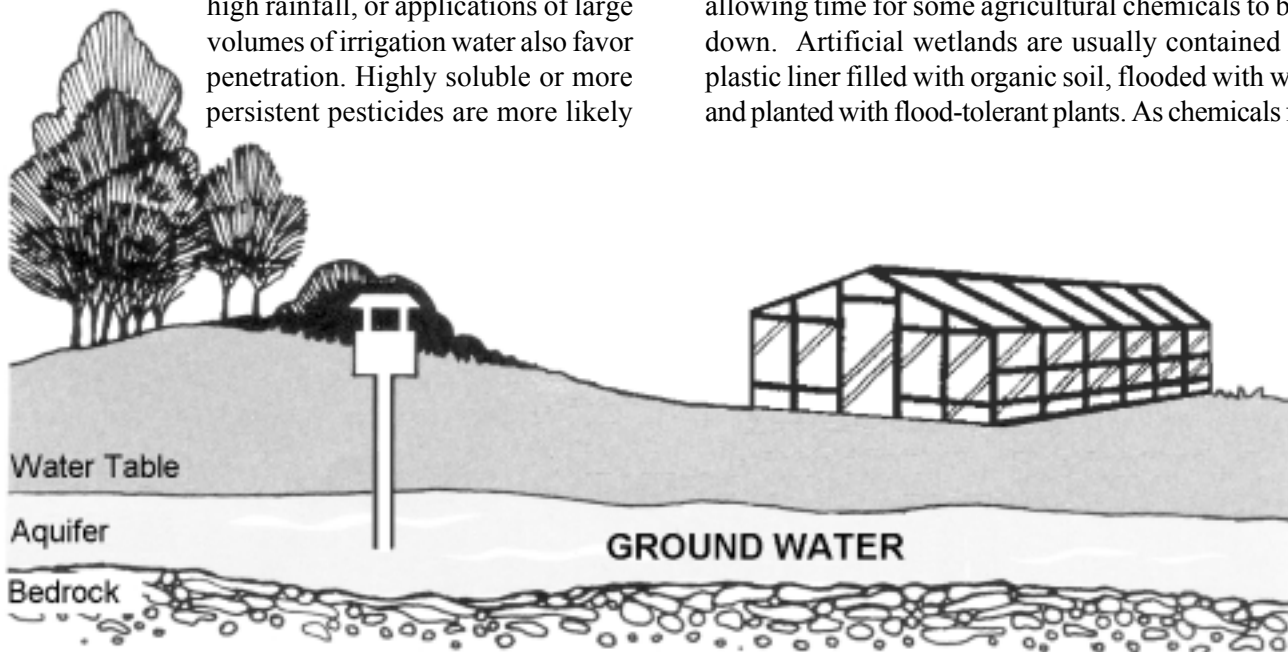
A national EPA survey of drinking water wells has shown that nitrates from fertilizers is a common pollutant of groundwater.

Containing and recycling runoff

It is important to ensure that runoff from the greenhouse irrigation and pest control operations does not enter surface water, groundwater or wetlands. Wherever possible, runoff water should be contained with impermeable floors to prevent contaminants from seeping into the underlying soil. Subirrigation systems, holding tanks and artificial wetlands provide additional runoff water management.

Subirrigation systems contain all irrigation runoff by recycling it within the greenhouse. No water escapes the greenhouse and there is no potential for groundwater contamination. Subirrigation systems include ebb-and-flood, capillary mat, trough, and nutrient film systems. Your Cooperative Extension office can provide specific information about each of these irrigation systems.

Holding tanks and artificial wetlands can be used to retain irrigation runoff. These systems can slow or halt the movement of runoff water into the environment, allowing time for some agricultural chemicals to break down. Artificial wetlands are usually contained by a plastic liner filled with organic soil, flooded with water, and planted with flood-tolerant plants. As chemicals from



irrigation runoff enter an artificial wetland they are broken down by constant exposure to moisture and air, biodegradation, and uptake by plants. Because some chemicals are not broken down by ultraviolet light, microbes or other natural forces, they may accumulate in holding tanks or in artificial wetlands, creating a hazard for workers or the public. These systems should be fenced.

Environmental risk



The risk of contaminating water resources is an issue of public concern. Once groundwater is contaminated, it is very expensive to clean up, if decontamination is even possible. Because pesticides are applied in greenhouses, growers must take steps to safeguard groundwater supplies.

The potential for pesticides to leach through soil is influenced by their chemical nature. Chemical family and formulation affect several features of pesticides including:

- **Solubility:** pesticides that are easily dissolved in water are more likely to be carried along by groundwater movement.
- **Environmental persistence:** soil microorganisms, sunlight, and reactions with soil chemicals break down pesticides after application. The longer it takes a chemical to degrade, the longer it presents a risk.
- **Adsorption properties:** pesticides can become bound to soil particles making them unavailable to leaching. How much of the chemical is bound and how tightly it is attached depends on the pesticide's chemical reactivity and the type of soil particles present.

How much of a pesticide actually leaches is influenced by how and when it is used. Even chemicals with a high potential for leaching will present a reduced hazard when their application is carefully planned. Application factors that influence pesticide leaching include:

- **Timing:** withhold or limit applications during wet periods of the year, such as early spring and late fall, or when heavy precipitation is expected. Groundwater movement is more likely to occur in saturated soils.
- **Avoid cold soils:** cold soils slow down the breakup of pesticides.
- **Avoid soil-applied pesticides when possible:** preemergence pesticides have the greatest risk of leaching. Although in some cases, the effectiveness of this type of treatment reduces the need for post-emergence applications, which decreases overall pesticide use.
- **Select foliar application methods:** foliar-applied pesticides may be bound to plant matter and decompose in soil faster than soil applied chemicals.
- **Use IPM practices:** monitor pest populations and use proper alternate control methods when possible. Apply chemicals only when the economic threshold is reached and pests cannot be controlled by other means. Applications made by the calendar can result in increased environmental and health risks, while providing limited benefit to the crop.

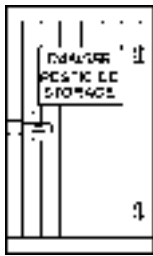
STORAGE AND DISPOSAL

Pesticides should be stored in an area that is structurally separated from home, office and general work areas and from water supplies. A separate building or shed is the best arrangement. See your Core Manual for specific storage regulations.

All doors and entrance ways into pesticide storage facilities should be clearly marked with warning signs. Storage areas should be locked and secure against accidental access by children or other uninformed persons and against vandalism. Entrances should be placed where they will not attract children.

Leakage from damaged pesticide containers in the storage area could enter and pollute the environment. Storage facilities must be situated on impermeable containment pads surrounded by raised berms. Both the floor and the berm should be sealed to create a continuous, water tight surface. All leaking or damaged pesticide containers should be placed inside an intact plastic drum or barrel. Always place a copy of the appropriate pesticide labels on the outside of the drum.

Impermeable floors and berms are especially important where pesticides are stored in bulk containers. Fluid storage tanks should have locked inlet and outlet controls that prevent unauthorized access. If possible, areas where tanks are kept should be secured by fences or located entirely inside locked facilities. A containment system to collect precipitation surface runoff or spills is recommended. Containment systems should be able to handle at least 1½ times the tank's storage capacity.



Personal protective equipment such as gloves, aprons and respirators, should be kept near, but not inside, the pesticide storage area. Workers must be able to reach protective equipment before entering the storage area. Select protective equipment that is appropriate to the types of pesticides being stored and the hazards they may present during routine procedures and possible emergencies.

A first aid kit equipped for initial response to pesticide poisoning should be available to, but not inside of, the storage area. A water supply of sufficient quantity for emergency wash or eyewash and for routine wash-up should be located conveniently to the storage area. At least 3 gallons of water is recommended for each handler using the site.

Inside the pesticide storage facility, pesticides should be separated by type and hazard potential. Herbicides, fungicides and insecticides should each be assigned separate areas within the facility. Pesticides which are flammable should be separated from nonflammable pesticides. Pesticides which may present a special hazard, such as the release of toxic fumes during a fire, should be assigned to a separate, designated area within the storage facility. A map should be made of the inside of the storage facility showing the main features as well as

the location of each type of pesticide. Copies of this map should be posted both inside and outside of the storage facility in areas readily available to emergency personnel.

Spill containment materials and fire extinguishers, appropriate for the types of pesticides being stored, should be easily accessed from the pesticide storage area. The local fire department should be notified annually of the types and quantities of pesticides being stored. A basic fire response plan should be prepared, submitted to the fire department, and reviewed regularly.

ENVIRONMENTAL REGULATIONS

State groundwater protection management plan

Under an EPA mandate, states must develop groundwater protection plans that demonstrate reasonable efforts to prevent the contamination of water resources. By adopting a plan, your state will retain the right to regulate highly leachable pesticides at the state level. Without a plan, the EPA would cancel use of such pesticides within the state.

Because some products are relied on for producing certain crops, it is in the best interest of all applicators to know and abide by the state plan. For a copy, contact Judith Singer, Department of Environmental Protection, 79 Elm Street, Hartford, CT 06106, (860) 424-3369.

SECTION 3 - REVIEW QUESTIONS
Worker and Consumer Safety Issues

1. The enclosed nature of greenhouses prevents any escape of pesticides into the environment.
_____ True _____ False
2. List 5 factors that affect drift of pesticide sprays within a greenhouse.
- a.
b.
c.
d.
e.
3. High temperatures (over 85°F) can volatilize herbicides used outside of the greenhouse causing damage to plants near vents or doors inside the greenhouse.
_____ True _____ False
4. Which are conditions that favor groundwater penetration by pesticides?
- a. sandy soils
b. application of large volumes of irrigation water
c. Use of highly soluble and persistent pesticides
d. all of these
5. What is a subirrigation system and how does it help prevent groundwater contamination?
6. What kind of floor should a pesticide storage have?
- a. dirt
b. wooden
c. sealed concrete
d. any of these
7. Personal protective equipment should be kept inside the pesticide storage area.
_____ True _____ False
8. At a minimum, how much water should be available for each pesticide handler using a storage/mixing site.
- a. 5 gallons
b. 3 gallons
c. 1 gallon
9. The local fire department should be notified annually about the types and quantities of pesticides stored at a greenhouse operation.
_____ True _____ False

SECTION 4

GREENHOUSE IPM

The goal of greenhouse operators is to produce healthy, vigorously growing plants free from all pest problems. Growers have often met this goal by making repeated pesticide applications whether a problem existed or not. However, today's economic and environmental pressures place increasing demands on growers to make precise management decisions. The current challenge facing growers is to reduce pesticide use and still maintain satisfactory pest management. Integrated pest management (IPM) is the method growers are turning to for answers. IPM is a pest control strategy that combines cultural, biological and chemical techniques to manage pests in an environmentally responsible manner. Growers who practice IPM achieve the same or better pest control as those who use chemical pesticides alone.

INTEGRATED PEST MANAGEMENT

Greenhouse operators who use IPM care about the quality of their crop and their environment. IPM techniques help growers determine when and where pest control is justified. Pesticides are used efficiently by carefully timing applications and long-term pest control is maintained with as little effect on the surrounding environment as possible.

Growers and managers responsible for producing such greenhouse crops as potted plants, bedding plants, cut flowers, hanging baskets, or vegetables, can use the IPM techniques described in this chapter to:

- Protect crop quality,
- Safeguard public health,
- Protect the environment,
- Reduce pest management costs, and
- Use pesticides wisely.

IPM TECHNIQUES

The IPM techniques most useful to greenhouse production systems are scouting, pest identification, timing treatments, and record keeping. You can learn IPM techniques from the Cooperative Extension or from private IPM consultants.

Monitoring and scouting



Scouting, also known as monitoring, is the basic cornerstone of IPM. Scouting is a visual inspection of the crop and pest traps to determine the health of the crop, its growth stage, what and how many pests are present, and what trends pest populations are following. Routine and careful scouting will detect pest populations when they first appear; that is, when they are easiest to control and before damage occurs. A grower who knows whether or not pests are present in a crop can replace a routine, preventative spray schedule with fewer, but better timed and more effective treatments.

When a pest is found on only a few plants or in a small area, localized control tactics are used. Spot treatments not only decrease the chance of misapplication or over-application, but use less material than blanket sprays and, thus, help to preserve beneficial organisms.

Scouting guidelines

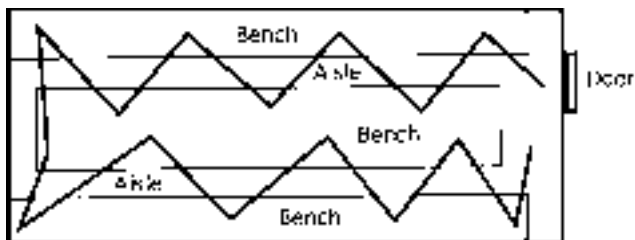
It is important to scout routinely, at least once every week through a crop's entire production cycle. Scouting twice a week is even better. Scout on a specific day and time and keep the same schedule throughout the season. This allows growers to track the development of problems and to catch new pests when they first appear.

The common pests found in greenhouse crops do not distribute themselves evenly through a crop. Therefore, the entire greenhouse must be scouted in a consistent pattern. Inspect plants grown on the ground, benches, and hanging from the greenhouse frame. The size of the greenhouse, the number and size of plants, and the size and location of the benches will influence the pattern and time needed to scout. Follow the same pattern each week.

Start your scouting pattern in one corner and end in the opposite corner. Walk through every aisle. Select plants randomly, but choose plants from every bench and from the ends and the middle of each bench. The more plants inspected, the better, especially if the benches are long. Always look underneath the benches for weeds.

Inspect each plant the same way. Start at the soil surface and work your way up the plant. Most of the insects will be on the underside of the leaves. For example, all immature greenhouse and silverleaf whiteflies are on the underside of the leaves. Start by turning over the older, lower leaves. Tipping the pot sideways may help. Then examine younger leaves further up the stalk. Finish with the flush growth. When you find a plant with a pest, flag it. This way you can relocate the pot and watch pest development. The flagged plant is your indicator plant. After you treat, go back to your indicator plant, turn the leaf over and see if you controlled the pest.

As you scout, record on a field data sheet the identification, location, growth stage, and severity of all pests present. Include how many individuals are counted and a description of the symptoms. You may also wish



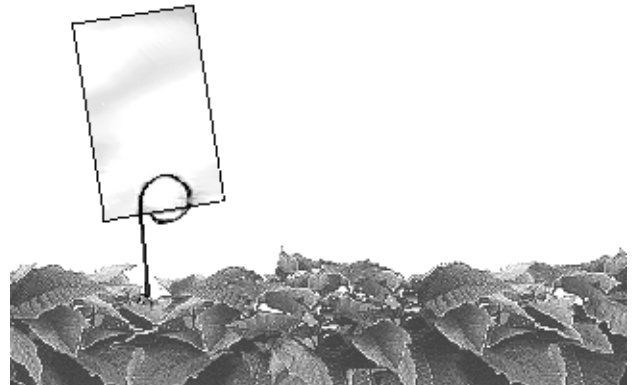
Standard zig-zag scouting pattern down aisles and between benches

to record physical data like day/night temperature, relative humidity and light levels. Preparing data forms in advance will save time and make analysis more consistent. If you find a plant or area that is more heavily infested than the rest of the greenhouse, take special note of the location. Take notes on where and what kind of weeds you find. Take notes on anything that you observe that is not normal. Count and record the total number of plants inspected. These notes can become valuable records of how pest problems develop and what control measures really work.

Insect monitoring cards

The benefits of insect monitoring cards include:

- Early pest detection
- Improved pest management decisions
- Improved timing of treatment applications
- Documentation of pests and their locations
- Measurement of pest population trends



Insect monitoring cards, also known as sticky cards or sticky traps, are used to detect the presence of insect pests and to estimate the relative size of pest populations. Sticky traps are made of a stiff paper card, usually colored bright yellow, covered with a nondrying, sticky substance which traps insects. Regular inspection and replacement of these cards provides up-to-date information on pest populations. If trap counts increase within an isolated area, that location may be spot treated. If the population is widespread, the entire greenhouse may need treatment. This approach maximizes the effectiveness of an insecticide and minimizes its use. After the treatment, fresh sticky traps are a convenient tool to gauge the success of the application.

Insects trapped on sticky cards provide excellent samples for positive identification of pest species. Blue sticky traps are specifically designed to attract thrips. Yellow sticky cards attract a wider range of insects including the following adult pests:

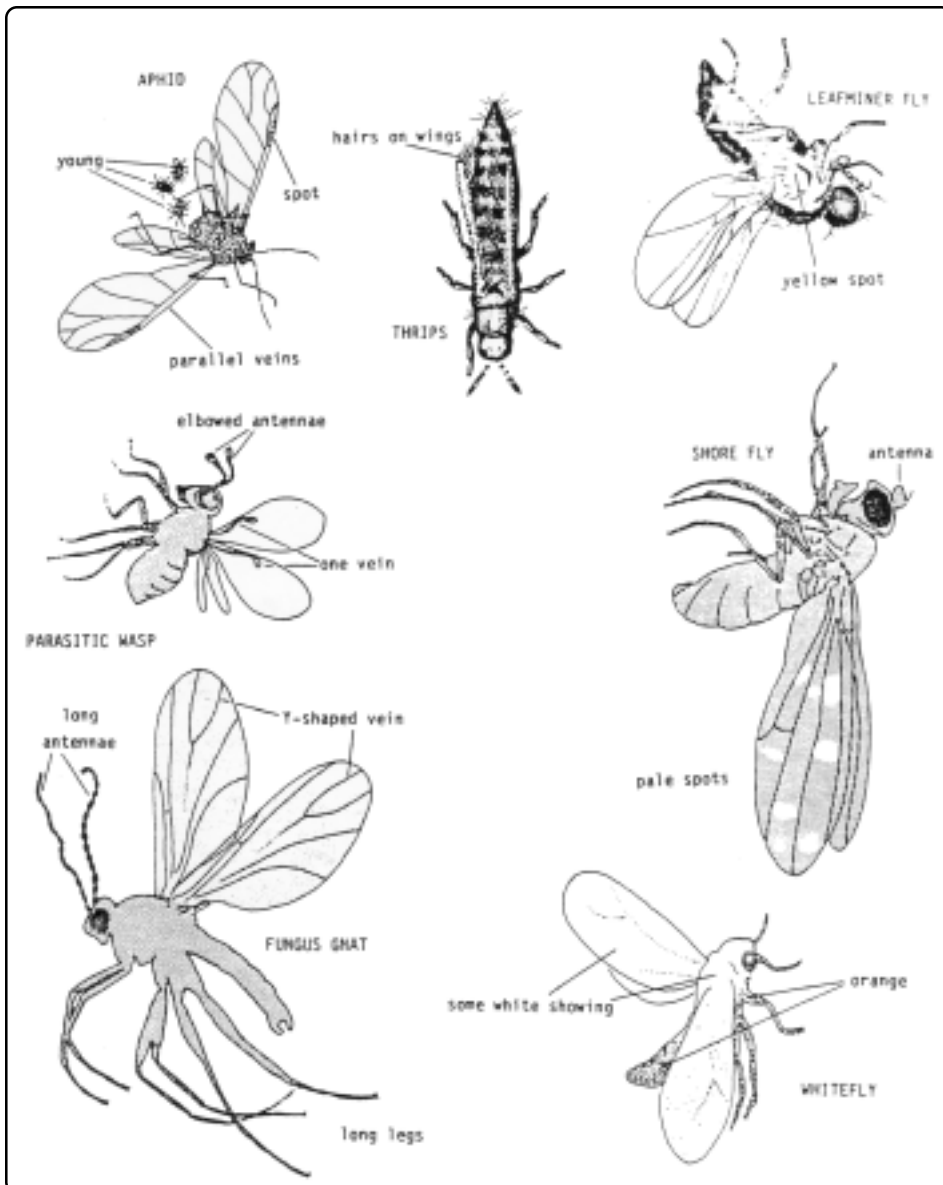
- Greenhouse whiteflies,
- Silverleaf whiteflies,
- Western flower thrips,
- Fungus gnats,
- Shore flies,
- Leafminers,
- Winged aphids,
- Leafhoppers,
- Other flying insects.

When placed horizontally at soil level monitoring cards work very well for early detection of newly emerged adult thrips, fungus gnats and leafminers.

How to use monitoring cards

The key to a successful monitoring program is the placement of the cards. Always place the cards immediately above the plant canopy. This is where most pest flight occurs. Depending on personal preference and growing conditions, there are a number of ways to attach and position the cards.

Attach the card vertically to a wire or wooden stake by stapling it or clipping it on with a clothespin. An



Insects on sticky traps

especially useful method involves gluing two clothespins back-to-back. One of the clothespins attaches to a stake, and the other is clipped to the card. This allows you to move the card upward as the plant grows in height. To avoid using stakes, punch a hole in the card and tie a string or wire to the card and suspend the card from the greenhouse frame. Hang the card vertically at and just above the top of the canopy.



Space monitoring cards equally throughout the entire area in a grid pattern. For best results place one card per 1000 sq. ft. For plants located on the floor or on benches, place the card just at the top of and over the plant canopy. As the plants grow, move the cards upward.

Keep insect monitoring cards in the greenhouse all the time. When installing the cards, number and date each card. It is important to record the pest levels on the field data sheet each week. Change the cards weekly. Place the cards in the same locations each week. Draw a map of the greenhouse and mark the location of each sticky card on the map.

Sticky cards are excellent for detecting pest migration into the greenhouse. Place cards near all entry ways including doors, sidewall and roof vents. Group your pest susceptible varieties together and place additional cards in these areas of the greenhouse. If a low pest population level is detected, immediately treat the area.

Place extra monitoring cards in areas where pests have previously been a problem. If a low pest infestation is detected, treat the area immediately.

Pest identification

The first step in pest management is accurate pest identification. In order to implement IPM techniques it is essential to know the major pests that are likely to appear, where to look for them, and how to identify them. It is also important to understand the biology of a pest and its interaction with other organisms and its environment.

Early identification and accurate diagnosis are fundamental to a successful IPM program. Misdiagnosis can result in improper control. Many chemicals are effective only at certain stages of the pest's life cycle. For example, wet spraying for whiteflies works best

when the majority of the whiteflies are in the early instar phase (first and second instars).

It is very useful to collect pest samples from your greenhouse and preserve them in vials filled with rubbing alcohol. Label them with the pest identification, the date and the location. They will become an important tool for identification and training new scouts. For help in identifying your pests contact the



Cooperative Extension Service; or Kenneth Welch, CT Agricultural Experiment Station, 123 Huntigton Street, New Haven, CT 06511, (203) 789-7239; or Richard Cowles, CT Agricultural Experiment Station, Valley Laboratory, 153 Cook Hill Road, Windsor, CT 06095, (860) 688-3647.

Timing

Many pesticides are only effective against certain pests, and often only against certain life stages of that pest. For example, insecticides are most effective against scales and mealybugs during their crawling stage, before they have produced their protective waxy covering. Pesticides applied against the wrong life stage of a pest are not likely to be very effective. This is one reason why it is important to know the correct identity of a pest as well as its life cycle and biology. In general, control treatments are most affective when they target the life stage of the pest that was scouted as being most numerous. For example, if more larvae are found than adults, use a larvicide; if adults predominate, use an adulticide. Repeated applications may be necessary to gain control of pests with overlapping life stages.

CONTROL METHODS

When control of a pest population is necessary, there are many control activities available. The specific method selected should be based on the type of pest causing the problem and the severity of the loss if the desired control is not achieved. Control methods fall into four basic groups:

- Cultural practices: in general, any activity that promotes plant health and vigor
- Mechanical methods: crop management activities often performed by hand labor in greenhouse crops

- Biological controls: utilizing predators, parasites and pathogens to manage pest populations.
- Chemical controls: when cultural and mechanical methods cannot provide the desired control

CULTURAL PRACTICES

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. Refer to Section 8 for further discussion of cultural practices that relate to plant health.

Sanitation

Sanitation provides the first line of defense against pest infestations by preventing the introduction of pests into uninfested areas. General practices include washing hands between crop production activities, wearing clean clothing, and avoiding placing plants, hose ends and other tools on the floor or any other contaminated surface. These practices will help to prevent the spread of pests.

Other sanitation practices include the inspection of incoming plant material before it is allowed into the growing area and the isolation of infested plants in a quarantine area. Bench surfaces, tools, plastic pots, and other crop production equipment should be disinfected between uses. Although heat is an effective sterilant, materials such as plastics may not withstand high temperature treatment. Chemical disinfectants labeled for this purpose are more commonly used.

Procedures should be designed for handling growing mixes, tools, and equipment to avoid contamination of the growing medium. Pasteurization of the growing medium is required if soil, sand, or other materials exposed to pests are used.

Weeds are a constant source of pest reinfestation. Pests such as whiteflies, aphids, thrips and plant pathogens live on weeds around the exterior of the greenhouse. Remove weeds for at least 10 feet around the perimeter of the greenhouse. Black plastic mulch covered with coarse gravel can be used to maintain this weed-free zone. It is especially important to keep weeds away from entrances and inlet vents.

Soil and plant debris should be removed from the greenhouse daily and placed on the compost pile or in a covered container away from the greenhouse. Locate compost piles at least 500 feet from the greenhouse.

Crop resistance

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

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

Sometimes better chemical pest control is achieved using resistant varieties. In addition, biological control organisms may be more effective when used with resistant crop varieties. In situations where plant resistance is not complete, partial resistance can at least aid in reducing pesticide use.

Fallow periods

Insects and mites can be a constant problem in greenhouses because there is often a continuous supply of plant material for food and reproduction. If all plant material is removed for a sufficient period of time, these pests may die of starvation. This is particularly true in cool, temperate areas where vents and doors can be closed for much of the year to restrict pest movement into and out of the greenhouse. To ensure effectiveness, the greenhouse temperature should be sufficiently warm during the fallow period to prevent pests from going into diapause (hibernation). All plant material of any sort, including weeds, must be removed. Fumigation of an empty greenhouse may increase the effectiveness of this tactic. Pests may also be eliminated by allowing a greenhouse to freeze overnight during winter. Obviously the economics of crop production may preclude fallow periods in a greenhouse, but the idea should be kept in mind when considering pest control options.

Watering practices

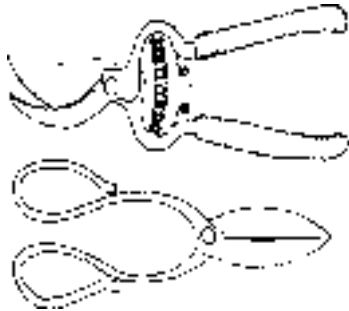
Overwatering can lead to plant disease problems, poor soil aeration, wet soil beneath benches, standing water and more. Algae, fungi and other organic material will grow in these moist areas, and lead to problems with fungus gnats and shore flies.

Conversely, plants that are under water stress are often more susceptible to insect and mite problems. Spider mites, in particular, favor dry environments. Careful attention to watering practices can reduce pest problems.

Plants are 80 to 90 percent water. The water in plant tissues holds the leaves and stems erect and is essential

for cell division and growth. Movement of water from the roots to the leaves circulates nutrients, removes waste products and helps cool the plant. Excess water is just as hazardous to plant health as lack of water.

MECHANICAL METHODS



Mechanical techniques use physical means to control pest numbers. Screens that exclude or confine pests, vacuuming, pruning and roguing are all examples of mechanical pest controls.

Screens

Entry-ways, air blasts and screens can be used to keep flying insects out of the greenhouse although screens also hinder air movement. Screens may also be used to separate the greenhouse into ranges to prevent pests from spreading throughout an entire production area. Pests physically confined to one part of the greenhouse are more easily controlled.

Because pests can be transported on clothing, workers should not be allowed to enter an uninfested area once they have visited an infested area, unless they are first disinfested.

Weed control

Weed control in the greenhouse cannot be overstressed! Weeds harbor insects, mites and plant diseases. No weeds should be tolerated in the greenhouse. Remove weeds regularly.

Remove unhealthy looking plants. Rogue out diseased or heavily infested plants. Check plants that have been in the greenhouse for over three months or plants that have become “pets”. These plants can harbor pest infestations.

Pruning and roguing

It is sometimes more cost effective to discard infested plant material than to attempt chemical control. This is true for many plant diseases, such as tomato spotted wilt virus which is vectored by western flower thrips. Pruning infested plant parts can also be an effective way to manage some pests on some crops. For example, removal of the lower leaves of poinsettias, after a healthy upper canopy develops, often reduces whitefly numbers.

BIOLOGICAL CONTROLS

Problems associated with pesticides have created the need for alternative pest control strategies that are economical, and effective. Biological control techniques are now available that may fill this need. Biological control uses living organisms (parasites, predators or pathogens) that are natural enemies of pests to regulate pest populations. The goal of biological control is to keep pest populations at a level too low to damage the crop, but just high enough to sustain the population of the natural enemies.

Predators and parasites



Predators are organisms that capture and devour their prey. Probably the most commonly known greenhouse predator is the ladybird beetle. A single ladybird (or ladybug) can eat 50 aphids per day. Other important insect predators include:

- Lacewings which feed on aphids, scales, mealybugs, thrips, mites, and insect eggs;
- The larvae of syrphid flies (also called ‘flower flies’) which consume aphids and small ants;
- Pedatory mites which feed on 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 which are useful as pest controls lay their eggs on or in the body of a pest species. When the eggs hatch, the immature or larval stages of the parasite develop by feeding on and killing the pest insect.

Parasitic insect species are highly specialized and usually will attack only one species of pest. Parasites useful in greenhouses are usually minute species of wasps that attack aphids, scales, whiteflies, leafminers, and other pest insects. See Appendix B for more information on commercially available parasitic species.

Pathogens

Pathogens are disease causing organisms including bacteria, fungi, viruses and nematodes. They play an important role in regulating pest populations. Several important pathogens are now marketed as pest control agents. For example the bacterium *Bacillus thuringiensis*, or "Bt", is marketed as an Gnatrol and provides control of a variety of leaf chewing caterpillars; and the fungus *Verticillium lecanii*, sold as Vetalec or Mycotel, helps control aphids and whiteflies in humid greenhouses.

CHEMICAL CONTROLS



Pesticides exhibit great variation in their effectiveness against individual pests. Some insecticides will control the immature forms of a pest but will not control the adult. Some insecticides are effective against mites, but most miticides (acaricides) are ineffective against insects. It is important to use an appropriate chemical against each pest to avoid wasted time, money, and pesticide. Pesticide labels contain information and specific instructions about which pests a product will control.

The shelf life of a pesticide can also affect its efficacy. Consult the pesticide label or the manufacturer if you have a question regarding the shelf life of a pesticide.

The misuse or overuse of pesticides can lead to problems with resistant pests. Pesticide resistance means the loss of previously effective chemicals and more costly alternatives. Some tactics for managing resistance are presented later (see "Managing resistance to pesticides").

Delivery

The method of pesticide delivery greatly affects treatment efficacy. In general, chemical control is most successful using application equipment that creates small pesticide droplets with uniform particle distribution, while providing good canopy penetration. The movement of systemic pesticides can compensate for incomplete coverage. Pesticides with systemic properties are able to move across leaves from the upper to the lower leaf surface. Systemic pesticides are taken up by a plant's vascular system and transported throughout its various parts.

Amount

The amount of pesticide used can affect its efficacy. The pesticide label is a legal document that is your guide for determining how much pesticide to use. For systemic insecticides applied to the soil, be sure irrigation water contacts the granules to release the insecticide into the growing media. The effectiveness of systemic insecticides can vary with the age of a plant and the amount of watering.

Managing resistance to pesticides

Insecticide resistance is a major concern for almost all the important greenhouse arthropod pests. A combination of factors has led to current resistance problems. These include pest biology, the intensity of past and present chemical use, aspects of the greenhouse environment, and commercial production practices. The following discussion suggests some useful ideas for any chemical control program.

Minimize insecticide use. If pest control relies exclusively on synthetic insecticides, then resistance is likely to occur. Therefore, the use of nonchemical control tactics (sanitation, weed elimination, soil sterilization, screening vents, biological control) should be maximized, and chemicals should be used sparingly.

Avoid persistent applications. Ideally, an effective insecticide should be applied at a concentration high enough (but not exceeding label limits) to kill all individuals in a population; then it should quickly

disappear. Pesticides which instead degrade slowly over time eventually are present at low concentrations that will kill only the most susceptible individuals. When only the weak individuals are removed from a population, only resistant individuals are left to reproduce creating an even more resistant population.

Aerosol formulations apply a short burst of highly concentrated insecticide and leave little residue. This application may select for resistance more slowly than a full coverage spray of the same insecticide, as long as resistance to the insecticide has not already developed.

Avoid tank mixes of more than one pesticide. A mixture of two insecticides may provide much greater short-term control than either insecticide used alone, but there is a danger in the long-term use of insecticide mixtures. The assumption behind the use of tank mixes is that there is little chance of resistance mechanisms to both pesticides occurring in any one individual. If this assumption is false, then continued use of the tank mix will select for these doubly resistant pests. Chemical control would then become much more difficult, because the pests would be resistant to multiple classes of insecticides.

Use long-term insecticide rotations. Use each effective insecticide for at least the duration of one pest generation before rotating to a different insecticide. If two insecticides are used within the same pest generation, the selection effect will be essentially the same as using a tank mix. This is because the same individuals would come into contact with both insecticides, although at slightly different times. To minimize the problems of overlapping generations and persistent insecticide residues, it might be wise to use the same insecticide for two or even three generations prior to rotating. The pesticides used in a rotation scheme should have different modes of action against the pest (i.e., they should be of different chemical classes), and resistance to the chemicals should be at a low level. For example, organophosphate and carbamate insecticides have similar modes of action and they should not be alternated in an insecticide rotation scheme.

Use pesticides with nonspecific modes of action. Insecticidal soaps and horticultural oils both have broad modes of action, and it is therefore unlikely that resistance will occur with either of these.

Integrate chemical and biological control. Insecticides applied to control insect pests can also harm or eliminate populations of beneficial insects which have been purposefully introduced into a greenhouse. Research has identified many insecticides that are compatible with the use of beneficial insects. The effective use of beneficial

insects can add an additional mortality factor that does not select for resistance and may conserve the effectiveness of insecticides.

SECTION 4 - REVIEW QUESTIONS

Greenhouse IPM

1. List the 4 IPM techniques most useful to greenhouse production systems.

- a.
- b.
- c.
- d.

2. What is the basic cornerstone of IPM?

- a. pesticide application timing
- b. scouting
- c. mechanical control
- d. records

3. Since most greenhouse insect pests are found on the top sides of the leaves, plant inspection should start from the top of the plant and work down towards the soil.

_____ True _____ False

4. Using Figure 1 below, draw a line to show an effective scouting pattern.



FIGURE 1

5. Blue colored sticky cards are specifically designed to attract white flies.

_____ True _____ False

6. Which are benefits of insect monitoring cards?

- a. early pest detection
- b. estimate size of pest populations
- c. gauge success of pest control treatments
- d. all of these

7. Sticky traps should be placed just above the plant canopy.

_____ True _____ False

8. For best results, how many sticky cards are needed to monitor 10,000 sq. ft. of plants?

- a. 5
- b. 8
- c. 10

9. How often should sticky cards be changed?

- a. daily
- b. weekly
- c. monthly

10. You must properly identify the pest and understand its life cycle and biology in order to know the proper timing of control measures.

_____ True _____ False

11. _____ provides the first line of defense against pest infestations by preventing the introduction of pests into uninfested areas.

12. Why should weeds around the exterior of greenhouses be removed?

13. During fallow periods, greenhouses should not be heated.

_____ True _____ False

14. Which pest problem is an indicator of water stress or dry environments?

- a. spider mites
- b. fungus gnats
- c. algae
- d. shore flies

15. List four examples of mechanical pest controls.

- a.
- b.
- c.
- d.

16. Biological controls are an effective way to totally eradicate a pest.

_____ True _____ False

17. Most insecticides are effective against mites.

_____ True _____ False

18. Which situations are likely to lead to pest resistance to pesticides?

- a. exclusive reliance on synthetic pesticides
- b. use of persistent pesticides
- c. repeated use of tank mixes
- d. all of these

19. To reduce pest resistance development, how long should the same insecticide be used?

- a. one time only
- b. for the duration of at least one pest generation
- c. less than the duration of one pest generation

20. Why is it unlikely that insects will ever develop resistance to products like insecticidal soaps and horticultural oils?

SECTION 5

PESTICIDES FOR GREENHOUSE PRODUCTION

SELECTING A PESTICIDE

There is a great variety of pesticides available. Chemicals are available to control nearly every type of greenhouse pest. There are several important factors to consider before using any pesticide. The first and most important step is correct identification of the problem:

- Inspect plants to confirm that the problem is caused by a pest
- Correctly identify the pest
- Make sure the chemical you choose will control the pest
- Make sure the pest is in a susceptible stage of development

Before purchasing a pesticide, consider its properties in relation to both the pest problem and the treatment location. The best way to learn about a product is to **READ THE LABEL**. Select the lowest risk product available based on:

- Signal word
- Potential health hazards
- Pests controlled/mode of action
- Environmental hazards
- Formulation
- Adjuvants



The label is the first and best source of information about using a pesticide. **READ IT**. Do not rely on color or design of the packaging when selecting a product. Many manufacturers offer a line of different chemicals that all are packaged the same. They may also have similar sounding names but they are actually very different compounds.

- Before you buy a pesticide, **READ THE LABEL**.
- Before you store a pesticide, **READ THE LABEL**.
- Before you mix a pesticide, **READ THE LABEL**.
- Before you apply a pesticide, **READ THE LABEL**.
- Before you dispose of pesticides or containers,

READ THE LABEL.

Federal regulations make it illegal to remove or destroy pesticide labels, or to use pesticides in any manner not listed on the label. **THE LABEL IS THE LAW**. This includes the information on the pesticide container and any written material supplied by the manufacturer. For a discussion of the parts of the label and the type of information provided, review the Core Manual.

Pesticide activity

Pesticide products used in greenhouse production include the following:

- Insecticides: effective against insects and related arthropod pests
- Fungicides: for reducing the spread of plant diseases caused by fungi
- Herbicides: to control unwanted plant growth
- Soil fumigants: used to reduce soil pests prior to planting crops

Modes of action

The way a pesticide acts against the living systems of pest organisms is called its **mode of action**. Generally, pesticides in the same chemical family have the same mode of action. If the desired control is not obtained with one product, understanding chemical families and modes of action makes it easier to select alternate products that will provide control. For example, many greenhouse insecticides poison the central nervous system of pests. If bifenthrin (Talstar) fails to provide control, switching to permethrin (Pounce) does not change the mode of action. Both are pyrethroids that interfere with transmission of impulses between nerve cells. Endosulfan (Thiodan) is an organochlorine pesticide that also works on the nervous system but with a different mode of action and, as a result, it may provide better control in this example.

In addition to having similar modes of action, pesticides in the same chemical family share other features in common. They are often available in the same formulations and used in much the same manner. Their persistence in the environment is usually comparable because the natural processes that degrade them are the same. Toxicity and risks to users also tend to be similar. There are, however, many exceptions to these similarities.

Pesticide action may occur where the chemical contacts the pest (**contact pesticides**), or within the pest after the chemical is eaten or absorbed (**systemic pesticides**). Some chemicals exhibit both types of activity. Systemic pesticides applied to plants are also called **translocated** pesticides. These chemicals move within the plant (or translocate) and control the target pest when the plant is attacked by disease or insects.

Where a resistant pest population is likely to develop, different chemical families should be routinely alternated. Don't simply change brands; similar compounds are produced by many companies. Read the label to make sure the products contain different active ingredients with different modes of action. Using products with different modes of action slows the development of resistance. Separating chemical treatments with mechanical or biological controls further reduces the development of resistance.

COMMON GREENHOUSE PESTICIDES

Common formulations

The Core Manual introduces the commonly available pesticide formulations. Many aspects of pesticide use are influenced by the formulation. The most important

factors to consider when selecting a product include:

- Health risks associated with using the formulation
- Required application method and equipment
- Risk of environmental damage by leaching or drift

Mixing pesticide products



Mixtures of two or more pesticides applied at the same time may provide added benefit for the greenhouse grower. Although tank mixes may lead to resistance development, by carefully selecting pesticides, both immediate and long term control may be achieved. Treatment for more than one pest at a time reduces the time and labor invested in control, leading to substantial savings. Approved combinations can be mixed by the applicator, as needed. **READ THE LABEL**. Tank mixes prepared by the applicator must be consistent with label instructions.

Some formulations and chemicals may be incompatible. This can result in loss of effectiveness against the target species, increased damage to nontarget plants, increased hazard to applicators, or the clogging of equipment. **READ THE LABEL**. It may list which formulations are compatible, and the order in which they must be added.

If combinations are not specifically restricted and compatibility is not stated on the labels, a jar test can be performed to determine compatibility of two or more products. Wear all personal protective equipment required by the most hazardous product when performing this test. Place one pint of water (or other carrier) to be used for tank mixing in a clean quart jar. The equivalent of one pound or pint per 25 gallons of finished mix is obtained by using the following amounts. Add product formulations in the order shown below, mixing after each addition.

- 1- ½ teaspoon of compatibility agents, activators or surfactants
- 2- ½ tablespoon of wettable powder or dry flowable formulations
- 3- ½ teaspoon of water soluble concentrates or solutions
- 4- ½ teaspoon of emulsifiable concentrates or flowables
- 5- ½ teaspoon of soluble powder formulations
- 6- ½ teaspoon of any additional adjuvants to be used, such as spreaders or stickers

Cap the jar tightly and invert 10 times. Inspect the mix immediately for uniform mixing. If sludge, clumps or non-dispersing oils are not formed, wait 30 minutes and check again. Minor separation that remixes easily is acceptable if tank agitation is good. If the formation of gums, sludge or clumps indicates incompatibility, do not use this combination of products. Dispose of the test mix according to label directions or, if unusable, follow DEP guidelines for hazardous materials.

The jar test only indicates chemical mixing compatibility; it does not indicate the effect it has on pest control activity. Some mixtures have an increased risk of phytotoxicity and they may promote the development of resistance to several types of pesticides at once. Compatible combinations should be tested on a small portion of crop. Wait several days after making test applications for injury symptoms to appear before making large scale applications. Application rates, schedules and precautions for using specific products are given in the New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide. This guide is produced every two years by Cooperative Extension specialists in the New England region. To obtain the current issue contact The University of Connecticut, Communications and Information Technology, 1376 Storrs Road, Storrs, CT 06269-4035, (860) 486-3336.

Some adjuvants are added during pesticide manufacture and are, thus, part of the formulation. Other adjuvants are added just before application. To decide when to use an adjuvant, **READ THE LABEL**. It will state when a particular adjuvant is needed, whether or not one should be added or when one is already present.

Adjuvants assist application or pesticide activity without being directly toxic to pests. However, many of these chemicals can present hazards to the applicators. The EPA has not required manufacturers to perform the same type of research and reporting on adjuvants that is required for pesticide registration. However, regulations are continually updated to protect the health of applicators and review and registration of adjuvants may be required in the future. Meanwhile, it is a good practice to use the same care in handling adjuvants as is used with pesticides.

Many, but not all, adjuvants function as **surfactants**, or surface active agents. Surfactants improve the retention and absorption of herbicides. The benefit they provide is offset, to a degree, by the increased drift hazard they cause. Reducing the surface tension of the spray solution permits it to break up into finer droplets, which are more likely to drift off target.

Drift control agents are adjuvants that help reduce the risk of drift. Pesticide drift is off-target spray deposit and off-target damage. **Spray thickeners** reduce drift by increasing droplet size and by reducing bounce or runoff during application. Use of these adjuvants helps to comply with drift regulations, which is especially important in areas adjacent to residential areas. Lo-Drift, Nalco-Trol and Drift Proof are examples of drift control agents.

Penetrating agents dissolve the waxy layer that protects the surface of leaves. This speeds up absorption with foliar treatments. Lower application rates used with these adjuvants may provide the same control as higher rates made without them; more chemical enters the plant before breaking down or washing off. Examples of penetrating agents include Arborchem and kerosene.

ADJUVANTS

Activity of adjuvants

Adjuvants, or additive compounds, aid in the mixing, application or effectiveness of pesticides. One class of adjuvants, **compatibility agents**, allow uniform mixing of compounds that would normally separate. Other types of adjuvants include **spreaders**, **stickers**, and **synergists**. There are nearly as many adjuvants as there are pesticides, and they provide a choice for every need.

PROPER HANDLING OF PESTICIDES

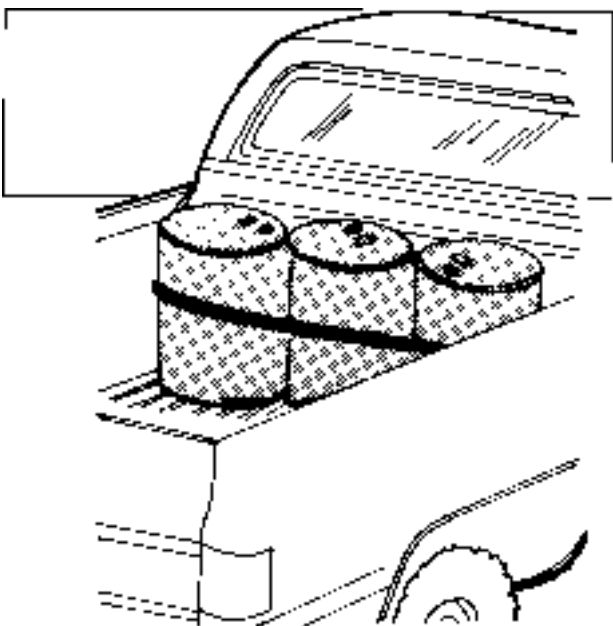
Using pesticides involves many responsibilities beyond the immediate needs of pest control. Greenhouse growers, like all agricultural producers, are expected to handle hazardous materials in a manner that reduces the exposure risk to other persons and limits contamination of the environment. Numerous federal and state regulations exist to help growers handle, store and apply pesticides properly.

In addition to FIFRA, EPA has further authority over pesticide use under the Superfund Amendment and Reauthorization Act (SARA) and the Resource Conservation and Recovery Act (RCRA). These federal regulations cover all materials classified as hazardous and, therefore, apply to pesticides. Pesticide handling and storage are also regulated by the Transportation Safety Act and the Occupational Safety and Health Act (OSHA).

Moving pesticides

Interstate transport of pesticides is regulated by the Federal Department of Transportation (DOT). Their guidelines for safe movement are common sense rules for any transport of chemicals. All pesticides should be in the original DOT approved containers and correctly labeled. All containers should be secured against movement that could result in breaking or spilling. Never transport pesticides in a vehicle that also carries food or feed products. Never transport pesticides in the cab of vehicles. Paper or cardboard containers should be protected from moisture. Never leave an open-bed truck containing pesticides unattended. Following these procedures is necessary when moving concentrated chemicals and is good practice for diluted mixtures.

Persons transporting chemicals must have proper protective clothing available for the safe handling of the containers. The protective gear should be in or on the vehicle for immediate access in case a spill occurs. Protection of the person managing or cleaning up a spill is the primary concern.



SPILL CLEANUP AND REPORTING

What to do when a spill occurs



When a minor spill occurs, make sure the proper protective equipment is available, and wear it. If pesticide has spilled on anyone, wash it off immediately, before taking any other action. Confine the spill with a dike of sand or soil. Use absorbent materials to soak up the spill. Shovel all contaminated material into a leak-proof container and dispose of it in the same manner as excess pesticides, as described in the Core Manual. Do not hose down the area; this spreads the chemical. Always work carefully to avoid making mistakes.

Streams and wetlands must be protected in the event of an accidental spill of any size. Even diluted chemicals pose a threat to natural habitats when released in large amounts. Extra precautions must be taken when drawing water from streams or ponds. Antisiphoning devices must be used and be in good working order. Tank mixes should be prepared at least $\frac{1}{4}$ mile from water resources. If this is not possible, make sure the ground at the mixing site does not slope toward the water, or construct an earthen dike to prevent pesticides from flowing into bodies of water or drains.

Major spills of concentrates or large quantities of spray solution are difficult to handle without assistance. Provide any first aid that is needed and confine the spill, then notify the proper authorities. Contact the local fire department using the 911 system, if available. Other phone numbers for fire departments, state and local authorities should be carried in the vehicles and by the applicators.

Regardless of the size of the spill, keep people away from the chemicals. Rope off the area and flag it to warn others. Do not leave the site unless responsible help, such as emergency or enforcement personnel, is there to warn others.



Significant pesticide spills must be reported to:
Oil & Chemical Spill Response
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106
(860) 424-3338

Applicators, or their employers, are responsible for telephoning a spray incident report as soon as practical after emergency health care and efforts to contain the spill have started. The state agencies decide if it is necessary to call **CHEMTREC** (Chemical Transportation Emergency Center), a public service of the Manufacturing Chemicals Association located in Washington, D. C. CHEMTREC provides immediate advice for those at the scene of an emergency. This service is available 24 hours a day (1-800-424-9300) for emergencies only.



SECTION 5 - REVIEW QUESTIONS
Pesticides For Greenhouse Production

1. Where a resistant pest population is likely to develop, pesticides with differing modes of action should be alternated.

_____ True _____ False

2. Cost of the product is the most important factor to consider when selecting a pesticide.

_____ True _____ False

3. Which type of adjuvant dissolves the waxy layer that protects the leaf surface and improves absorption of pesticides.

- a. stickers
- b. spreaders
- c. penetrating agents
- d. synergists

4. Tank mixing two pesticides together may promote the development of pest resistance to both pesticides at once.

_____ True _____ False

5. If a minor spill occurs you need not wear any protective clothing when cleaning it up.

_____ True _____ False

SECTION 6

EQUIPMENT AND CALIBRATION

The scale of greenhouse production varies greatly from one operation to another. It may range from a few benches of mixed seedlings to an entire house dedicated to a single crop. Appropriate pesticide application equipment should be used at each individual site. Using the proper equipment will make pesticide applications easy and efficient.

Selecting application equipment is as important as choosing the proper pesticide. Usually, a single sprayer will not meet all the needs of a greenhouse grower. The choice of equipment is influenced by these factors:

- Type of pesticides and/or fertilizers
- Pesticide formulations
- Capacity of equipment compared to size of crop areas
- Operator safety features
- Ease of operation, calibration and maintenance
- Crops grown

GREENHOUSE SPRAYERS

Manual sprayers

Where several greenhouse crops are grown near each other, manual sprayers are useful because of their limited size and spray range. Individual plants or weed patches can be easily spot-treated while not affecting neighboring rows. Several types of sprayers are available that deliver 0.1 to two gallons per minute (gpm) at pressures up to 100 pounds per square inch (psi). Their small capacity is adequate only when a few plants or rows require treatment. These sprayers are relatively inexpensive, simple to operate, easy to handle and easy to clean and store.

TRIGGER PUMP SPRAYERS are used for many types of liquid applications. Squeezing the trigger forces spray mixture out of the nozzle as a stream. Droplet size can be controlled on some models with adjustable nozzles. Capacity of the plastic spray bottles is very limited, usually less than one gallon. These are generally used



for spot spraying of weeds with ready-to-use herbicides.

Areas accessible to garden hoses or water wagons can be treated with **HOSE-END PROPORTIONERS**.



These simple mixers use the flow of water to draw concentrated pesticide from the reservoir. Chemicals are mixed with the water stream as it leaves the hose. Any formulation that is diluted with water can be applied with this equipment, but wettable powders and emulsifiable concentrates require frequent shaking. Several precautions must be taken with hose-end proportioners for safe use and proper application. Handling concentrated pesticides requires adequate protection with personal protective equipment. Extra care is needed to prevent spills, splashes and misapplications. The proportioner must be checked for correct functioning and be calibrated before each use. An antisiphoning device must be installed between the proportioner and the water source to prevent backflow and contamination of water supplies.

Manually powered **KNAPSACK SPRAYERS** consist of a liquid supply tank, pump, holding chamber, hose and wand assembly with a control valve attached to a nozzle system. A support frame and harness stabilize the unit and attach it to the operator's back. The pump draws liquid from the supply tank and delivers it to the chamber where it is held under pressure until the valve on the wand is opened. The pressure forces the liquid through the nozzle which breaks it into small spray droplets. Because the pressure drops as the flow continues, periodic hand-pumping is required.

Knapsack sprayers are very popular and adapt well to many greenhouse situations. Understanding the safety features and functional design of your sprayer will enhance its effectiveness.

- **Knapsack sprayers should provide for safe and efficient operation:**

- They should stand upright for easy filling, cleaning and storing.
- They should have a carrying handle and durable, adjustable straps that distribute weight comfortably on any user.
- Even with a full tank, they should be easy to lift and strap in place.
- They should have well placed, easy to use controls



- **The tank features:**

- The tank shape should conform to the operator's back.
- The shape should be suitable for rapid and complete draining.
- It should have an adequately sized inlet opening with basket strainer and a tight fitting cap.
- The cap should be easily tightened and loosened by hand.
- The tank should have an easy to read volume gauge.
- The tank should be equipped with an agitator.
- The tank should have pressure gauges and pressure adjustment controls.

- **The pump features:**

- The pump stroke should be a comfortable length.
- Normal pumping rates should produce maximum output.
- Pumps should be removable for easy servicing.
- Pump volume should be adequate for a multi-nozzle boom.
- Pumps should have minimum friction in linkages.

- **The wand and nozzle assembly features:**

- Wands should be rigid and strong.
- A positive shut-off spray control valve should be provided to prevent drips.
- The wand should be long enough for all intended uses.

- Store the wand in a safe place when not in use.
- Wands should be equipped with a nozzle appropriate for intended pressures.
- Wands should have an in line strainer or filter

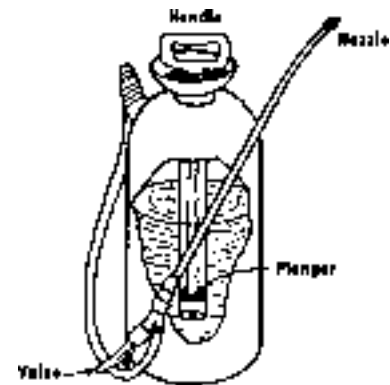
- **Construction:**

- Only corrosion-resistant materials should be used.
- The sprayer should be resistant to mildew, rot, and degradation caused by sunlight.
- Sprayers should be constructed of strong, lightweight material.

Knapsack sprayers provide fairly accurate delivery if equipped with a pressure gauge or pressure regulator. Nozzles must be designed to work within the pressure range of the equipment and calibrated for the working conditions present.

LEVER PRESSURIZED KNAPSACK SPRAYERS with external pressure chambers (Birchmeyer sprayers) can also be used in greenhouse production. These systems are well suited to low-volume and low-pressure foliar applications. The operator needs to pressurize the external pressure chamber only infrequently to produce the proper spray stream. Overpressurizing these sprayers results in a fine, mist-like spray that causes improper coverage and risks off-target drift.

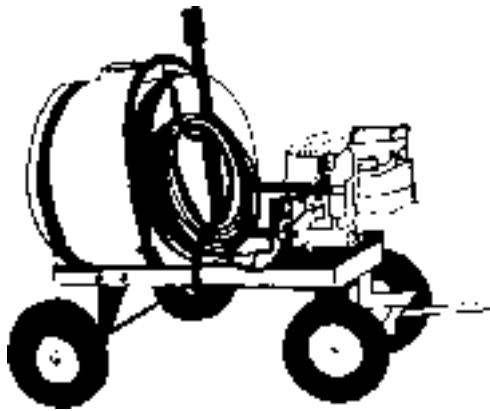
The supply tanks of **COMPRESSED AIR SPRAYERS** are pressurized either with a hand-operated plunger or carbon dioxide cartridges.



Compressing air in the space above the spray mixture forces the liquid through the nozzle. The pressure in the tank drops as the material is applied. This decrease in pressure can be partly overcome by filling the tank only 2/3 full with spray material, which leaves ample air space for initial expansion. Repressurizing the tank frequently also helps maintain uniform application. Many of these sprayers lack pressure gauges or controls, making operator experience an important factor in consistent

coverage. These types of sprayers should not be used for insecticide or fungicide applications where uniform coverage is crucial. For sprayers equipped with pressure gauges, the tank should be repressurized when the pressure drops 10 psi from the initial reading.

Powered hydraulic sprayers



Power-operated hydraulic sprayers distribute large volumes of prepared pesticide by forcing the solution through nozzles. Both the pressure and nozzles used affect droplet size and how thoroughly the spray target is covered.

When complete coverage is not required, as with soil incorporated insecticides, **LOW-PRESSURE HYDRAULIC** systems deliver pesticides with a low risk of drift. They deliver low to moderate volumes of spray, usually 10 to 60 gallons per acre, at working pressures ranging from 10 to 50 psi.

HIGH-PRESSURE HYDRAULIC systems are better suited for applications where plant surfaces must be completely covered, as with protectant fungicides. Air currents produced by the high pressure spray stream distribute the small droplets on all surfaces of plants. The risk of off-target drift is much greater with high pressure systems. High-pressure hydraulic systems are equipped to deliver large volumes of spray, 20 to 500 gallons per acre, under pressures ranging from 50 to 400 psi or more. All hoses, valves, nozzles and other components must be designed for high-pressure applications.

CONTROLLED DROPLET APPLICATORS (CDA) use spinning and oscillating disks to produce raindrop sized sprays. These types of spray applicators were developed specifically to reduce off-target drift. They disperse spray droplets using mechanical means, rather than hydraulic pressure. A small volume of spray material under low pressure is converted to a shower of

large, uniformly sized drops as it spins off the edge of a rotating disk. Droplet size is controlled by rotation speed. Rotary or raindrop applicators are available for attachment to booms or to backpack sprayers. Because these applicators may be mounted vertically or horizontally, a wide range of swath widths is possible. These devices are expensive but greatly reduce the risk of drift or other off-target damage. Their precision makes them useful for greenhouse applications.



MISTBLOWERS use a high-velocity, large-volume air stream to apply concentrated pesticide mixtures. The goal of air stream applications is to replace all air within the crop canopy with pesticide-laden air from the sprayer. This requires adequate air volume from the equipment and correct travel speed. Newer designs release the air stream close to plant surfaces, allowing slower speed which can reduce drift.

Because the pesticide is carried by air, a limited amount of water is used to prepare treatments for mistblowers. The small volume of water, compared to hydraulic applications, permits greater coverage from a single fill in less time. In addition, turbulence from the air stream can provide better coverage of plant surfaces. However, mistblowers greatly increase the risk of drift. Only broadcast applications can be made with air stream systems. Because of the risk of off-target damage, herbicide applications should never be made with air stream applicators.

The most recent **ELECTROSTATIC SPRAYERS** are much like mistblowers in that they are low volume applicators using air to form and propel spray droplets. The major difference is that electrostatic sprayers also electrically charge the droplets. Charged droplets repel each other and thus avoid collisions which would form larger drops. In addition, charged droplets



are electrically attracted to the target plants which carry an opposite charge. When applied from above, charged spray droplets moving past the upper leaf surface are actually attracted back to the underside of the leaf.

Electrostatic sprayers atomize the treatment mixture. This means that the droplet size is so small that they are difficult to see at all. Because of the speed at which material exits the nozzle and the highly concentrated spray solution, practice and skill are required for proper application with an electrostatic sprayer. Complete coverage is only obtained by pointing the nozzle directly at the target plant. Operators should rely on the air stream to move plant leaves and propel droplets through dense foliage for thorough coverage.

Even distribution is obtained if plants are sprayed from two different sides. With each pass of the nozzle, the operator should sweep past the plants to promote leaf movement. The atomized pesticide is deposited so finely that leaves may still appear dry after treatment. Because of this it is difficult for the operator to see if plants have been treated. Current manufacturer's recommendations state that if the mistblower operator observes plant leaves moving during the spray operation, then the leaves have been treated adequately.

Thermal foggers

These are low volume applicators used in the greenhouse industry. Thermal foggers use a specially formulated carrier that is injected with the pesticide into an extremely hot, rapid air stream. The air stream is then propelled into the greenhouse producing a dense vapor of very small droplets that penetrate the greenhouse like an aerosol fog. The rate of application depends on the size of the metering orifice. Thermal foggers that are designed to treat larger areas have large

tanks and require more time to dispense the greater volume of pesticide mixture.

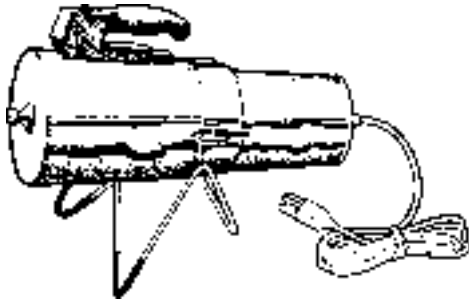
Thermal foggers can be carried by an operator, moved on a cart, or operated from a fixed location in the greenhouse. Effective use of thermal foggers usually requires moving them around the greenhouse. Moving the fogger gives uniform distribution of spray material. Operating a fogger from any fixed position below the target area will deposit most of the material on the floor near the fogger. It is quite easy for an operator to carry a fogger and watch the fog's movement through a room to ensure good distribution. The fogger nozzle should be aimed at an angle, slightly above the top of the crop. Aiming the fogger nozzle directly at the plant canopy may cause thermal or chemical burns to the plants.

Because the effectiveness of thermal foggers is dependent on room temperature, relative humidity and air flow in the greenhouse. These factors also affect the length of time between application and safe reentry into the greenhouse. High temperature and low humidity make spray droplets fall out of the air more quickly than with moist and cool air.

Mechanical foggers

Mechanical foggers, cold foggers and aerosol generators are low volume applicators that atomize treatments mechanically to generate a cloud of very small spray droplets. They use external fans to propel the spray cloud toward the target and to promote air circulation within the greenhouse. Research has shown that mechanical foggers deposit more spray material on the upper sides of leaves than on the undersides.

The size of the fan and the capacity of the spray tank determine the size of room that a mechanical fogger can effectively treat. Since most mechanical sprayers



are meant to be operated from a fixed position, more than one may be needed to treat larger greenhouses.

Aerosol bombs / smoke generators

Aerosol bombs or smoke generators contain highly concentrated pesticide formulations. They use a pressurized propellant to disperse pesticide. Aerosol and smoke spray clouds are made up of very small droplets that provide very good coverage.

Application rates for aerosols are based on the volume of air in the greenhouse. This is an economical method of treatment for small greenhouses. However, as with foggers, using aerosols and smoke bombs does not ensure good foliage penetration or good coverage of both leaf surfaces. Using the correct number and proper distribution of pesticide containers will help ensure uniform distribution of the material throughout the entire room.



Hazards of foggers/fumigants and aerosol bombs

These types of application have a potential for causing explosions when used improperly. Follow all rate recommendations carefully, especially where ignition sources exist.

SPRAYER COMPONENTS

Nozzles

A variety of materials are used to make nozzles, including brass, stainless steel, ceramic and nylon. There are advantages and disadvantages with each type of material. However, it is wisest to invest in the best quality nozzles available. Brass nozzles are relatively inexpensive, but they wear rapidly with abrasive materials, such as wettable powders and liquid fertilizers. Stainless steel and hardened stainless steel are the most resistant to wear, but their expense discourages some users. Frequent replacement of brass nozzles usually makes their use more costly in relation to the area sprayed.

The smooth surface of nylon nozzles makes them relatively resistant to wear, but the threads are easily damaged in use, especially when overtightened. Modified nylon tips in metal housings avoid some of these problems. However, some solvents react with nylon, causing the material to swell and become unusable. Ceramic spray nozzles are also abrasion resistant, but are expensive and breakable.

There are different types of spray patterns produced by nozzles each designed for a specific application. Choosing the proper nozzle for a particular treatment will ensure good coverage and minimum drift. The selection of a nozzle is determined by the type of treatment being applied as well as certain aspects of the spray equipment such as flow rate and operating pressure. Herbicides are applied at low pressure to produce large droplets that reduce drift. Higher pressures are used with fungicides to produce small droplets for better coverage of foliage. Insecticides are applied with pressure ranges between these two extremes. Drift control adjuvants work best with nozzles that reduce the number of fine and mist-like drops. To be effective and safe, nozzles may need to be changed for different pesticide applications.

The different types of fan nozzles are designed to work only within certain pressure ranges. Even slight changes in spray pressure will alter the pattern produced by a fan nozzle. It is also important that the nozzles are at the proper height above the target. Otherwise the spray pattern will not provide uniform coverage. The required height depends on the nozzle angle and spacing along the boom. Refer to manufacturer charts for the correct spacing, height and pressures for various fan nozzles.

The tapering-edge spray pattern produced by flat-fan nozzles provides uniform coverage when overlapping nozzles are used on boom sprayers.



Even flat-fan nozzles deliver the same fan shape but the droplet distribution is even across the entire pattern. These are used for banded applications where spray from adjacent nozzles does not overlap. Applications made selectively over the tops of crops or between rows use this type of nozzle.

Flooding fan nozzles used with low pressure produce large drops in a wide spray angle. These nozzles reduce drift and prevent clogging. Adequate coverage with flooding nozzles requires spray patterns that fully overlap.

Twin orifice flat-fan nozzles are designed for applications that require good penetration and coverage of foliage. Two small openings in the nozzle direct spray streams that form smaller droplets using the same low pressures as conventional flat-fan nozzles. The small openings are subject to clogging and require finer strainers than other nozzles.

Cone nozzles are used for insecticide and fungicide applications when thorough foliar coverage is needed. Cone nozzles used with high pressure form small, lightweight droplets. Because the risk of drift is greatly increased, these nozzles should only be used when complete coverage is required. Low volume applications are made with hollow cone nozzles that concentrate the spray around the edge of the pattern. Solid cone nozzles that evenly distribute pesticide in a circular pattern are used for high volume applications.

Other special purpose and improved nozzles are available for use on greenhouse crops. Consult manufacturer information for the proper selection and use of nozzles suited to your application needs.

Other components

Flow control devices are necessary to make the tank, pump and nozzles work together. Depending on the application system, these devices may include pressure regulators, unloader valves and control valves.

Because both the spray pattern and flow rate are determined by operating pressure, each sprayer should be equipped with a pressure gauge. The gauge should be placed where it may be easily seen.

Strainers are also required for effective treatments. Strainers trap particles and debris in the spray mixture and protect the pump, control devices and nozzles from damage.

CHEMIGATION

Chemigation, or the practice of applying materials through watering systems, requires constant attention to how the material is applied and to the operation of the watering system. The chemigation system must be kept separate from the water supply to prevent any contamination.

Chemigation with a nozzle watering system must be done in a manner consistent with the pesticide label. The nozzles must provide the correct total output and droplet sizes. Nozzle watering systems do not provide adequate coverage of leaf undersides or effective canopy penetration.

The output of a chemigation system should be frequently checked to ensure the correct rate of pesticide is being applied. The output should be measured using accurate collection containers.

CALIBRATION

Calibration is the process of measuring and adjusting the amount of pesticide your equipment applies to the target area. It is a routine part of using any application system. This is not a once-a-year job. It is a good idea to calibrate spray equipment on a regular basis. As a minimum equipment should be calibrated during the first day of the spray season or when equipment is first put into use, and whenever nozzles are replaced. Failure to calibrate pesticide application equipment can result in plant injury, creation of a hazardous situation and wasted money. Frequent calibration identifies worn nozzles and keeps the operator aware of factors that affect application

rate, such as travel speed, pressure at the nozzle, and type of nozzle in use. Multipurpose sprayers must be calibrated for each different use.

Calibrating application equipment is not difficult. Be sure that all parts are clean and operating correctly and follow the manufacturer's directions carefully. Spray equipment calibration begins by determining three factors:

- Correct pump operating pressure
- Type of carrier or diluent
- Spray volume required

Operating pressure depends on the spray system chosen. Each pump has a range of pressures in which it operates most efficiently. Operating within these limits provides steady pressure output and protects the spray system from damage. The specific pressure to use is determined by considering the drift hazard and penetration recommendations for the pesticide used.

The type of carrier limits the selection of nozzles that can withstand the pressure, volume and formulations without excessive wear. Low-pressure foliar applications often use water as the carrier. Manufacturers provide charts to assist in selecting the proper nozzles for use with different types of carriers.

The volume of spray needed for effective coverage is stated on the pesticide label. Rates are often expressed as the amount of diluted pesticide mixture to use per area, such as "20 gallons per acre." If the application rate is given as weight of active ingredient per area, for instance "do not exceed 20 pounds a.i. per acre," the volume of diluted mixture this produces must be determined before proceeding.

When a range of acceptable volumes is given such as "up to 100 gallons per acre" the size of the spray tank and area to be treated will determine the actual spray volume to use. Proper coverage of mature plants requires greater spray volume per area than younger plants. Application rates for soil-applied herbicides should be appropriate for the soil texture. Over-application to sandy or porous soils can lead to leaching or off-target injury problems.

Hydraulic systems

All hydraulic sprayers, including booms and hand-held wands, are calibrated with similar procedures. Because the amount of spray delivered by these systems depends on how fast the pesticide mixture flows from the nozzle and how quickly the nozzle is moved over the target area, calibration requires a few calculations. The arithmetic is very straight forward when worked

through carefully. Check the Core Manual for more information.

The first step in calibration is to find the delivery rate of the nozzles. This is done by pumping water through the nozzles for a timed period, say five or 10 minutes, and collecting the spray for measurement. Nozzle flow varies with the size of the nozzle tip and the nozzle pressure. Flow through the nozzle is proportional to the square root of pressure. In other words, to **double** the flow rate, pressure must be **increased four times**. An accurate pressure gauge is required to maintain proper spray pressure. The delivery rate per minute (in gallons per minute, GPM, or in ounces per minute, oz/min) is found by dividing the volume collected by the number of minutes. Fill the spray tank at least half full of water when calibrating your spray system. (Because residues from spray mixes may remain in the tank, always wear chemically resistant gloves, long sleeves and a face or eye shield while performing calibration steps.)

The recent introduction of calibration tools makes it easy to measure the flow rate of nozzles. Spray tip testers provide direct readings of the rate as water is pumped through the nozzles. This eliminates the need for timed collection and the subsequent calculations.

Hand-held wand calibration

Hand-held wands with single or clustered nozzles may be supplied from either knapsack sprayers or power sprayers with larger tanks. Liquid applications made with any hand-held wand can be performed accurately when pressures, swath width and walking speed are controlled. This means that each piece of equipment must be calibrated for the individual using it. Operators using hand-held wands must develop a uniform speed of application and check frequently to assure that a consistent rate is maintained.

Uniform applications require practice applications with water. These can be made to asphalt or concrete surfaces of parking lots, or to strips of wrapping paper placed in actual field conditions. Uneven applications can be noted as the surface dries. Adjust walking speed and repeat the process until sprays are uniform.

To begin calibration, determine the swath width; this is the width of the row or inter-row space to be treated. Fit the application equipment with the proper nozzle and adjust the pressure to produce the desired swath width. Finally, determine a comfortable walking speed, in feet per second, for the operator. Several passes over a measured distance of actual field conditions should be averaged to find the travel speed. Gallons per acre (GPA) is determined with the following formula:

$$\text{GPA} = \frac{\text{oz/min} \times 5.7}{\text{ft/sec} \times \text{swath width}}$$

where,

oz/min = nozzle output per minute, in ounces

ft/sec = walking speed of operator during application

swath width = width of row, in feet, treated in a single pass.

This calculation provides the rate of application PER ACRE of actual treatment. It may be necessary to determine the amount of pesticide needed for a single fill of the applicator's tank and how many refills will be needed to treat an acre. The following example demonstrates the necessary calculations for a knapsack sprayer using the above formula.

Example: An operator wants to apply five pounds of a pesticide per acre as a two-foot wide band of spray using a four gallon capacity backpack sprayer. The nozzle discharges 38 ounces of solution per minute. The operator walks at four feet per second while making applications. The dilution rate for the pesticide under the given circumstances is found by substituting the numbers into the formula:

$$\text{GPA} = \frac{38 \text{ oz /min} \times 5.7}{4 \text{ ft /sec} \times 2 \text{ ft}} = 27 \text{ gal /acre.}$$

Treating one acre would require mixing five pounds of product with 27 gallons of water. Since the sprayer only holds four gallons, the amount of product to use per fill is determined as follows:

$$\begin{aligned} \text{oz/fill} &= \frac{\text{backpack capacity in gal}}{\text{GPA}} \times \text{oz product /acre} \\ &= \frac{4 \text{ gals}}{27 \text{ gal /acre}} \times 80 \text{ oz /acre} \\ &= 11.9, \text{ or just about } 12 \text{ oz /fill.} \end{aligned}$$

Note that for this example,

$$\text{oz product/acre} = 5 \text{ pounds} \times 16 \text{ ounces/pound} = 80 \text{ oz}$$

The length of row each fill of the sprayer treats is determined using the following formula:

$$\text{row length/fill} = \frac{\text{backpack capacity} \times \text{row length/acre}}{\text{GPA}}$$

where, backpack capacity is expressed in gallons, and,

$$\text{row length/acre} = \frac{43,560 \text{ sq ft/acre}}{\text{swath width in feet}}$$

Continuing our example, we first determine row length per acre,

$$\begin{aligned} \text{Row length/acre} &= \frac{43,560 \text{ sq ft/acre}}{2 \text{ foot swath}} \\ &= 21,780 \text{ ft/acre.} \end{aligned}$$

Now we can complete the calculation,

$$\begin{aligned} \text{Row length/fill} &= \frac{4 \text{ gal sprayer} \times 21,780 \text{ ft/acre}}{27 \text{ gal/acre}} \\ &= 3,226 \text{ feet.} \end{aligned}$$

And so to make our application at the given rate per acre, nozzle discharge, and walking speed, we will need 12 ounces of pesticide diluted in four gallons of water for each fill of the backpack sprayer. Each fill treats 3,226 feet of row using a two foot swath width. For an acre, the sprayer must be filled seven times (27 divided by 4 = 6.75).

Mistblowers

It is not possible to collect the nozzle output of air stream sprayers, so calibration begins by determining the amount of output over a short period of time. The equipment is placed on a level area and the tank filled with water. If the tank lacks calibrated markings, the water must reach a level that can be duplicated on refilling. Before beginning, check for leaks around tanks and seals; make sure all nozzles are clean and operating properly.

While standing upwind, operate the equipment at its normal speed and pressure. Open all valves to the nozzles and start a stopwatch at the same time. Run the sprayer for several minutes before closing the valves and record the exact time elapsed. Measure the volume of water needed to refill the tank to the original level and calculate

the volume of water sprayed per minute. Repeat this process at least twice and average all runs to determine the nozzle output. If measurements are made in ounces per minute the same equations given above may be used for calibration.

CLEANING AND MAINTENANCE

While using any application system, be alert for changes in the spray pattern. Gaps caused by clogged nozzles or spreaders can result in poor control. Worn nozzles can lead to over-application, which increases costs and may cause excessive residue. Always protect yourself first. Wear all the personal protective equipment specified on the pesticide label when repairing or maintaining spray equipment. This is a wise precaution, even when you think the equipment has been properly cleaned.

Cleaning the application system

Sprayers need to be cleaned to prevent corrosion of equipment parts and to reduce the risk of crop injury from cross contamination. Trace amounts of one pesticide can react with another or carry over to the next spraying. With extended contact, small amounts of some pesticides can damage sprayer components, including stainless steel and fiberglass tanks. Pump components must be protected from corrosion.

No cleaning method is foolproof. However, careful cleaning will usually remove all but insignificant amounts of insecticides and fungicides. Herbicides carried over into an insecticide spray mix could be very damaging to susceptible crops, such as vegetables. Therefore, two separate sprayers, one for herbicides only and one for all other pesticides, are recommended for greenhouse producers.

When cleaning, the general procedure is to first flush with water, then add the appropriate cleaning solution to the tank, agitate and flush again. Always flush with clean water to remove any cleaning solution. Remove nozzle tips and screens; clean them in strong detergent solution or kerosene, using a soft brush.

Some pesticide combinations may produce a paste-like coating in the sprayer. Flushing after each load can help to remove this. If water alone does not dissolve and remove the buildup, add Stoddard solvent, kerosene or another low flammable solvent; allow the paste to dissolve, then agitate and flush into a collection area or tank for future disposal as hazardous waste. Then

continue general cleaning procedures.

A thorough cleaning with the proper solution should be made whenever pesticides are changed or before storing equipment. Contaminated storage conditions can cause more damage to the pump or other components than actual use. The cleaning solution depends on the pesticide to be removed. **READ THE LABEL** for cleaning instructions or see your Core Manual for more information.

Prevent pesticide contamination

Choose the area used for equipment cleanup carefully. Ideally, the cleanup area should have a sealed, concrete floor and curbing with a sump to catch contaminated water and pesticides. Avoid contaminating water supplies and prevent injury to plants or animals. Do not make puddles that might be accessible to children, pets, farm animals or wildlife. The rinse water and cleaning solution may be sprayed on a site consistent with the pesticide label directions, or disposed of as hazardous waste in an approved landfill. Avoid discharging all of the cleaning solution in a small area.

An operator should end the spray application with an empty tank or a minimum amount of pesticide mix remaining. Excess materials can be applied to additional sites as approved on the product label. Or the tanks can be drained, with the excess contained and disposed of in an approved manner for hazardous waste. Remember to completely label any containers holding pesticides or prepared mixtures.

An alternative for handling excess spray mixtures, rinsates from triple-rinsing containers, and waste water from cleaning equipment is to use these materials as the diluent for the next batch of the same chemical. All containers holding such rinsates should be clearly and fully labeled the same as the original container. Store these with other pesticide products in a secure, preferably locked, place.

Check the manufacturer's recommendations for your sprayer when preparing it for storage. Light oil in the final flush leaves a protective coating on tank, pumps and hoses. This is not recommended for sprayers with rubber components. Rubber gaskets, diaphragms or pump rollers swell and weaken when exposed to oil. Automotive antifreeze with a rust inhibitor can prevent freezing and prevent corrosion in case all the water is not drained from the pump. Read the owner's manual for the proper care of your sprayer systems. Always wear the proper personal protective equipment when performing any cleaning or maintenance activities.

SECTION 6 - REVIEW QUESTIONS

Equipment and Calibration

1. What must be done to properly use hose-end proportioners ?
 - a. wear personal protective equipment
 - b. install an antisiphoning device
 - c. take extra care to prevent spills
 - d. all of these
2. Backpack sprayers should be equipped with agitation.
_____ True _____ False
3. Applicators using lever pressurized sprayers need not worry about off-target drift.
_____ True _____ False
4. Which type of sprayer is better suited for applications where plant surfaces must be completely covered?
 - a. low-pressure hydraulic
 - b. high-pressure hydraulic
 - c. lever pressurized knapsack
 - d. none of these
5. Use of mistblowers greatly increases the risk of drift.
_____ True _____ False
6. Thermal foggers can be left in one spot in the greenhouse and still get total coverage.
_____ True _____ False
7. Which sprayer type gives good coverage on the undersides of leaves?
 - a. thermal foggers
 - b. mechanical foggers
 - c. electrostatic sprayers
 - d. all of these
8. Proper nozzle choice is crucial to achieve good coverage and minimize drift.
_____ True _____ False
9. Herbicides should be applied at high pressures for optimum coverage and drift reduction.
_____ True _____ False
10. Chemigation systems should be combined with the water supply system.
_____ True _____ False
11. Which are acceptable alternatives for handling excess spray mixtures?
 - a. apply to another site consistent with the pesticide label
 - b. dispose of as hazardous waste
 - c. use as a diluent for the next batch
 - d. all of these

SECTION 7

FUMIGATION

Fumigants are not used very often in New England greenhouses. Most growers avoid the problems discussed below by using artificial media. Nevertheless, fumigants are sometimes used to treat greenhouse soil. Fumigation can control many pests that may compete with, attack and/or injure the crop such as:

- Plant-parasitic nematodes, including root-knot, root lesion (meadow), and cyst
- Soilborne disease causing organisms, including the fungi *Pythium*, *Rhizoctonia* and *Phytophthora*
- Weeds including lamb's-quarters, bermudagrass and quackgrass
- Insects including wireworms, cutworms and garden symphylans

FUMIGANTS

Hazards of using fumigants

Most fumigants are highly hazardous materials and must be used only by individuals trained in their proper use. Many greenhouse operations use steam sterilization

to accomplish the same ends as soil fumigation. Steam sterilization is safer and at least as effective as fumigation. If the grower elects to use chemical fumigants, specialized information and training are needed. The purpose of this chapter is to outline that specialized information.

Nature and effects of fumigants

Fumigants are pesticides that reach the target in the form of a poisonous gas. In contrast, smokes, fogs and aerosols are dispersed as very fine particles or clumps of molecules. Fumigants disperse in clouds of millions of single molecules of the gas. Fumigants can penetrate cracks, crevices and the commodity being treated. Fumigants kill when they are absorbed or inhaled by the pest. Fumigants must be applied in sealed enclosed spaces, since once the gas escapes to the atmosphere its effectiveness is lost. Fumigants are not long lasting, and once they are gone, reinfestation can occur.

Toxicity of fumigants

Fumigants are highly hazardous materials and must be used only by individuals trained in their proper use. They are highly toxic to plants, animals, and humans.

Methyl Bromide

Chemical name:	Bromomethane
Appearance:	Clear, colorless gas or liquid when under pressure or refrigeration.
Weight:Gas:	3.3 times as heavy as air, tends to sink.
Liquid:	14.4 pounds per gallon.
Odor:	Odorless. Often mixed with chloropicrin which is used as a warning odorant.
Reactivity (relevant to liquid methyl bromide only):	
Aluminum:	Severe explosion hazard.
Magnesium:	Severe explosion hazard.
Zinc:	Severe explosion hazard.

They are often fast acting, some are odorless and cannot be seen. As a new pesticide applicator you must become knowledgeable about the fumigant you use before applying it. Each fumigant acts in its own unique way, and requires specific knowledge of its hazards and nature. Remember, there are no old careless fumigators.

Inhalation exposure



Acute exposure: Do not breathe vapor. Symptoms may be delayed anywhere from 1 to 12 hours after exposure to high concentrations; lower concentrations result in less severe symptoms within a period of 12 to 24 hours. Reported effects: headache, visual problems, nausea, vomiting, abdominal pain and death.

Chronic exposure: repeated exposure may result in adverse central nervous system effects including muscular pains, speech problems, blurred vision and mental confusion.

Skin contact



Acute Exposure: contact with the liquid may cause irritation, burning or tingling sensation, redness and swelling. Large amounts can cause blisters, numbness and aching pain. Liquid methyl bromide can be absorbed through the skin and cause symptoms described under inhalation. Death can occur from absorbing liquid methyl bromide through the skin.

Important Note: Do not wear protective gloves, adhesive bandages, tight jewelry, contact lenses, or tight fitting clothes while using methyl bromide. It can be

trapped between the apparel and the skin, causing severe symptoms.

Eye contact



Vapors and liquid may cause transient irritation and conjunctivitis.

Ingestion



Ingestion of liquid is unlikely, however, it can cause throat and stomach irritation as well as the symptoms described under inhalation.

Methyl bromide alternatives

The primary fumigant used for soil treatment in greenhouses is methyl bromide. However, the EPA has labelled methyl bromide as a Class I ozone-depleting chemical and it is now being phased out of use. A total ban on domestic production and import goes into effect by the year 2000. Alternatives include chloropicrin, Vorlex, Vapam (metam-sodium), Telone (dichloro-propene), and Basamid (dazomet). All of these chemicals are highly toxic and their future registration status is uncertain.

There are a wide variety of less toxic alternatives including solarization, steam sterilization, soil sterilization, hot water, composting, resistant varieties, *Trichoderma* seed treatments, microwaves, and more. These less toxic alternatives are best used in combination.

FUMIGATION WITH METHYL BROMIDE

NOTE: THE FOLLOWING SECTION ON SOIL FUMIGATION PERTAINS ONLY TO THE USE OF METHYL BROMIDE PRODUCTS CONTAINING CHLOROPICRIN AS A WARNING ODORANT

Protective clothing

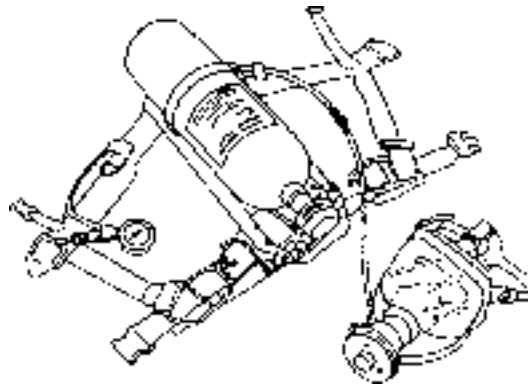
Methyl bromide may be trapped inside clothing and cause skin injury. Wear loose shirts, long trousers and socks that are cleaned after each wearing. Do not wear jewelry, gloves or other gas confining apparel. If full-face respiratory protection is not required, wear full face shield for eye protection when handling liquid. After exposure, immediately remove clothing, shoes and socks. Do not reuse contaminated clothing until it is thoroughly decontaminated. Drenched shoes cannot be adequately decontaminated.

Respiratory protection

If the concentration of methyl bromide in the work area, as measured by a pump detector with appropriate tubes, does not exceed 5 ppm, no respiratory protection is required. If this concentration is exceeded at any time, all persons in the fumigation area must wear a NIOSH/MSHA approved self-contained breathing apparatus (SCBA) or combination air-supplied/SCBA respirator or evacuate the area. (Examples of approved methyl bromide pump-type detectors are Draeger, Kitagawa, MSA, and Sensidyne).

These requirements mean that a minimum of two SCBA respirators and at least one approved methyl bromide detector are required to be available before methyl bromide is used. If the fumigation is done out of doors the SCBA is not required, but is recommended. If the fumigation is done inside a greenhouse, the SCBA must be worn when the gas concentration is greater than 5 ppm.

Measuring the concentration of methyl bromide is an important part of the fumigation job. The only detectors accurate enough to measure 5 ppm are the pump-type detectors listed above. The fumigator must have one of these and use it if the fumigation is done inside. Exterior fumigation does not require the testing equipment, but its use is still recommended. Without a pump-type detector, there is no other way a fumigator



can be sure the concentration of methyl bromide is safe. Halide detectors can be used to monitor for leaks, but a halide detector does not measure the concentration accurately enough to be approved for entry without respiratory protection.

Soil fumigation

Directions for Methyl Bromide; THESE PRECAUTIONS MUST BE FOLLOWED PRIOR TO SOIL FUMIGATION:

- Comply with all local regulations and ordinances. Obtain an application permit from regulatory agencies as required.
- Never fumigate alone. It is required by the WPS to always have a trained assistant with the proper protective equipment, present in case of accidents.
- Persons in charge of all operations must advise other workers of all safety precautions and procedures. In addition, they must instruct their helpers in the mechanical operation of the equipment.
- Check the fumigant delivery system for leaks before beginning operation. Two trained and equipped persons must be present during introduction of the fumigant.
- During soil fumigation, at least 10 gallons of water must be readily accessible at the site of application. This water must be potable and in containers marked "Decontamination water not to be used for drinking."

THESE PRECAUTIONS MUST BE FOLLOWED DURING THE SOIL FUMIGATION:

- Two trained persons must be present during introduction of the fumigant.

- Do not make application of this fumigant when there is little or no air movement or when there is an atmospheric inversion.
- When changing the cylinders, be certain they are turned off and that the fumigant system is not under pressure.

THESE PRECAUTIONS MUST BE FOLLOWED AFTER SOIL FUMIGATION:

- Post all treated areas with WPS warning signs until aeration is complete and ventilation requirements are met.
- Two trained persons must be present during removal of the tarpaulin, if used.
- Keep all animals and unauthorized people away from the area during removal of tarpaulin, if used.

Pretreatment soil preparation

Plow, rip or otherwise till the soil to the depth to which effective treatment is required. The soil should be worked until free of clods or large lumps. Residue from previous crops should be worked into the soil to allow for decomposition prior to fumigation. Soil moisture should be adequate for seed germination. Coarse textured soils can be fumigated with higher moisture content than fine textured soils. For best results, soil should be kept moist for at least four days prior to treatment. Do not fumigate if the soil temperature is below 50° F. For best results, fumigate when soil temperature is 60° F to 80° F at the depth of 6 inches.

Raised tarp method

Raised Tarp Fumigation Method for Plant Beds and Other Small Areas:

- Dig a trench around the perimeter of area to be treated, throwing soil to the outside so it can be used to bury tarpaulin edges after covering.
- To support the cover and provide a small gas dome to facilitate fumigant distribution place items such as inflated balloons, crumpled fertilizer bags, or burlap bags stuffed lightly with hay or straw on the soil surface of the area to be treated.
- Evaporating pans or vaporizers are used for the volatilization and uniform dispersion of fumigant. Shallow pans or basins made of plastic or metal, except aluminum are satisfactory. Remember, aluminum poses an explosion hazard and is not compatible with liquid methyl bromide. Use one

evaporator pan for each 300 to 400 square feet of area. Special opening devices are available for use of 1 and 1 1/2 pound cans that combine the opener and evaporative pan functions, and are designed to be used with all parts under the tarp.

- For delivery of methyl bromide gas from outside the tarp, polyethylene tubing is required. Anchor one end of each polyethylene tube into an evaporating pan with tape or a suitable weight. This ensures that the liquid will be directed into the evaporating pan.
- Extend the free ends of the polyethylene tubes outside of the area to be covered.
- After the supports and tubing are in place, cover the area to be fumigated with polyethylene film or other suitable material.
- Seal by placing the outside edges of tarpaulin in the trench and covering them with soil. Tamp soil down so edges will not pull loose.
- Attach a polyethylene tube to the can applicator or cylinder valve outlet and release fumigant. Use a cylinder dispenser or scale to meter small amounts from cylinders. Fumigant may be vaporized before introduction by means of a commercially manufactured heat exchanger, by using a copper coil immersed in a vessel of hot water or by immersing a can in hot water. CAUTION: Puncture the can with the device before immersing it in hot water; keeping the outlet pointed up to allow only vapor to enter the polyethylene tube.



Special instructions for greenhouse soil fumigation

The use of methyl bromide in confined spaces presents a potential hazard to humans and plant life. Special precautions must be taken in order to minimize this hazard. It is the responsibility of the individual supervising the fumigation operation to see that all safety precautions are strictly observed. Before the fumigation operation commences, the supervisor of the fumigation job shall have conducted handler training for all personnel involved in the fumigation (handler requirements are part of the WPS), removed all persons from the area who are not directly involved in the fumigation, and inspected the equipment to ensure proper application.

Fumigation of greenhouse soils may be done by any of the tarpaulin methods described, depending on the greenhouse size and accessibility to equipment. If a wind is blowing, all injection should be made upwind from a previous injection site. Immediately after tarping and injection of the fumigant, a qualified person, wearing protective equipment, should monitor the tarped area with a halide detector. If excessive leaks are found, the source of the leak should be resealed immediately.

During this operation, all windows and doors should be open and fans operating to maximize ventilation. The greenhouse must be placarded on all entrances to the fumigated area with approved WPS signs and any other information required by labeling.

Reentry into treated areas

After fumigation, treated areas must be aerated until the level of methyl bromide is below 5 ppm. Do not enter the treated area without proper equipment before this time. Protected workers entering the treated area for short term tasks (not to exceed one hour in any 24 hour period) must be provided with a respiratory protection device (NIOSH/MSHA approved self-contained breathing apparatus (SCBA) or combination air-supplied/SCBA respirator). Only a certified applicator or trained handler may remove placards.

Potting soil fumigation

Potting mixes including compost, soil mixes, and manure can be fumigated with methyl bromide. Fumigation should take place outdoors or in a well ventilated area away from desirable plants or occupied buildings. The material to be treated should have a temperature of 60° F or higher, be loose, and be moist

enough for good seed germination. To ensure a good seal, pile the material on a concrete floor or on wet ground. Pile to a depth of 18 inches. Piles two to three feet high can also be treated provided perforations are made in the pile surface at one foot intervals to assist penetration. Once the pile has been made, install supports to hold the cover a few inches above the pile surface to aid in proper fumigant diffusion. Evaporating pans are essential for the volatilization and uniform dispersion of fumigant except where a vaporizer is used. Shallow pans or basins made of plastic or metal (except aluminum) are satisfactory for this purpose. For delivery of methyl bromide from outside the tarpaulin, polyethylene tubing is required. Anchor one end of each polyethylene tube into an evaporating pan with tape or a suitable weight. This ensures that the liquid will be directed into the evaporating pan.

Place evaporating pan(s) with anchored applicator tubing about 30 feet apart on the pile surface. Extend the free ends of the polyethylene tubes outside the area to be covered. Cover with a polyethylene sheeting or other gas confining material of 4 mil or greater thickness. Seal the edges by burying, covering with moist sand or soil. Attach applicator tube to the can or cylinder valve outlet and release fumigant. Use a cylinder dispenser or scale to meter small amounts from cylinders. Special devices are available for use of 1 and 1½ pound cans that combine the opener and evaporating pan functions, and are designed to be usable while entirely under the tarpaulin. At the end of the exposure period, unseal opposite ends of the tarpaulin and allow to aerate for at least 30 minutes before completely removing the tarp. To avoid phytotoxicity, aerate for 24-72 hours before planting.

Potting mixes in flats may also be treated. Arrange the flats in loose crisscross stacks no more than 5 feet high, then cover and seal as described above. Introduce the fumigant at the top and in the center of the stack. Use one injection point for each 100 cubic feet. Aerate for 24 hours.

SECTION 7 - REVIEW QUESTIONS

Fumigation

1. Use of sterile growing media helps growers avoid using fumigation.

_____ True _____ False

2. Fumigants provide long-lasting plant protection from reinfestation by disease and insect problems.

_____ True _____ False

3. List three alternatives to methyl bromide.

a.

b.

c.

4. What must be available before methyl bromide is used in a greenhouse?

a. two SCBA respirators

b. one SCBA respirator

c. one methyl bromide detector

d. none of these

5. In emergency situations fumigants may be applied by one person.

_____ True _____ False

6. Soil texture, temperature and moisture greatly effect fumigant effectiveness.

_____ True _____ False

7. All personnel involved with application of fumigants must be trained, at a minimum, as:

a. licensed applicators

b. agricultural workers

c. pesticide handlers

SECTION 8

THE GREENHOUSE ENVIRONMENT

ABIOTIC DISORDERS

Abiotic disorders are caused by nonliving factors such as environmental or cultural conditions. They produce a wide range of symptoms, ranging from a simple loss of vigor to rapid death of plants. Those causing the most severe damage are the easiest to recognize and correct. Because some symptoms can go unnoticed, unfavorable conditions and practices may continue for long periods. During this time, plants are under stress, which makes them susceptible to pathogenic diseases. For example, if powdery mildew develops on a plant usually resistant to this disease, an examination might reveal that the plant was consistently over-watered, resulting in high moisture and humidity in the planting area. In this case, correcting the cultural practice that allowed the pathogen to become established may be adequate treatment.

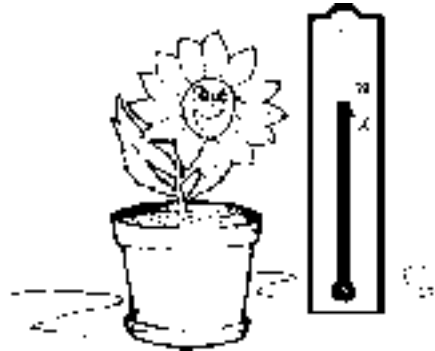
The abiotic factors which affect optimum plant performance are:

- Light, temperature, water and air
- Nutrient levels and balances
- Pollution
- Pesticide injury
- Mechanical injury

In many cases, it is the suboptimal levels of the first and second factors that lead a plant to disease and insect problems. For this reason, it is important to be aware of the specific needs and sensitivities of each crop.

TEMPERATURE

Generally, the warmer the air temperature, the faster a plant will grow and develop, assuming all other conditions are optimum. Plant leaf temperature is a function of light level and air temperature, and is regulated by transpiration. Sudden changes in air temperature will affect humidity and transpiration rates, and can result in temperature stress.



The difference between day and night temperature is as important as the actual temperature values. The processes which produce food for plants to grow and develop (photosynthesis) stop working at about 95°F and above. The processes which make the plant grow and develop (respiration) continue at night. At a certain low temperature (specific to the crop) these processes will also stop.

Recent research has improved our understanding of temperature control. Researchers have found that for certain plant species such as chrysanthemums, lilies, and poinsettias, high night/low day temperatures will reduce or eliminate the need for application of plant growth regulators.

The technique of temperature control of plant height is based on the concept of average temperature. The concept is that plants grow and develop at a rate dependent on the average temperature they receive over a 24 hour period.

$$\text{AVG Temp} = \frac{(\text{day temp} \times \text{hrs day}) + (\text{night temp} \times \text{hrs night})}{24}$$

If plants growth is behind schedule the daily average temperature is raised to speed up development. If plants growth is ahead of schedule the daily average temperature is lowered to slow down development.

Plant height is influenced by the difference (DIF) between Day and Night temperature:

$$\text{DIF} = \text{Day Temperature} - \text{Night Temperature}$$

A positive difference (higher day than night) will produce taller plants. A negative difference (higher night than day) will produce shorter plants. Plant height can be decreased by lowering the day temperature and also by increasing the night temperature. It can also be achieved by inducing a relatively cooler temperature for the first two hours after sunrise. DIF affects the length of the stem internodes rather than the number of leaves.

A table of Day/Night temperature combinations and their effect on average Daily Temperature is included for those growers who may wish to experiment with this technique (see Table I. Day and Night Temperatures Needed to Produce Various Average Daily Temperature). Keep in mind that the threshold temperatures necessary for flower induction for specific crops still apply.

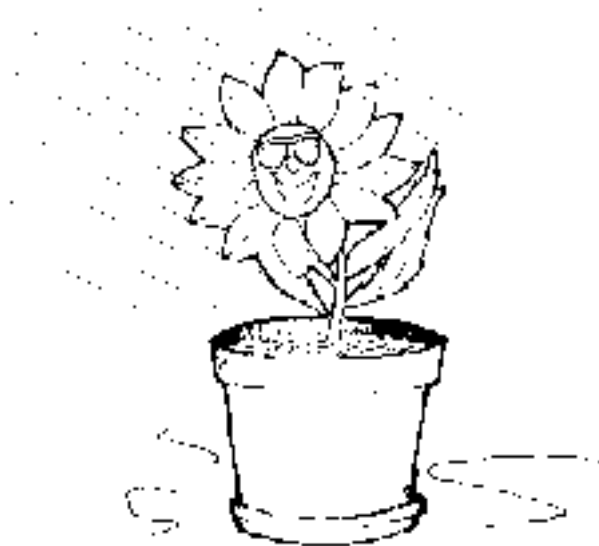
For optimum plant performance, it is important to accurately maintain the desired temperatures with a minimum of fluctuation around the set point. High temperature injury results in tissue collapse due to desiccation or overheating of cellular fluids and is more prevalent on young tissues and at leaf margins.

Unless freezing occurs, low temperature problems are more subtle. Slow growth, chlorosis of the leaves, defoliation, and various nutritional and pathogenic diseases often occur after plants are exposed to low temperatures. When propagating plants, the soil temperature must be monitored, since the rooting medium is often cooler than the air temperature due to evaporative cooling. Low temperatures can slow the growth of seedlings, or the rooting of cuttings. A sudden rise in air temperature may result in moisture condensing on leaf surfaces, providing conditions favorable to some plant diseases.

LIGHT

Light intensity, quality, and duration are important for optimum plant growth and development. Generally, plants grow more with blue light because each unit of blue light contains more energy than red light. Plants need red light for timing their daily and seasonal clocks. Many growers have successfully used supplemental lighting to increase the light intensity during cloudy days and during the fall, winter and spring. (See Table II - Common Supplemental Light Intensities for Various Ornamental Crops for more information.)

Greenhouse plants may be divided into two broad groups: those tolerant of full sun, and those requiring partial shading. Insufficient light levels can result in poor coloration, leggy growth, and slow development. Exces-



sive light results in bleaching of foliage and, in severe cases, high temperature injury, since light radiation raises the leaf temperature. Proper spacing, timely watering, and shading when necessary can correct high light problems.

The acclimatization of tropical plants to maintenance levels is done over a 3 - 6 week period. This involves lowering the intensity and adjusting the duration of light to similar levels encountered in indoor plantings. When plants do not undergo this gradual change, leaf yellowing and leaf drop usually occur. Acclimatization also requires adjusting the fertilizer rates to 10 - 20 percent of original levels and adjusting soil moisture according to the size of plant, ambient humidity, air movement and temperature.

WATER

The moisture requirements of plants are closely tied to light and temperature factors. Potting mediums should be well drained. Underwatering encourages salt accumulation and may lead to serious damage when plants wilt during bright, hot weather. Overwatering is a common cause of root disease. Roots are unable to obtain enough oxygen in a constantly saturated media. This leads to tissue death which provides an entry site for plant pathogens.

The initial nutrient, salt, pH, alkalinity, and sanitary levels of water supplies must be given consideration before developing a watering and fertilizing program. Water analysis should form the basis of any such program.

Table I. Day and Night Temperatures Needed to Produce Various Average Daily Temperature

TEMPERATURE		AVERAGE DAILY TEMPERATURE					
DAY	NIGHT	9 HR DAY	10 HR DAY	11 HR DAY	12 HR DAY	13 HR DAY	14 HR DAY
12	12	12.0	12.0	12.0	12.0	12.0	12.0
14	12	12.8	12.8	12.9	13.0	13.1	13.2
16	12	13.5	13.7	13.8	14.0	14.2	14.3
18	12	14.3	14.5	14.8	15.0	15.3	15.5
20	12	15.0	15.3	15.7	16.0	16.3	16.7
22	12	15.8	16.2	16.6	17.0	17.4	17.8
12	14	13.3	13.2	13.1	13.0	12.9	12.8
14	14	14.0	14.0	14.0	14.0	14.0	14.0
16	14	14.8	14.8	14.9	15.0	15.1	15.2
18	14	15.5	15.7	15.8	16.0	16.2	16.3
20	14	16.3	16.5	16.8	17.0	17.3	17.5
22	14	17.0	17.3	17.7	18.0	18.3	18.7
12	16	14.5	14.3	14.2	14.0	13.8	13.7
14	16	15.3	15.2	15.1	15.0	14.9	14.8
16	16	16.0	16.0	16.0	16.0	16.0	16.0
18	16	16.8	16.8	16.9	17.0	17.1	17.2
20	16	17.5	17.7	17.8	18.0	18.2	18.3
22	16	18.3	18.5	18.8	19.0	19.3	19.5
12	18	15.8	15.5	15.3	15.0	14.8	14.5
14	18	16.5	16.3	16.2	16.0	15.8	15.7
16	18	17.3	17.2	17.1	17.0	16.9	16.8
18	18	18.0	18.0	18.0	18.0	18.0	18.0
20	18	18.8	18.8	18.9	19.0	19.1	19.2
22	18	19.5	19.7	19.8	20.0	20.2	20.3
12	20	17.0	16.7	16.3	16.0	15.7	15.3
14	20	17.8	17.5	17.3	17.0	16.8	16.5
16	20	18.5	18.3	18.2	18.0	17.8	17.7
18	20	19.3	19.2	19.1	19.0	18.9	18.8
20	20	20.0	20.0	20.0	20.0	20.0	20.0
22	20	20.8	20.8	20.9	21.0	21.1	21.2
12	22	18.3	17.8	17.4	17.0	16.6	16.2
14	22	19.0	18.7	18.3	18.0	17.7	17.3
16	22	19.8	19.5	19.3	19.0	18.8	18.5
18	22	20.5	20.3	20.2	20.0	19.8	19.7
20	22	21.3	21.2	21.1	21.0	20.9	20.8
22	22	22.0	22.0	22.0	22.0	22.0	22.0

Watering practices

Overwatering can lead to plant disease problems, poor soil aeration, wet soil beneath benches, standing water and more. Algae and fungi growing in these moist areas and on accumulating organic matter lead to problems with fungus gnats and shore flies.

Conversely, plants that are under water stress are often more susceptible to insect and mite problems. Spider mites, in particular, favor dry environments. Careful attention to watering practices can reduce pest problems.

Plants are 80 to 90 percent water. The water in plant tissues holds the leaves and stems erect and is essential

for cell division and growth. Movement of water from the roots to the leaves circulates nutrients, removes waste products and helps cool the plant. Excess water is just as hazardous to plant health as lack of water. Over- and under-watering result in 85 percent of indoor ornamental plant losses.

The problem of excess water

More plants are killed by excess water and poor drainage than by any other cause. The high rate of respiration and growth in the roots requires a constant supply of oxygen in the growing medium. Two situations

exclude oxygen from the root area. The first is a result of soil characteristics. Poorly drained soils retain water in all pore spaces, directly blocking out air. The other is the result of improper watering. When too much water is applied, the excess drains from the container, but a moisture layer remains on the smallest roots. This acts as a barrier to oxygen absorption.

Evidence of over-watering may take a month or more to appear after the soil is flooded. As roots die due to lack of oxygen, apparently healthy leaves begin to die. Foliage loss continues until the leaves are reduced to the number the remaining roots can support.

Overwatering problems are avoided by watering plants only when needed, not on a predetermined schedule. Good judgment is required to determine not only when to water, but how much. If there is any doubt, it is better to err on the side of dryness and withhold water.

Knowing when to water plants

An experienced worker can tell when to water by stroking a plant's foliage. Crisp, rigid leaves indicate adequate moisture is still available. Knowing the dry weight of small movable planters and pots provides a hint to the water content. Soil color is also a clue to the moisture it holds. These skills are usually gained through long experience with plants.

The best watering schedule is determined by probing the soil, either by hand or with a small tool. The goal is to determine when soil moisture is nearly depleted and needs replacing. Test three spots in each container by plunging the thumb and index finger, up to the second joint, into the growing medium. Wear gloves to avoid exposure to residual chemicals in the potting medium. By squeezing a pinch of soil, an experienced worker can gain a good indication of the water content.

- If the pinch of soil drips, it is too wet
- If it holds its shape, it is properly moistened
- If it crumbles, it is too dry

How to water

It is best to apply water by hand, not with automatic systems. Individual plant needs are met only when each container is personally tended. A water breaker nozzle or wand aerates the water and breaks it into rain-like drops. A fogging nozzle maybe used when misting is necessary. Hand application permits the use of these tools without wetting the foliage of sensitive species. The chance of disease increases whenever foliage is wet for



long periods. As long as the foliage is not wetted, the time of day plants are watered does not contribute to disease.

Apply enough water to allow at least one-tenth to drain from the container. This leaching of the soil carries away excess fertilizers and soluble salts that could build up in the growing medium. It is necessary to water the entire surface of the growing medium each time; water flows down through the soil with little sideways movement. Frequent, shallow watering may be harmful because most of the subsurface soil is left dry. Plant health is improved when each container is watered thoroughly, but less often.

Quality of water

Water safe to drink is adequate for watering plants, except it should not be softened. The sodium used to replace calcium in hard water injures plants. High sodium levels also break down soil structure. Hard water does not harm plants, but excess soluble salts need to be leached from the soil occasionally.

Some city water systems add fluoride to drinking water supplies. When used on foliage plants, a few sensitive species show tip burn and other symptoms as fluoride levels build up in the soils. Chlorine gas used to make drinking water supplies safe does not generally present a problem to plants. Enough chlorine escapes into the air during watering that little threat to plants occurs. Deionized water is also suitable for application to plants.

PLANT NUTRIENTS

There are 17 chemical elements essential for plant health. Carbon, oxygen and hydrogen are readily available to plants from air and water. The other 14 nutrients are absorbed from the growing medium by the roots. When the natural soil nutrients are depleted, fertilizers replace the missing elements and maintain plant health.

Table II. Common Supplemental Light Intensities for Various* Ornamental Crops (Using High Pressure Sodium Vapour Lights)

Crop	W.m. ⁻² (PAR)	Intensity (klux)	Foot Candles	Daylength (Hours)	Stage of Crop	Comments
Alstroemeria	6	2.16	200	13	Flowering	13 hrs & will promote flowering
African Violets	6	2.16	200	18	Stock Plants	
Bedding plants - general	12	4.40	400	16	Seedlings	Will prevent stretching on cloudy days
Begonias Fibrous	6	2.16	200	18	Seedlings	Avoid high light intensities
Rieger	6	2.16	200	14	Stock	
Bromeliads	6	2.16	200	18	Seedlings	
Cactus	9	3.24	300	18	Seedlings	
Calceolaria	3	1.08	100	24	Flower Forcing	
Carnations	12	4.40	400	18	Seedlings Flowerings	
Chrysanthemums	15.5	5.6	500	20	Stock plants and cuttings	Can use for long day treatment
Cyclamen	6	2.16	200	18	Seedlings	
Geraniums	6	2.16	200	18	Cuttings	
Gerbera (cut)	6	2.16	200	18	Continuous	
Gerbera (potted)	6	2.16	200	16	Seedlings	
Gloxinia	9	3.24	300	18	To flowering	
Hydrangea	18	4.4	600	24	Cutting	
Kalanchoe	6	2.16	200	18	Stock plants	Long days prevent flowering
Lilies	9	3.24	300	18	Bud blasting	Prevents bud drop
Orchids	9	3.24	300	16	Flowering	
Poinsettias	4.5	1.62	150	18	After pinch	During periods of cloudy weather
Roses	15.5	3.24	500	20	Flowering	Mid- winter
Snapdragons	9	3.24	300	16	Seedlings	
Stephanotis	4.5	1.62	100	18	Flowering	

*Growers with lower cost electricity may supplement with higher light intensities in some cases.

** Watts per square metre.

Six elements are required in large amounts to build plant cells and to form the compounds that carry out plant processes. These are called macronutrients due to the high demand by plants. The use of these nutrients soon depletes the growing medium of nitrogen, phosphorus and potassium. These three elements are the primary macronutrients. The secondary macronutrients include calcium, magnesium and sulfur. These are required in relatively large amounts but are not depleted as quickly as the primary macronutrients. "Complete" fertilizers supply only the primary macronutrients (often listed as simply N-P-K) and not all nutrients as the name suggests.

Nitrogen is used in greater amounts than other nutrients. It has a major role in growth and reproduction. Deficiencies are indicated by yellow leaves and general

poor health of plants. Nitrogen excesses result in poor disease resistance and weak growth. There are two forms for application; ammonium nitrogen and nitrate. Nitrate is easily leached from soil, but is replaced by vitrification of the ammonium form. Fertilizers with both forms in equal amounts provide a continuous source of nitrogen to plants.

Phosphorus is essential for all plant growth. Adequate supplies hasten maturity, influence good root development and aid in the use of other elements. Leaching is not a problem because it binds tightly to soil particles, however this makes it unavailable to plants. Superphosphate is often used as a soil additive before planting to provide adequate quantities. High fluoride levels in superphosphate can result in tip burn of sensitive species.

Table III. ROLE OF NUTRIENTS IN PLANT HEALTH AND DEFICIENCY SYMPTOMS

CHEMICAL ELEMENT		FUNCTION IN PLANTS	DEFICIENCY SYMPTOMS
MACRONUTRIENTS - Required in relatively large quantities			
Nitrogen	(N)	Basic component of most compounds from proteins to light gathering pigments.	Stunting, loss of vigor. Leaves yellow in general or between veins, older first.
Phosphorus	(P)	Important in cell division, flowering, fruiting and root development.	Stunting, dark green leaves. Older veins turn purple or red.
Potassium	(K)	Involved with stomata opening and closing. Affects uptake and transport of minerals.	Small plant size, leaf tips and margins lose color, turn brown. May lose old leaves.
Calcium	(Ca)	Forms cell walls. Maintains structure of soil, availability of other minerals.	Death of stem tips, poor root growth. Leaves turn brown and fall.
Sulfur	(S)	Important for respiration functions. Part of aromatic oils formed by some plants.	General loss of green; plant pale, but not dry.
Magnesium	(Mg)	Component of pigments. Behaves much like calcium in soil.	Old leaves lose color between veins. No dead spots occur.
MICRONUTRIENTS - Needed only in small or trace amounts			
Iron	(Fe)	Essential in pigment production. Aids respiration.	Yellow color between veins that remain green, worse on new growth.
Zinc	(Zn)	Essential for formation of growth hormones.	New leaves small, narrow, pale. Generalized leaf spots.
Manganese	(Mn)	Assists in chemical reactions.	Looks like low iron, but wider green lines next to veins. Spots develop.
Boron	(B)	Aids water absorption and sugar transport.	Stunting, new growth deformed. Tip may die.
Copper	(Cu)	Assists in chemical reactions.	Young leaves look wilted, deform to cup shape. Color loss between veins.
Molybdenum	(Mo)	Aids uptake and use of nitrogen.	Stunting, leaves become mottled and curl inward.
Chlorine	(Cl)	Activates chemical reactions.	Plants prone to wilt. Dry, bronze-colored spots on leaves.

Potassium is important to the movement of food and nutrients within the plant. It helps maintain overall vigor and promotes root formation. Potassium requirements are not as great as nitrogen; any deficiencies are easily corrected by using any complete fertilizer.

Commercially prepared 'complete feed' fertilizers contain N-P-K and trace elements. Usually the trace elements in the mix will be sufficient to produce a good crop. Iron, in some cases (especially if the media has a pH greater than 6.5), may need to be supplemented. NOTE: These fertilizers may not contain calcium and magnesium in sufficient levels to satisfy plant needs. Generally, premixed fertilizers will have to be supplemented with calcium nitrate and Epsom salts or magnesium nitrate. Dolomitic limestone in the media will also supplement calcium and magnesium levels. Some complete feed fertilizers have been introduced that contain higher levels of secondary elements or micronutrients, for example, magnesium and molybdenum, thereby reducing the need for supplements.

Nutrient ratios are equally as important as the actual values in the media. Some nutrients interfere with or promote the uptake of other nutrients. For example, the calcium:magnesium ratio should be maintained at 1:0.4 for optimum uptake of both nutrients. Other nutrient ratios influence plant growth. A nitrogen:potassium ratio of 1:1 will generally produce normal growth and height development, whereas a nitrogen:potassium ratio of 5:8 will often produce darker, shorter plants.

Another point to consider is that vegetative growth requires relatively more calcium and nitrogen while plants that are actively flowering require more phosphorus and potassium.

Micronutrients

Of the 17 essential elements for proper plant growth, 8 are required in very small amounts. These are the micronutrients which include iron, boron, manganese, zinc, sodium, copper, chlorine, and molybdenum. Sodium and chlorine are sufficiently available in root media or as fertilizer contaminants. The other six micronutrients must be applied in fertilizer applications. Some of these become a small part of important biochemicals. Iron, for example, has a central role in the structure of chlorophyll. Other micronutrients assist chemical reactions without becoming part of plant tissues. Thus, the element copper participates in important reactions during plant respiration but is usually not absorbed by plant tissue.

There is a fine line between micronutrient deficiency and levels toxic to plants. Deficiencies of most micronu-

trients are unlikely to occur when a growing medium is based on natural soil. Special mixtures of these nutrients are available for the occasional need. Soilless growing media require application of all elements before use. The organic portion of some mixes can compete for micronutrients, as well, making routine fertilization necessary.

Deficiencies and Excesses in an IPM System

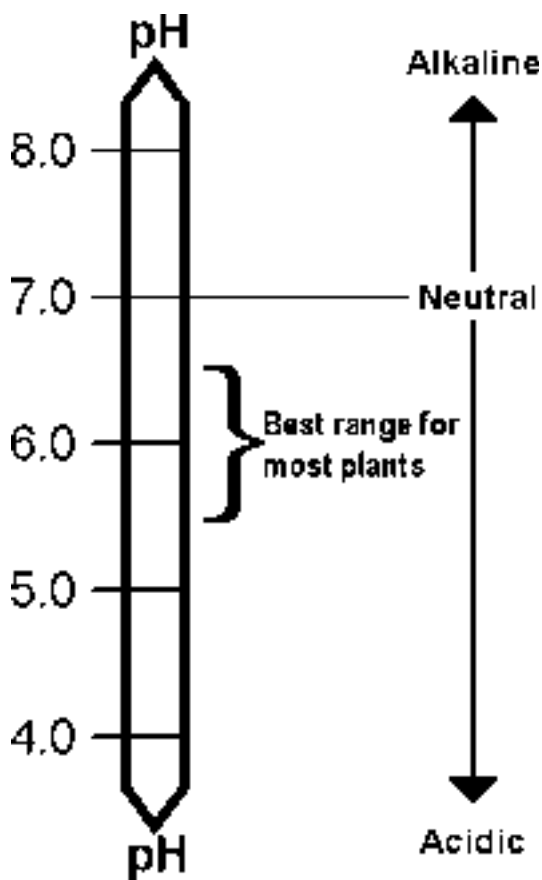
A plant's health and performance is dependent on the availability of the necessary macronutrients and micronutrients. Some crops require more of certain elements than others. For example, poinsettias are known to require molybdenum in higher quantities than most other crops. Micronutrients, especially copper, molybdenum, and boron can reach toxic levels fairly quickly through over application.

Nutrient deficiencies often result in slow growth and poor leaf shape or coloration. Excess nitrogen produces soft leaf tissues which are more susceptible to foliar diseases such as Botrytis. Chrysanthemum leafminers appear to be attracted to plants grown with high nitrogen levels. Nutritional deficiencies or excesses may be avoided by checking feeding formulas and verifying that all 12 of the required elements are available in the correct quantities. Ensure that the correct amounts of fertilizers are incorporated into potting mixes. A soil test may be necessary. A simple test of pH and conductivity can often indicate if soil conditions are adequate. Tissue analysis can be used to determine the levels of elements actually present in a plant and to verify fertilizer imbalances. (See Table III - Role of Plant Nutrients in Plant Health and Deficiency Symptoms for more information.)

IMPORTANCE OF pH

The acid or alkaline nature of soil is measured on the pH scale, which ranges from 0 to 14. Neutral compounds, such as distilled water, have a pH of 7. Acids have a lower pH; alkaline substances, a higher number. Most indoor ornamental plants grow best in slightly acid soils, in the range of pH 5.5 to 6.5.

Soil pH should be adjusted, if necessary, before planting. Adding lime, in the form of dolomite or calcium carbonate, will raise the pH of an extremely acid soil. Sulfur compounds are used to lower the pH of alkaline soils. The amount of amendment needed to reach the desired pH depends on the starting pH and the amount of organic material in the soil mix.



Release of nutrients from fertilizers and their availability to the plants is controlled by soil pH. If the pH is too low (acidic), the conversion of ammonia nitrogen to nitrate is slowed down. When pH levels are high (alkaline), micronutrient availability is reduced. Routine use of most fertilizers lowers the soil pH. Soil testing for pH and nutrient levels is part of a well managed plant maintenance program. Testing should be routinely scheduled.

FERTILIZATION PROGRAMS

A well managed fertilization program provides adequate nutrients to the plants at all times. Too little or too much in the growing medium impairs plant health. Excess fertilizer will not make a sick plant healthy and can kill a plant suffering from other problems.

Fast growing plants in production greenhouses have high nutrient demands. These are met with frequent fertilizations and the use of slow release fertilizers. Once plants are placed in landscapes, their nutrient needs are greatly reduced. The high levels of fertilizers used in production can be harmful to plants under low light conditions.

Fertilizer applications should be timed to the growth cycle of plants. Many plants go through a period of dormancy when there is little growth. Chemicals applied during this time are of little use to the plant and may result in harmful excesses. Most plants have a period of active growth through the spring and summer. Not only are light levels higher, but increased temperatures encourage greater plant activity. Nutrients should be readily available in the soil at this time. This is particularly important when lighting systems rely heavily on natural light.

Forms of fertilizers

Several forms of fertilizers are available for use on indoor ornamental plants:

- Liquid, must be diluted before use
- Soluble crystals, dry salts that dissolve in water

A comparison of two products (in 10 pound bags) with different N-P-K analyses

Product A		Product B	
N-P-K is 30-10-20		N-P-K is 15-5-10	
30%	of 10 # = 3 # N	15%	of 10 # = 1½ # N
10%	of 10 # = 1 # P	5%	of 10 # = ½ # P
20%	of 10 # = 2 # K	10%	of 10 # = 1 # K
Total N-P-K	= 6 #	Total N-P-K	= 3 #
Filler	= 4 #	Filler	= 7 #

- Tablets, soluble forms in easy-to-measure tablets
- Slow release, granules or plastic-coated forms that release nutrients over several months
- Organic, materials that release nutrients at low rates over long periods of time

Fertilizer can be a major expense. The form chosen is not important as long as the required nutrients are provided. Complete fertilizers list the percent of nitrogen phosphorus and potassium in a standard format. A 30-10-20 fertilizer means that 30 percent of the compound is available nitrogen, 10 percent is phosphorus and 20 percent potassium. A fertilizer with an N-P-K analysis of 15-5-10 has the same relative amounts of nutrient (3 parts nitrogen: 1 part phosphorus: 2 part potassium), but lower amounts available per pound.

Other factors that influence selection of a fertilizer include the form of nitrogen, chemical purity, solubility, effect on pH, uniformity, ease of handling, personal experience and price.

Application rates

Fertilizer recommendations are developed for the ideal growing conditions of a greenhouse; application rates are related to the light available to plants. Plants in most greenhouses need only one tenth or less of the amount needed under full growth conditions.

Frequent applications of reduced rates provide nearly constant nutrient levels. Low application rates also maintain plant health without encouraging excessive new growth. Routine soil testing is necessary to develop a schedule suited to each maintenance site. When fertilization is required, select a formulation intended for greenhouse use. Always **READ THE LABEL** before application and make sure other requirements are met. Apply only to active plants, and not during dormancy.

Nutrients are soluble chemical salts. When dissolved in the soil water, they compete with root hairs for moisture. Diluting formulations to one-half (or less) of the recommended rate reduces the chance of over-fertilization. As long as chemical concentrations are higher in the roots, water moves into the plant. When high levels of salts occur in the soil, water fails to move into the roots as easily. "Fertilizer burn" (where leaves lose color and turn brown) is evidence of this condition. Excess nutrients can occur from a single overapplication, or from one or more of the following:

- Excessive fertilizer applications
- Improper watering schedule and methods

READ THE LABEL !



- Use of hard water with naturally high salt levels
- Poor soil drainage
- Drying out of soil on concentrated fertilizer program
- Using soils with high fertilizer retention

Leaching soils helps reduce high soluble salt concentrations. Recurring problems require changing other factors contributing to the high levels.

AIR

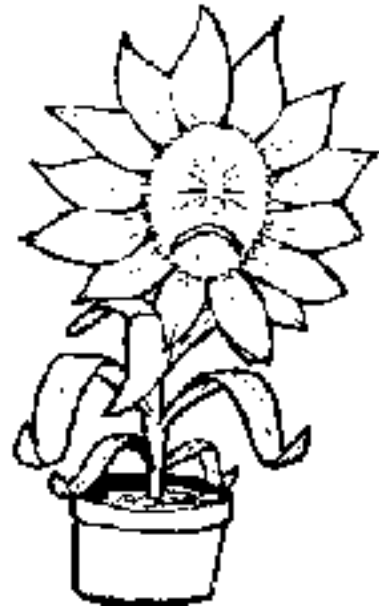
Adequate ventilation and air circulation can reduce the incidence of many foliar diseases. The humidity in the air is crucial to the health of plants. Humidity levels must often be reduced in greenhouses to avoid water condensation on leaves and flowers. High humidity levels can result in guttation and edema.

Guttation occurs in some species as a seepage of cellular fluids from the margins or edges of leaves. Although guttation may not harm the plant, it can indicate a humidity problem, and favors the development of bacterial diseases.

Edema is a disorder brought on by wet conditions and high humidities. Cells rupture due to excessive turgor pressure (internal plant water pressure), creating calloused corky spots on the undersides of leaves and sometimes on the stem. Ivy geraniums are especially sensitive.

In addition, certain minerals such as calcium, which move only through the water conducting xylem tissues, may not be translocated efficiently under excessive air humidities.

Carbon dioxide (CO₂) is essential for plant growth. Next to water it is the nutrient used in the greatest quantities by the plant. Plants will stop growing when the CO₂ concentration drops below 180 - 200 ppm. CO₂ can be supplemented to 1,000 ppm whenever daytime ventilation is reduced. Under very low light conditions supplemental CO₂ will have a minimal effect on plant growth. There may be an economic advantage to supplemental CO₂ at 350 - 400 ppm during periods of ventilation as canopy CO₂ levels can drop to 200 - 250 ppm when the greenhouse is fully vented. CO₂ burners can be placed overhead but the best location is to inject CO₂ at the crop level. It is highly desirable to control CO₂ levels with an automatic controller. Utilization of a time clock system does not provide precise control for optimum production. Some sensitive species may be damaged by CO₂ levels above 2,000 ppm. Humans should not work in levels exceeding 5,000 ppm.



POLLUTION

Pollution of soil, air, or water is an occasional cause of greenhouse plant disorders. Symptoms can be confused with those produced by plant pathogens. Air pollutants can harm plants, even when levels are so low that no threat to human health exists. Some of the pollutants which may cause problems are sulphur dioxide, ozone, PANs (peroxyacyl nitrates), carbon monoxide, and ethylene.

Small amounts of ozone can be produced from metal Halide and VHO florescent lights. Ordinarily this will not be a problem unless the growing structure has a low air exchange rate and lights are placed close to the foliage. Some brown flecking due to ozone may appear on tender bedding plant seedlings grown close to VHO fluorescent lights.

Carbon monoxide (CO) injury can occur when improperly installed oil or gas heaters are used. CO is colorless and odorless and is a severe health risk to humans.

Ethylene damage can be associated with incomplete combustion of propane or natural gas, or an excess of senescing vegetation. Operation of gasoline engines such as those found on some sprayers in greenhouses can produce injurious levels of both carbon monoxide and ethylene. Symptoms vary from burning of flowers and foliage to twisted, deformed or 'blind' growth. Many plants, orchids and ferns in particular, are sensitive to very small amounts of ethylene in the air. This gas is released when gasoline or oil is burned; it is also pro-

duced by plant tissues, such as ripe apples. Ethylene injury symptoms include leaves bending down at the stems, the yellowing and dropping of older leaves and slowed growth. In addition, blooms develop abnormally on flowering plants, or buds fall without opening.

A few crops, such as calathea, cordyline, dracaena, freesias, gerberas, gladioli, lilies, maranta, tulips, and zebrina, are sensitive to fluorides which are sometimes found in water supplies, certain fertilizers, and soil aggregates (e.g. some perlites). Avoid using high fluoride 0-46-0 (superphosphate) in media mixes. Calcium has been utilized to tie up fluorides.

Cleaning agents can produce fumes harmful to plants. This is particularly true of harsh chemicals used to clean floors or carpets. Fumes from commercial strength ammonia can blacken foliage and cause plant death. Other symptoms produced by exposure to toxic fumes include loss of foliage or curled leaves.

Plants installed near indoor pools can be damaged by chlorine that escapes into the air. Symptoms include bleaching of leaves and dying of plant tissues. Heavy tobacco smoke can harm plants by settling on leaf surfaces and blocking the pores used for gas exchange. Even concentrated fumes from paint or varnish will injure plants. Proper ventilation usually prevents harmful gases from reaching toxic levels.

Wood treated with creosote or pentachlorophenol should not be used in containers or around planting areas. Fumes from these wood preservatives can injure or kill plants. Early symptoms are bleaching of foliage and yellowing along leaf edges. Wood treated with copper or zinc naphthanate (Cuprinol) can be used around plants.

PESTICIDE INJURY TO CROPS

Given the right circumstances, almost any pesticide could injure any plant. Greenhouse pesticides are formulated to be as safe as possible to target crops, but injury to certain varieties or species may occur.

Spray injury can occur as marginal or complete leaf burning, leaf spots, flower spots, or distorted growth. Damage from drench materials may also produce root death, resulting in sudden wilting, and sometimes the death of part or all of the plant.

Misuse can be a cause of pesticide damage to plants. Some common causes are overapplication (too much chemical or too frequent); application to wet foliage (especially with fumigants); improper timing; and application to nonregistered crops.

The following precautions can minimize pesticide injury problems:

1. **READ THE LABEL** - be sure of the proper use, application rates, and methods of applying the product. Labels often specify varieties and species that may be harmed.

2. **CHECK THE FORMULATION** - the specific formulation of a pesticide as dusts, wettable powders, emulsifiable concentrates, etc., can affect its safety to plants. If you use a new formulation of a familiar product, test it on a small group of plants first.



3. **TIMING** - the state of plant growth is an important consideration for a pesticide application. Young seedlings and flower parts are generally more susceptible to injury than are vegetative phases of growth.

4. **PLANT ENVIRONMENT** - plants may be more susceptible to pesticide injury when under stress. Injury may also occur when pesticides are applied to wet foliage. A good time to spray is often in the early morning or late afternoon. Pesticides should not be applied when temperatures exceed 77 - 86°F.

5. **TESTING** - before using a new material or mixture, or whenever a new pesticide is being used on a crop, it is a good idea to test it on a small number of plants. If no symptoms occur within a few days, it is likely safe for crop use.

MECHANICAL INJURY

Plants can be severely damaged through mishandling. Seedlings are particularly susceptible to injury during transplanting, so care must be taken to avoid stem and root damage.

Improper watering practices such as too much pressure, or volume, and the application of excessively cold water can be very damaging. Fans can cause damage if they cause a lot of whipping about and desiccation of foliage.

Plants are usually capable of recovering from some degree of mechanical injury, however, it may serve as a starting point for further problems including infections. By using common sense in avoiding injuries, it is possible to prevent a lot of further problems and expense.

SECTION 8 - REVIEW QUESTIONS

The Greenhouse Environment

1. Which are abiotic disorders?
- a. fungal diseases
 - b. pollution injury
 - c. pesticide injury
 - d. all of these
2. Temperature controls can reduce or eliminate the need for plant growth regulators.
- _____ True _____ False
3. What does DIF equal?
- a. night temperature - day temperature
 - b. day temperature - night temperature
 - c. day temperature + night temperature
4. Night time temperatures higher than daytime temperatures result in taller plants.
- _____ True _____ False
5. Which conditions may be caused by insufficient light?
- a. poor coloration
 - b. leggy growth
 - c. slow development
 - d. all of these
6. What is acclimatization?
7. Which of these pest problems can be seriously affected by watering practices.
- a. fungus gnats
 - b. shore flies
 - c. spider mites
 - d. all of these
8. Which factor kills more plants than any other?
- a. insects
 - b. fungi
 - c. excess water
 - d. lack of water
9. Evidence of over-watering may take a month or more to appear after the soil is flooded.
- _____ True _____ False
10. Water softening and fluoridation can present problems to plants.
- _____ True _____ False
11. Which element is a primary macronutrient?
- a. calcium
 - b. copper
 - c. potassium
 - d. all of these
12. Soilless growing media is rich in micronutrients.
- _____ True _____ False

13. List two pest problems that may be aggravated by over application of nitrogen fertilizers.

a.

b.

14. What is the optimum soil pH range for most plants?

a. 4.5 to 5.5

b. 5.5 to 6.5

c. 6.5 to 7.5

d. 5.0 to 6.0

15. Sulphur is added to soil to increase the pH.

_____ True _____ False

16. Under low light conditions more fertilizer should be applied to keep plants healthy.

_____ True _____ False

17. Improperly installed heating systems can release gases that may damage plants.

_____ True _____ False

18. Which of these precautions can minimize pesticide injury problems?

a. proper application timing

b. no applications when temperatures exceed 77° - 86°F

c. testing a new mixture on a small number of plants

d. all of these

GREENHOUSE PESTS

Floricultural crops are attacked by many pests such as insects, mites, slugs, and snails. Although it is beyond the scope of this publication to deal with every pest on an individual basis, information on pest identification, type of damage, biology, and management strategies are given for a few of the more common pests. Your county Cooperative Extension office can help you identify these pests and recommend appropriate control measures. Apply chemicals only to crops for which their use is registered and stated on the label. Pesticides used inside greenhouses must be labelled specifically for greenhouse use. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

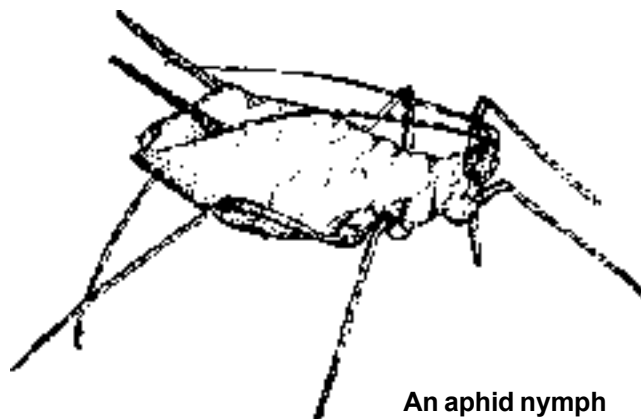
Growers with successful pest management programs know how to identify the common pests. They understand pest biology and they recognize the damage each pest can cause. Successful growers have their pest scouting and management strategies planned before crop production begins so they can identify and respond to an infestation quickly and effectively. They also keep abreast of new developments in pest management.

Crop production should start with a greenhouse as free of pests as possible. Incoming plant material should be inspected for pests or signs of pest damage. Infested plants should be refused or isolated for treatment.

Pests enter the greenhouse in a variety of ways. A weekly routine of scouting plant material throughout all growing areas for signs of pests and their damage can help detect infestations when they are still small and manageable. A 10X hand lens and insect traps, such as yellow sticky cards, are quite useful for weekly scouting.

APHIDS

Aphid species differ in size, coloration, and food preferences. They are all generally small (1 to 3 mm) and soft bodied. Within each species, individual aphids may or may not have wings.



An aphid nymph

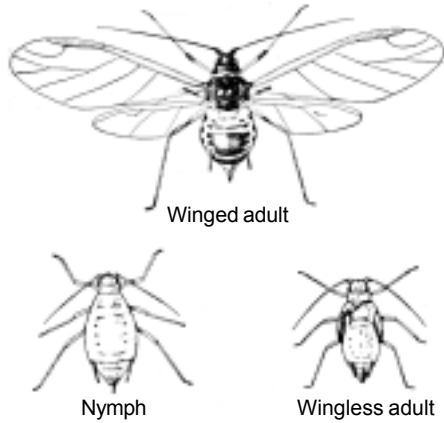
The most common greenhouse aphid species is the green peach aphid, *Myzus persicae*, although recently the melon aphid, *Aphis gossypii*, has increased in frequency. The green peach aphid attacks a wide variety of floral crops. Its color can vary from light green to rose. Melon aphids attack fewer plants including chrysanthemums and hibiscus. Their color may vary from light to very dark green. The chrysanthemum aphid, *Macrosiphoniella sunburn*, is only found on chrysanthemums and varies from dark red-brown to blackish-brown.

Correct identification is important for efficient aphid control. For example, pyrethroid insecticides may be very effective against chrysanthemum and melon aphids but not against green peach aphids.

Because color can vary within a species so much, color alone is not a reliable indicator for aphid identification. Positive species identification of most aphids requires a 10x hand lens or, preferably, a dissecting microscope. Your Cooperative Extension office can assist you with aphid identification.

Aphids are commonly encountered on many floral crops, and their presence alone can decrease the aesthetic value of a plant. These insects feed by inserting their mouth parts through plant tissue and removing plant sap. They tend to move to new host plants and actively search for soft, fresh plant tissue to feed upon. They also may be found feeding on buds, stems, and the lower surfaces of leaves. Their feeding can lead to plant stunt-

ing and deformities. Large numbers of aphids can remove enough nutrients from a plant to affect its vigor. Aphids excrete a sweet, sticky substance called honeydew. This secretion makes leaves shiny and sticky and can also serve as a food source for a fungus known as sooty mold. Aphids may devalue a crop with the white cast skins they leave



Green peach aphid, *Myzus persicae*.

behind as they molt from one life stage to another. Last but not least, aphids are responsible for the transmission of about 60 percent of all plant viruses on agricultural crops worldwide.

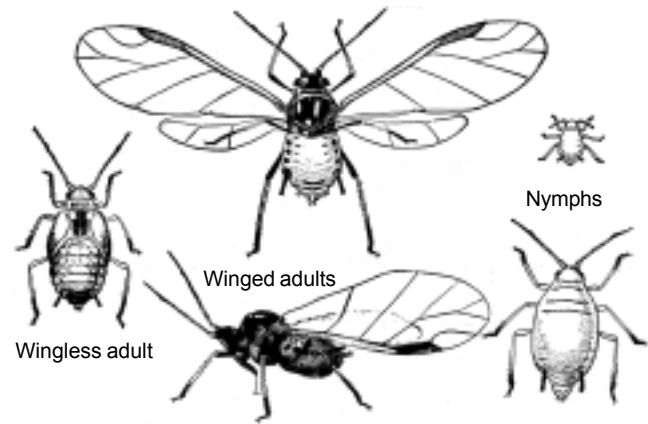
Aphids produce eggs only under short-day conditions in the fall. However, during most of the season aphids can give birth to live young in as few as 7 days without mating or egg production. This allows their populations to increase explosively.

Aphid management is much more successful when an infestation is detected and controlled early in a crop production cycle. Not only are aphids fewer, but phytotoxic damage to blossoms can be avoided. Therefore, a regular scouting and monitoring program is essential.

To successfully monitor aphid populations, it is necessary to inspect plant foliage at least once a week. Several plants on each bench throughout the greenhouse should be checked, particularly those varieties on which aphids seem to occur most frequently. Aphids can be spread on clothing, so plants located near walkways and doors should be included. Stems and lower surfaces of all leaves on each plant should be examined. A map of infested locations can help target areas to be sprayed and monitored.

The use of yellow sticky cards may provide an early warning of aphids in the greenhouse, particularly in the spring and summer. Winged aphids that are active outdoors during these times often invade the greenhouse.

Sanitation is a vital part of aphid control. Carefully inspect plant material brought into the growing areas; do not purchase infested plants or cuttings. Eliminate all weeds in or near the greenhouse; they can serve as a reservoir for migrating insects or for insects carried by ants.



Melon aphid, *Aphis gossypii*.

Applications of insecticidal soaps and highly refined horticultural oils can provide effective aphid control in some cases and should be evaluated by growers. These pesticides kill exclusively by contact. Soap kills primarily by disrupting insect membranes; oil kills primarily by suffocation. Neither material gives residual control, thus thorough coverage is crucial. It is very unlikely that aphids will develop resistance to these insecticides. The lack of resistance problems, coupled with low mammalian toxicity and compatibility with natural enemies, make these insecticides worth using. Label directions should be followed carefully to avoid plant damage.

Insecticide resistance can vary from greenhouse to greenhouse, and aphid strains with various levels of resistance to various chemicals may be introduced via incoming plant material. Therefore, it is difficult to generalize about the efficacy of a particular insecticide. By keeping careful records and scouting for aphid populations on a regular basis, growers can evaluate the efficacy of various chemicals under their own conditions.

To aid in evaluating insecticide efficacy, mark several aphid infested plants with flags or flagging tape, and record an estimate of the number of aphids on each. Several days after insecticides are applied, the number of surviving aphids should again be recorded. Examine plants carefully and frequently to determine if repeat applications are required. It may be necessary to treat an infestation as often as twice a week.

Insecticides that have systemic properties tend to be more effective than contact insecticides for green peach

aphid control, provided a sufficient amount of insecticide reaches the aphid feeding sites. Contact insecticides, however, may be very effective against other aphid species. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

Aphids have many natural enemies, including ladybird beetles, lacewings, flower flies, parasitic wasps such as *Aphidius matricariae*, and the predaceous midge *Aphidoletes aphidomyza*. Several of these are available from commercial insectaries (see Appendix B).

Aphidius and *Aphidoletes* should be used in combination; *Aphidoletes* provides rapid control of large populations and *Aphidius* provides control of low populations.

In addition, aphids are attacked by certain fungal diseases specific to insects. Researchers are investigating the use of these natural enemies for aphid control on greenhouse crops.



MITES

Two-spotted spider mites



The most commonly encountered greenhouse mite is the two-spotted spider mite. Mites are close relatives of insects and are sometimes referred to as red spiders, although they are not spiders at all. They are minute arthropods, and their largest life stage, the adult female, is less than a millimeter in size. The body of the adult female and of most immature stages is oval shaped, usually light yellow to green, with two large dark green spots on either side. All life stages have eight legs except

for the larval stage, which has six.

Spider mites attack virtually every florist crop, including most species of foliage plants. They cause severe chlorosis in attacked plants because the mites feed by “stabbing” cells with their piercing mouthparts and sucking out the juice. Spider mites remove chlorophyll from plant cells and reduce photosynthesis. Removal of chlorophyll produces the characteristic stippling or mottling of foliage and sometimes causes leaf drop.



Two-spotted spider mite, *Tetranychus urticae*.

When mite populations are low, they prefer to attack the lower surfaces of leaves. As the population increases they tend to move upward. In severe infestations, plants may be covered with the characteristic webbing of the mites, which is why they are referred to as spider mites.

Females lay up to 12 eggs per day on the underside of leaves, usually in the fine webbing that the mites constantly produce. One female is capable of laying more than 100 eggs during her lifetime. The eggs hatch in as few as 3 days, depending on temperature, and the newly hatched mites (called larvae) immediately begin feeding. After as few as 5 days, the mites pass through two nymphal stages and become adults. Females begin laying eggs within 1 to 3 days. Mating is not required.

Survival, development time, and reproduction are greatly influenced by environmental factors such as temperature, humidity, and host plant. Temperature is the most important factor. The development from egg to adult takes about 7 days at 81°F and about 20 days at 64°F. Rapid population increase can occur at temperatures warm. Spider mites do best under hot, dry conditions and develop faster on water-stressed plants.

Pesticide resistance can be a common problem in spider mite control. Unfortunately, many strains of mites exist, and many of these strains are resistant to certain acaricides (miticides). Currently there are a variety of effective acaricides, but unless these chemicals are used carefully and sparingly, it is only a matter of time before resistant strains evolve.

Weeds are an alternative food for spider mites and should be eliminated. A weekly routine plant inspection program is the best method for spider mite management. Plants should be scouted carefully for the first signs of leaf stippling caused by spider mites. Choose plants randomly from each bench and inspect the lower leaf surfaces for mites. Particular attention should be given to areas of the greenhouse where mites may be spread on the clothing of workers, such as along walkways and near entrances. Attention should also be focused on plant species or varieties that are particularly susceptible to mite infestations and in areas of the greenhouse that have a history of mite problems.

Efficient and regular scouting can lead to early detection. Application costs can be reduced and large area sprays can be avoided by spot spraying early infestations.

Infested plants should be marked and reinspected with a hand lens several days after treatment to evaluate the degree of control. Some miticides are not effective against mite eggs and repeat applications may be needed after 5 to 7 days. Thorough coverage of upper and lower leaf surfaces is critical for effective mite control. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

Care should be taken when using insecticides in areas where spider mites are present. Research indicates that carbaryl and certain pyrethroids and organophosphates may actually increase mite populations by increasing nitrogen levels in plant leaves.

Commercially available predatory mites can be effective alternatives to chemical treatment. Multiple releases are usually required and heavily infested areas may require a miticide treatment before predatory release. Predatory mite species include *Amblyseius californicus*, *A. cucumeris*, *A. fallacis* and *Phytoseiulus persimilis*. See Appendix B for more information.

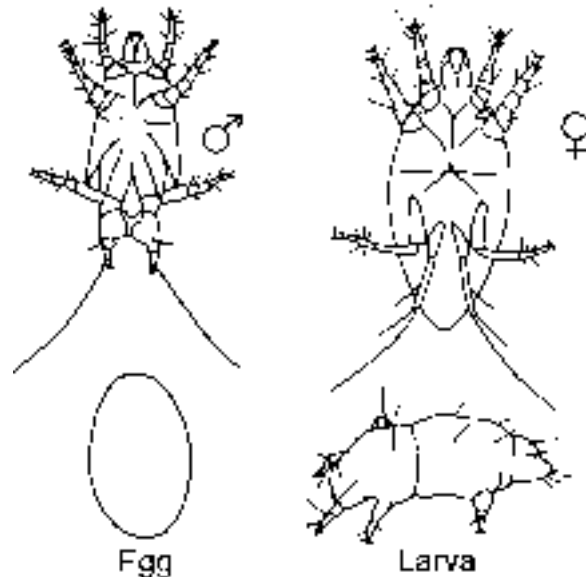
Cyclamen mites

These microscopic pests are rarely seen by growers. The damage they cause, however, can be extensive. The tiny mites hide in protected locations on the host plant, usually the buds and flowers. They are serious pests of a number of flowering and foliage plants, including cyclamen, African violet, ivy, snapdragon, chrysanthemum, begonia, and fittonia.

Cyclamen mites feed by piercing plant cells. It is possible that cyclamen mites also damage plants by injecting a toxin as they feed. The foliage expanding from infested buds often becomes so curled and distorted that

plants are unmarketable.

Unfortunately, their extremely small size makes it difficult to detect an infestation of cyclamen mites before damage occurs. The injury they cause can resemble thrips feeding damage, phytotoxicity, or physiological disorders. To avoid inappropriate control actions, plants that display curled distorted leaves should be carefully examined for the presence of cyclamen mites using a hand lens or, preferably, a dissecting microscope.



Cyclamen mite, *Phytanemus pallidus*.

Female cyclamen mites lay 1 to 3 eggs each day and a total of 12 to 16 during their lifetime. Mating is not required for egg production; unfertilized eggs develop into males and fertilized eggs develop into females. The eggs require 4 days to hatch at 70° F. The life cycle depends on temperature but is usually completed in 1 to 3 weeks.

Cyclamen mites may spread by air currents, by direct contact between plants, or by workers who handle infested plants. Chemical control is difficult because the mites are difficult to reach with acaricides. It is usually necessary to make two or three spray applications to achieve control. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

When feasible, the mites can be satisfactorily controlled by immersing infested plants in water heated to 110° F for 30 minutes. This is obviously not a practical means of control when large numbers of plants are involved, but it is a very useful way to eliminate isolated infestations. Certain species of predaceous mites may also be useful for biological control.

WHITEFLIES

Two species of whiteflies infest greenhouse plants. These are the greenhouse whitefly (GHWF, *Trialeurodes vaporariorum*) and the silverleaf whitefly (SWF, *Bemisia argentifolii*). SWF is becoming more common on poinsettias. It is not uncommon to find both whitefly species in the same greenhouse. SWF can be a very damaging greenhouse pest because of its broad host range, its resistance to insecticides, and its potential to vector a variety of plant virus diseases. Any grower experiencing unusual difficulty in controlling GHWF may unknowingly be battling this newer whitefly pest.

A hand lens or other magnifying device should be used to tell the difference between these two whiteflies. Observe the pupal stage to differentiate between them. The “skin,” or “pupal case,” left behind after the adult emerges can also be used for identification. No other life stages, except perhaps the adult, can be used for reliable identification.

The pupal stages of both species are commonly found on the underside of leaves. The pupal case of GHWF has parallel sides which are perpendicular to the leaf surface, giving the pupa a disk-shaped or cake-shaped appearance. SWF pupae appear more rounded, or dome-shaped, with no parallel sides. The GHWF pupae have a tiny fringe of setae around the rim of the pupa in top view. The SWF pupae have no fringe or setae around the edges. Both species may have several pairs of longer filaments arising from the top of the pupa. Usually these filaments are larger and more obvious on GHWF than on SWF, but this characteristic can vary depending on the host plant on which the insect developed. Therefore, the size of these filaments is not a reliable trait and should not be used for identification. These differences are not difficult to see with a 10X hand lens.

The adult GHWF is larger than the SWF and holds its wings fairly flat over its abdomen in a plane almost parallel to the leaf surface. The SWF adult is slightly more yellow in color and holds its wings roof-like against its abdomen, at approximately a 45-degree angle with the leaf surface. Wings are held tightly against the body. Although the appearance of the adults can be used to differentiate between these two species, the pupal stage must be used for confirmation.

Whitefly adults are small, white, fly-like insects. They are considered pests primarily because their presence detracts from the aesthetic value of greenhouse ornamentals. Feeding damage can cause plants to become chlorotic. Their honeydew excretions make leaves sticky



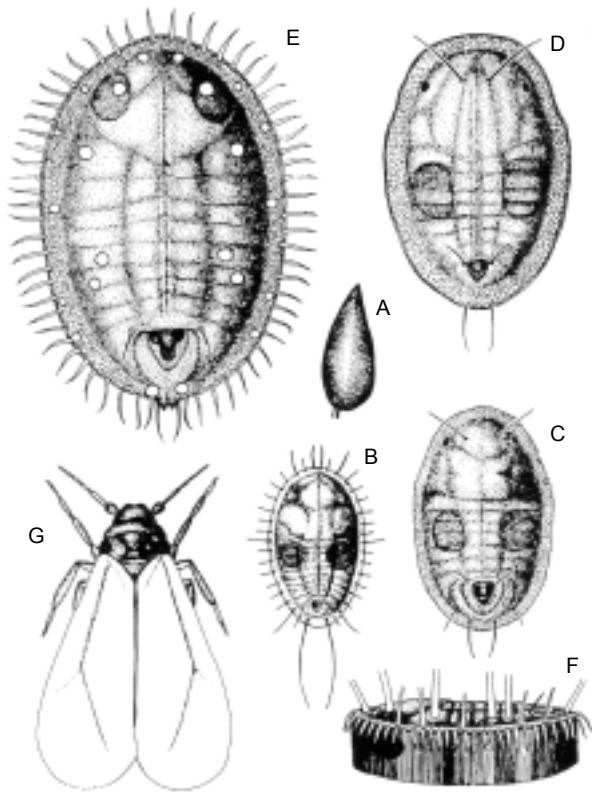
Adult whiteflies on citrus.

and shiny and serves as a food source for a grayish black sooty mold fungus, which interferes with photosynthesis and detracts from the plant's appearance.

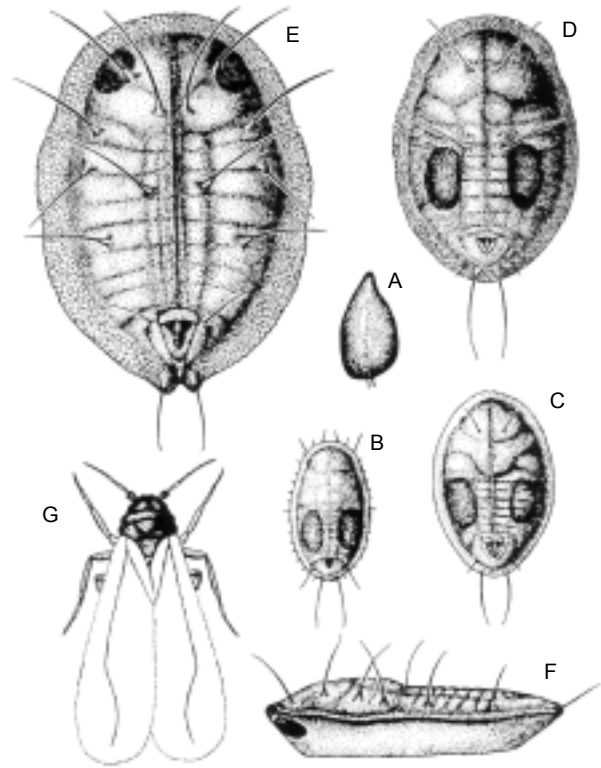
Based on our present knowledge, the life cycles of GHWF and SWF on poinsettia are generally similar. Eggs are deposited on the underside of leaves, sometimes in a crescent-shaped pattern. The spindle-shaped eggs are white when first laid and turn gray with time. At temperatures between 65 and 75°F, the eggs hatch in about 10 days for GHWF and 12 days for SWF. The tiny first nymphal stage, or crawler, hatches from the egg, crawls a few millimeters, and settles down to feed. It does not move from this spot until emerging as an adult. GHWF and SWF pass through three more nymphal stages before adult emergence. The pupal stage lasts 4 days for both species. The pupal stage is recognized by the red eye spots visible through the pupal case.

The entire life cycle of GHWF and SWF takes an average of 32 and 39 days, respectively, to develop from egg to adult on poinsettia. About 14 to 16 days of this time are spent as eggs or pupae which are tolerant of most labelled insecticides.

An adult female can begin laying eggs from 1 to 4 days after emergence. Mating is not necessary for egg production. A female may lay up to 200 eggs and live up to 1 month, but this depends greatly on the whitefly species and environmental conditions, such as



Greenhouse whitefly, *Trialeurodes vaporariorum*.
A, Egg. B-E, Nymphs. F, Pupa. G, Adult.



Silverleaf whitefly, *Bemisia argentifolii*.
A, Egg. B-E, Nymphs. F, Pupa. G, Adult.

temperature and host plant.

Infestations may build rapidly if not controlled early, and overlapping life stages are common. All whitefly life stages are found almost exclusively on the lower surface of leaves. Adult whiteflies are capable of flying at least 50 feet over a 24 hour period, although most seem to remain within 10 feet of their emergence site.

The following are guidelines for the management of whiteflies:

- Start the season with a clean greenhouse. If possible, eliminate all plants in the greenhouse, including weeds, for at least one week. All immature whiteflies will be removed when plants and weeds are removed, and any adults will die due to lack of food. If complete plant removal is not possible, eliminate all weeds and thoroughly inspect other plants in the greenhouse for the presence of immature or adult whiteflies. Consider discarding infested plants, or move them to another greenhouse for treatment.
- Prevent whiteflies from being introduced into the greenhouse. Examine cuttings and new stock on arrival for the presence of immature and adult whiteflies before adding them to the existing crop. Do not assume that plants are uninfested just because adult whiteflies are not seen; eggs and other immature stages may be

present. Inspect the underside of leaves for the presence of any life stage.

- Learn to recognize the first signs of a whitefly infestation. Train all greenhouse workers to recognize the early signs of an infestation, including the presence of immature stages on the underside of leaves. Spot check the leaf undersurface of several plants throughout the greenhouse weekly. Place yellow sticky cards just above the canopy and check them weekly to monitor whitefly adult populations. Use one card for every 1000 sq ft. Record whitefly numbers on the cards to monitor adult whitefly levels.
- Prevent the spread of whiteflies from one greenhouse range to another. Avoid wearing yellow, a color highly attractive to whiteflies. Consider using screens or other barriers to exclude or confine the pests.
- Learn which plants or cultivars are more susceptible to whitefly infestations. Group these plants together and monitor them carefully.
- Treat plants when the first signs of infestation are noticed; do not wait until clouds of adults can be flushed out of the plants. Roguing infested plants may delay the start of insecticidal sprays. To estimate the degree of control after an

insecticide treatment, prior to application locate several infested leaves, mark them with flagging tape or by another means, note the approximate number of immature whiteflies, and apply the insecticide. Several days after application, reevaluate the number of whiteflies on the marked leaves.

Although chemical control should be viewed as only one aspect of a total whitefly management program, it presently is an extremely important aspect. The eggs and most of the last nymphal stages of both the GHWF and the SWF are tolerant to most labelled insecticides; the adult and young immature stages are more susceptible. If an infestation contains all life stages, repeated insecticide applications are necessary to kill individuals that progress from the resistant stages to an insecticide-susceptible stage.

It is not always wise to judge the performance of an insecticide merely by the presence or absence of adult whiteflies after a single application. For example, with some insecticides all adult whiteflies could be killed on the day of the application, but individuals in the last nymphal stage would remain unaffected. A day or two later adults emerge from this unaffected stage, and the grower may wrongly assume that the insecticide was not effective. Several applications may be necessary for an accurate evaluation of a new insecticide.

Spray intervals depend, in part, on the residual effectiveness of each insecticide used, the length of time the whiteflies stay in an insecticide-tolerant life stage, and the size of the population. With a low to moderate infestation, non-systemic insecticides (foliar sprays and aerosols) should be applied every 5 to 7 days through the duration of one whitefly generation (21 to 30 days); aerosols should be applied somewhat more frequently.

Whiteflies occur on the underside of leaves, and most of the life stages are stationary and do not crawl over treated leaf surfaces. If sprays are directed against the immature stages, the insecticide must be applied so that it comes in contact with the insect. Thorough coverage and good canopy penetration are therefore critically important. Respacing plants may increase canopy penetration.

Registered systemic insecticides can be very effective, as long as a sufficient amount is translocated to sites at which whiteflies are feeding. Systemics are usually most effective when applied early in the crop's development. If necessary, applications should be repeated every 3 to 4 weeks.

A heavy whitefly infestation may call for systemic insecticide applications twice a week when this is permitted on the label. Such a heavy use of insecticide may damage plants and should therefore be reserved

only for extremely severe infestations. In some instances heavily infested plants should be thrown out. A grower who experiences a major whitefly problem should consider the circumstances that led to the problem to avoid repeating past mistakes.

The choice of which insecticide(s) to use depends on several factors. Always read and follow all label directions. An insecticide's phytotoxic potential may change with the crop or plant cultivar and with different environmental conditions. Also, whitefly populations can develop different levels of resistance to different chemicals from one greenhouse to another. A given insecticide may therefore provide effective control in one greenhouse but not in another. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

In summary, for effective whitefly control, maximize nonchemical control efforts and avoid unnecessary sprays. Treat at the first sign of an infestation and maintain control during early crop development to avoid problems later. When nonsystemic insecticides are used against a low or moderate infestation, apply every 5 to 7 days for the duration of one pest life cycle. To minimize pesticide resistance problems, avoid unnecessary sprays, avoid using insecticide tank mixes whenever possible, and rotate insecticides from different chemical classes every pest generation about every 1½ to 2 months. Monitor population levels weekly with yellow sticky cards and with crop inspections.

Biological control may be difficult for whitefly infestations. The parasitic wasp *Encarsia formosa* is not effective against silverleaf whitefly. A more efficient parasite, *Eretmocerus californicus* is difficult to establish. The coccinellid predator, *Delphastus pusillus* requires high prey density. For more information, see Appendix B.

SCALES AND MEALYBUGS

Scale insects and mealybugs are often difficult to control for several reasons. First, they are not easily detected because they do not always resemble an insect; often they are mistaken for plant parts. It is easy for them to go unnoticed, particularly at the onset of an infestation when their numbers are low. Second, a waxy secretion covers their bodies and protects them. It is difficult for insecticides to effectively penetrate this wax barrier. Third, they often occur on the underside of leaves, in leaf axils, or on roots. These cryptic habitats make detection difficult and provide protection from

sprays. Fourth, they can rapidly develop overlapping generations so that all life stages are present at a given time. Certain stages are not susceptible to insecticides, so repeated sprays are usually required at regular intervals to contact all the susceptible stages in the population.

Mealybugs and scales are related to aphids and whiteflies. They are all classed in the insect order Homoptera. These soft-bodied insects feed with stylet-like mouthparts. They insert their stylet into plant tissues and suck plant juices.

Early detection is very important for effective control. Greenhouse workers should be trained to recognize these pests and the early symptoms of damage. As soon as an infestation is detected, it is best to isolate the plant(s) if possible to prevent spreading the problem to uninfested plants. It may even be wise to discard a badly infested plant(s) rather than spend time and money on control attempts while risking further spread of the infestation.

If contact insecticides are used, they should be applied during the crawler stage of scales and mealybugs. Repeated applications are therefore necessary to contact the susceptible stages as they are produced. Spray intervals will depend on the residual effectiveness of the insecticide used, which may vary from 0 to 3 weeks. The inclusion of a spreader-sticker can improve coverage, penetration, and residual activity, although the risk of phytotoxicity may be increased. Good coverage is important for contact insecticides. Insecticidal oils and soaps can sometimes be effective, killing more life stages of these pests than many contact insecticides, but they provide no residual control. Again, thorough coverage is critical.

Systemic insecticides may kill actively feeding stages of scales and mealybugs, assuming adequate amounts of insecticide are translocated to the feeding site. Systemics will not kill the egg stage. An additional application may be necessary after 3 to 4 weeks if the residual activity of the systemic is inadequate after this time period in order to kill newly hatched insects. Fumigant insecticide formulations can be effective against mealybugs and should be applied at 10 to 14 day intervals. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

The potential for biological control of certain mealybug and scale pests, particularly in interior plantscape settings, continues to improve. Parasitoids and predators of these pests are commercially available. Information regarding the use of these natural enemies and integrated control of these pests can be obtained from commercial insectaries (see Appendix B).

Armored scales



Florida red scale, *Chrysomphalus aonidum*.

Armored scales are usually smaller than soft scales and their shapes vary between species, from a circular shape to an irregular shape resembling an oyster shell. Color may vary with life stage, sex, and species. Color ranges from shades of white to gray, red, brown, or green. These insects secrete a hard waxy shield over their bodies. This shield may separate from the body of armored scales, but it is inseparable from the body of soft scales.

Some common armored scale pests of greenhouses and interior plantscapes include oleander scale, Boisduval's scale, San Jose scale, Florida red scale, fern scale, greedy scale, purple scale, and cactus scale. Contact your local county Cooperative Extension office to assist you with identification of the common armored scales.

It is very important to detect the early stages of an armored scale infestation. Besides detecting the actual insects on the plants, knowing the symptoms of an infestation on the plant is very important. Armored scales can produce either yellow or brown spots or streaks on the leaves. They may also cause general yellowing of the foliage, poor growth, and encrustations of both stems and leaves. In very large populations they can cause twig dieback and even plant death. Unlike mealybugs and soft scales, armored scales do not produce honeydew.

Aspects of the biology and life cycle of armored scales can vary significantly between species; the following is a general description. The eggs are produced next to the female underneath her scale cover or shield. Some species give birth to living young. Females can produce 20 to 400 eggs. These hatch into crawlers, a stage that is susceptible to insecticides. The natural mortality of crawlers is high. They move a short distance from where they were hatched, find a suitable place to settle down and feed, and do not move again for the remainder of their lives. Females pass through two nymphal stages prior to adulthood. Males pass through two additional short pupal or resting stages. The tiny winged males do not live long. Females begin to produce

eggs after mating. The entire life cycle can take 60 to 120 days to complete, depending upon temperature and species. Several generations may occur during the year, and all life stages may be present at any one time.

Soft scales



Black scale, *Saissetia oleae*.

Soft scales can be fairly large (2 to 5 mm) and usually have a circular or oval shape. They are often shades of gray or brown, but some species appear black. The shield cannot be detached from soft scales. Common species include black scale, brown soft scale, hemispherical scale, and Niger scale.

By feeding on young tissue, soft scales cause distorted foliage, yellow leaves, and, in large populations, dieback of twigs and branches. Soft scales (and mealybugs) produce a sugary excrement called honeydew, which can fall onto leaves and make them shiny and sticky. Honeydew can support the growth of unsightly sooty mold. The presence of honeydew and sooty mold is a good indication of an infestation. Because ants are attracted to honeydew, their presence on the plants may also signal an infestation.

The general life cycle of soft scales is fairly similar to that of armored scales. Eggs or living young are produced beneath the female's body. Females can produce more than 1,000 eggs. Crawlers hatch after 1 to 3 weeks, crawl over the leaf and stem for several days eventually finding a suitable feeding site at which they remain through adulthood. Like armored scales, the crawler stage is the most sensitive to insecticides. Females pass through three or four immature stages before adulthood; males pass through four immature stages. Adult males emerge as tiny, delicate, winged insects which live only a few days. The life cycle of

females is roughly 40 to 80 days, depending, again, on factors such as host plant, temperature, and species. All life stages may be present at any one time.

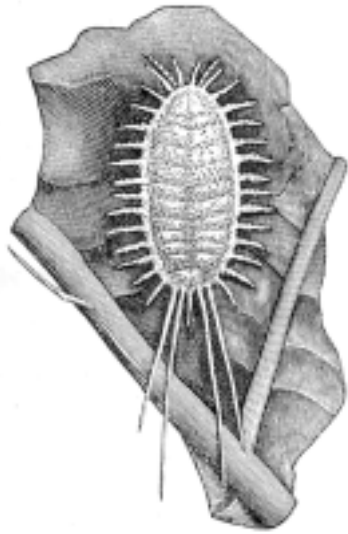
Mealybugs



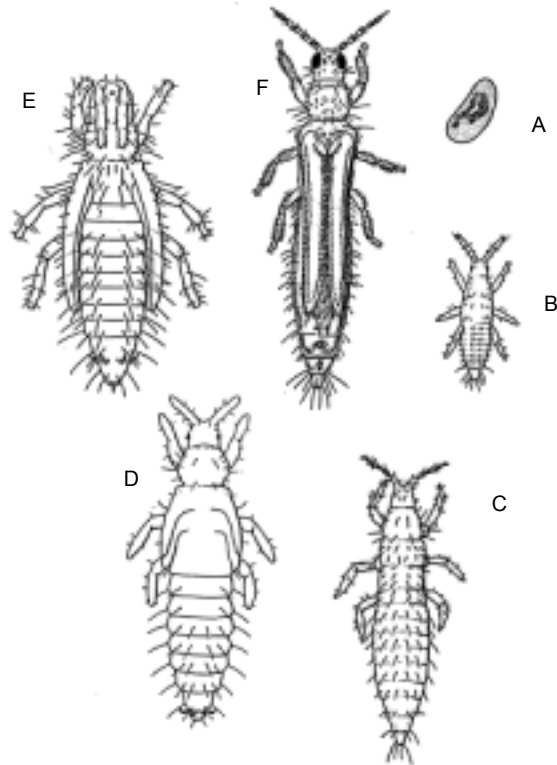
Mealybugs are small (1 to 8 mm long), soft bodied insects covered not by a hardened cover or shield but with a layer of white cottony wax. They can be found infesting all parts of a plant, including the roots. Their body shape is an elongated oval. Some produce short spinelike filaments along the margins of their bodies and posterior filaments may be quite long. Mealybug pests of greenhouse crops include the citrus mealybug, the obscure mealybug, and the longtailed mealybug.

Mealybug infestations can cause leaf distortion, particularly on new growth. As they feed, some species inject a toxin, which can produce necrotic spots, general yellowing, or leaf drop. Mealybugs produce honeydew which can support the growth of sooty mold. Their production of a white cottony wax and their very presence on leaf axils or underside of leaves detract from the appearance of the plant. As with soft scales, ants are attracted to honeydew, and the presence of ants may signal a mealybug infestation.

Life cycles vary tremendously among different species but may be generalized as follows: Females produce from 300 to 600 eggs, usually in a white cottony covering called the ovisac. Some species give birth to live young. The eggs mature in the ovisac for approximately 2 weeks, then hatch into crawlers. The crawlers are the life stage most susceptible to insecticides. Although slow moving, all subsequent life stages of mealybugs are mobile, not stationary like scale insects and whiteflies. It is therefore easy for this pest to move from leaf to leaf or plant to plant and spread an infestation over many plants. Males are tiny, winged insects. Life cycles last from 30 to 70 days.



Longtailed mealybug, *Pseudococcus longispinus*.



**Western flower thrips, *Frankliniella occidentalis*.
A, Egg. B-C, Larvae. D, Prepupa. E, Pupa.
F, Adult.**

THRIPS

Several species of thrips can infest greenhouse floral crops, but the most severe pest in recent years has been the western flower thrips (WFT), *Frankliniella occidentalis*. This discussion will be confined to WFT.

WFT, previously found primarily west of the Rocky Mountains, are now common in greenhouses throughout the world. They have probably been spread on infested cuttings. WFT can be found year-round inside greenhouses in the Northeast as long as plants (including weeds) are available for food and temperatures are favorable. It is not known whether WFT can overwinter outdoors in this climate.

Some people identify WFT as any thrips that can not be controlled by insecticides and there may be some truth in this method of identification.

Thrips are tiny insects. Adults are 1 to 2 mm in length and have narrow bodies with fringed wings. Colors can vary from straw yellow to brown. It is not possible to accurately identify which thrips species is infesting a crop in the greenhouse, even with a hand lens. Minor differences in morphological structure are used to tell one species from another. Therefore, adult thrips must be inspected under a compound microscope to accurately determine the species. Contact your local county Cooperative Extension office to assist you with identification

WFT feed by piercing plant cells and sucking out the cell fluids. The collapse of plant cells caused by thrips feeding can result in deformed plant growth and

flowers. Damage on the surface of expanded leaves or petals appears as small silvery patches which display tiny greenish black fecal specks left by the thrips. WFT damage the appearance of African violets by spreading pollen over the flowers.

One of the most serious threats of a WFT infestation is the pest's ability to spread tomato spotted wilt virus. There is no cure for this disease, and one WFT adult can infect a plant after feeding on it for only 30 minutes. Because both the virus and the thrips have such a wide range of plant hosts (including weeds), it may be difficult to eradicate the virus once it is present in a greenhouse.

Control of western flower thrips is extremely difficult due to several biological characteristics of this species. Eggs are inserted into plant tissue and are thus protected from insecticides. The egg stage lasts from two and a half to four days. The eggs hatch into larvae, which usually remain protected inside flower buds or terminal foliage.

The insect passes through two larval stages, both of which feed in these protected areas. The first larval stage lasts 1 to 2 days, the second larval stage lasts 2 to 4 days. Toward the end of the second larval stage, the insect stops feeding and moves down into the soil or leaf litter to pupate.

The insect passes through a prepupal and pupal stage, during which no feeding and little movement occurs. The prepupal stage lasts 1 to 2 days, and the pupal stage lasts 1 to 3 days. While in the pupal stage in the soil, the insect is not exposed to insecticides directed at the foliage.

The adults can survive from 13 to 75 days and lay 40 to 250 eggs (depending on temperature and host plant). They are also primarily found feeding in protected areas of the plant such as flowers and terminal buds.

The pest's rapid development time (egg to adult in 7.5 to 13 days at fluctuating temperatures), rapid reproductive rate, and its presence in protected parts of the plant can allow an undetected infestation to quickly become a major problem. They fly readily, although they are not strong fliers, and may be carried on wind currents or clothing to greenhouses near an infestation. They can fly from a sprayed to an unsprayed area, or they can move into or out of a greenhouse through doors or vents. Effective chemical control is complicated by insecticide resistance. Resistance to certain organophosphate, carbamate, and synthetic pyrethroid insecticides has been documented in certain populations of WFT.

Weed control is critical to thrips control. Weeds, whether inside or outside the greenhouse, are a refuge for thrips (as well as tomato spotted wilt virus). Weeds should be eliminated inside the greenhouse and from the area immediately outside the greenhouse as far as is reasonably feasible, particularly near vents and doors. Weed barrier covered with coarse gravel can be used to maintain a weed-free zone around a greenhouse.

Early detection of a thrips infestation is critical because the symptoms of their feeding are often not noticed until after the damage has occurred. Also, an infestation is easier to control when it is small. Yellow sticky cards provide an easy way to detect the onset of an infestation. To monitor the movement of thrips, place yellow cards just above the crop canopy, about one per 2,000 square feet, as well as near doors and vents and over thrips-sensitive cultivars. Recent research has shown that blue sticky cards catch more thrips than yellow ones, but because other insect pests are also attracted to yellow cards, it may be more efficient to use yellow cards for general pest monitoring.

The number of thrips per card should be recorded and graphed weekly to monitor population levels and aid in control decisions. Although it is more efficient to use sticky cards to detect and monitor thrips, flowers can also be checked for thrips by tapping a blossom over a sheet of paper. Yellow and white flowers seem to be particularly attractive to thrips. Useful trap plants include the following petunia varieties: Summer Madness, Super Blue Magic and Calypso.

Although effective thrips management can be difficult, adequate control can be achieved by a combination of physical, cultural, and chemical measures. Prevention is the first step in a management program. It is easier to prevent an infestation than to manage an established one. Growers should avoid purchasing plant material infested with thrips. Research has shown that the use of fine screens (200 to 400 mesh) or barriers over vents can help prevent the movement of thrips into a greenhouse. Researchers are also examining the use of materials such as Visqueen to cover plants on greenhouse benches. Greenhouse workers should avoid wearing yellow or blue so that thrips are less likely to be spread on workers' clothing.

Adequate chemical control depends on the insecticide selected, the number and frequency of applications, the application method, the spray particle size, and pesticide rotation.

The addition of sugar to the spray mix may enhance thrips control. The sugar acts as a bait and draws thrips out onto the leaf surface. Unfortunately, results have been mixed. Sugar can also cause the development of sooty mold. Add sugar in the ratio of 1 pound to 100 gallons of warm water.

Several insecticide applications should be made at 5 day intervals to reduce a thrips infestation significantly. None of the recommended insecticides are effective with only one application. Research has shown that 5 day application intervals are more effective than 7 day intervals.

Ideally, insecticides should be applied with equipment that produces very small spray particles (less than 100 microns). Spray particles of this size are best because they penetrate deep into the protected areas of the plant where the thrips are found and provide the most efficient use of insecticide if coverage is thorough. Smoke or aerosol fog formulations of effective insecticides can also improve control.

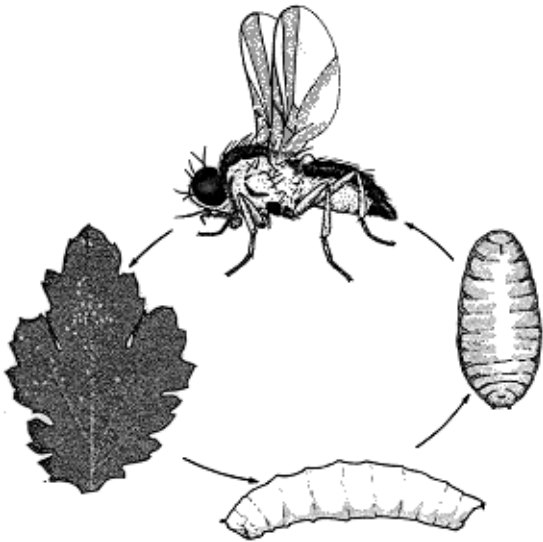
Rotating the use of insecticides from different chemical classes can be an effective way to delay the problem of insecticide resistance. It is best, however, to use an effective insecticide for more than one generation of a pest before rotating to another insecticide. Given the duration of the life cycle of WFT, an effective insecticide should be used for 2 to 3 weeks before switching to an insecticide from another class of chemicals. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

Research on biological control of WFT is being conducted in several laboratories worldwide. Current emphasis is on commercially available species of the

predaceous mites *Amblyseius cucumeris* and *A. barkeri*, a parasitic wasp, *Thripobius semiluteus*, and several species of minute pirate bugs in the genus *Orius*. Research with two fungal pathogens, *Metarhizium anisopliae* and *Beauveria bassiana*, may also lead to commercial formulations. See Appendix B for more information on biological control.

LEAFMINERS

Although a number of species of leafminers can attack florist crops, the most common are flies of the family Agromyzidae, and the most common and severe pest species is *Liriomyza trifolii*. These tiny flies (2mm)



A common leafminer, *Liriomyza trifolii*.

are yellow and black, resemble small fruit flies, and are strong fliers.

Females make small punctures on upper leaf surfaces with their ovipositors. Females and males feed on exuding plant juices from these punctures, and, in some of them, females will lay a single egg. The punctures turn white with time and give leaves a speckled appearance. On hatching, the larvae slash open surrounding cells using their sickle-like mouth hooks. As the cells are ruptured, the larvae move forward to destroy more cells. Continuing in this fashion, they leave winding trails, or mines, in the leaf. The mines increase in length and width as the insects grow. The appearance of the larval mines reduces the aesthetic value of the plant.

The duration of the life cycle depends on temperature and host plant. In general, eggs hatch in 4 or 5 days. The larvae feed within the leaf for 4 to 6 days, molting

twice. Third instar larvae usually chew a small slit in the lower leaf surface and drop to the soil or onto lower leaves to pupate. The pupal stage can last from 35 days at 58° F to 9 days at 80° F.

The best initial defense against leafminers is to refuse to accept infested cuttings. Incoming plant material should be inspected for leaf stipples and active mines and held for several days to see if mines develop from leaf stipples. Yellow sticky cards can be used to detect adult activity and to monitor population levels.

Contact sprays to control adults should be repeated at 3 to 4 day intervals to kill those adults that continue to emerge from puparia during the 10 to 14 days following initial treatment. Systemic insecticides can be very effective against the larvae. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

Recent work on the biological control of leafminers has been successful on certain flower crops. Releases of parasitic wasps as well as nematodes that only attack insects have been successfully used under certain conditions.

CATERPILLARS

Caterpillars or “worms” are the immature or larval forms of butterflies and moths. Some of these insects are exceptionally large, and others, when young, are barely visible without magnification. Included within this diverse group are armyworms, cutworms, leaf tiers, leaf rollers, and loopers.

These insects cause damage only as larvae; the adults either do not feed or feed only on nectar. The larvae, however, more than compensate for the adults’ innocuous behavior. With their strong jaws, caterpillars consume large amounts of foliage, tender stems, and even whole flowers. When their feeding does not cause the total loss of small seedlings, they often leave ragged, unmarketable plants. The preference of some species, such as the beet armyworm, for tender bud and shoot tissue can produce continued pruning of a crop such as chrysanthemums and ruin its value for cut flowers.

Many of these pests cannot successfully overwinter in Maine. Greenhouse infestations occur only when infested stock is brought in. Other caterpillars do not usually persist in the greenhouse, but adults can be attracted by lights and fly in from outdoors to lay their eggs. This commonly occurs with cabbage loopers.



Because there are so many caterpillar species, it is difficult to generalize about their life cycles. Some species lay eggs on the plants; others lay eggs on the soil. Some caterpillars prefer to hide in the soil during daylight and emerge to feed only at night; others remain on the plants at all times; and still others fold leaves around themselves for protection. Some species change to adults (pupate) in soil; others pupate on the plant. The list of differences is long and proper identification of the pests before beginning a control program is necessary. Your Cooperative Extension office can assist you and advise you of the best control program.

A careful and routine scouting program is important for optimum pest control. Plants should be inspected for signs of leaf feeding. Screens placed over air inlets can exclude adult moths. Some caterpillars can be controlled by the biological control organism *Bacillus thuringiensis* (Bt) var. *kurstaki*. This bacterium is sold commercially under several trade names. Bt is an excellent first choice for controlling caterpillars because it is practically nontoxic to humans, insects or any other animal other than caterpillars, it does not affect beneficial insects, and it does not have adverse effects on the environment.

FUNGUS GNATS AND SHORE FLIES

Fungus gnat adults are small, slender black or dark brown flies about 1/8 inch long. The two wings are delicate and either smoky or clear. The many-segmented antennae are longer than the head. Legs are long and thin. Adults are weak flyers and may be found flying or running over soil surfaces or leaves.

The larva, which is the life stage that actually damages greenhouse plants, is legless and wormlike, with a white body and a distinct black head capsule. It is about 1/4 inch long during its final stages of development.

The fungus gnat may be confused with another small dark-bodied fly called the shore fly. Considered harmless, shore flies do not affect greenhouse crops in any way. They feed on algae growing on the soil surface and are favored by the same wet conditions that are attractive to fungus gnats. With both insects, large numbers of adults may be a nuisance.

Shore flies have more robust bodies than fungus gnats and their antennae are very short. Their most distinguishing characteristic, however, is the presence of five light-colored spots on each of their dark wings. Shore flies are also stronger, faster fliers than fungus gnats. In the larval stage, shore flies can be distinguished by the opaqueness of the body and the absence of a head capsule. Shore flies feed by means of a pair of small mouth hooks. They have a characteristic forked air tube at the posterior end of the body.

Fungus gnats are associated with the use of artificial soil mixes high in organic matter. These flies are attracted to damp locations where fungi flourish. Fungi are a major part of their diet, but the larvae do not limit their feeding to fungi. They are general feeders and can injure a number of flower crops grown in the greenhouse.



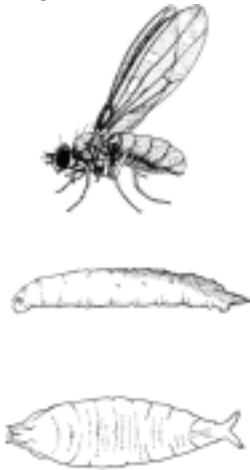
Common fungus gnat, *Lycoriella* sp. or *Bradysia* sp.

Fungus gnats can be especially destructive to seedlings and young plants as they are becoming established. Larvae may attack the roots of growing plants, resulting in retarded plant development. Under the stress of water deficiency, foliage may wilt. Leaf yellowing and leaf drop may result. Plant parts (such as stems) below the surface of the soil may also be invaded. Tunneling of the larvae may cause collapse of the stem. The larvae also may introduce bacterial or fungal pathogens as secondary invaders.

Poinsettia and geranium cuttings are particularly vulnerable to fungus gnat attack after they have been “stuck” in the growing medium. Formation of calluses is impeded or prevented, resulting in slow or poor root initiation.

In addition to direct injury to growing plants, fungus gnat adults or shore flies emerging from marketed potted plants can be a nuisance to the consumer in the retail shop, garden center, home, hospital, or other location.

Mated female fungus gnats deposit 75 to 200 eggs, singly or in clusters. The creamy white eggs are laid in cracks and crevices of the soil surface, and subsequent immature stages can be found within the top 1 inch of the soil surface. Eggs mature in 3 to 6 days, giving rise to white, transparent or slightly translucent, legless larvae. Larvae feed and develop for about 2 weeks at 72°F. Pupation occurs in the soil. After about 4 to 7 days, adults emerge from the pupal skin. They live about 1 week. The life cycle is very dependent on temperature; development time increases as temperatures decrease. Overlapping life stages are common.



Shore fly, *Scatella stagnalis*.

Good sanitation practices, such as removing discarded plant material and growing media and eliminating weeds growing beneath benches or elsewhere in the greenhouse, will minimize fungus gnat and shore fly problems. Care should be taken to eliminate standing pools of water on solid benches, on walks, and under benches. Badly infested containers of plants should be removed. Piles of plant debris should not be allowed to stand in the greenhouse. Do not over-water plants.

Fungus gnat and shore fly infestations can be detected and monitored with yellow sticky cards. Weekly inspections of yellow sticky cards can reveal the onset of an infestation, and continued recording of the number of adults per card per week can aid in evaluating the efficacy of control efforts.

To monitor adults, sticky cards should be placed horizontally, just above pot level. To monitor larvae, place a cube of potato tuber in direct contact with the surface of the potting mix; larvae will migrate upward into the tuber. Inspect tubers frequently.

Chemical applications can be aimed at the larvae or the adults, but the best long-term control targets the immature stages. Insecticidal drenches or soil surface sprays can be effective. Certain insecticides may not affect eggs or pupae, and repeated applications may be necessary before control is achieved. Also, if chemical applications are directed only against the larval stages, it may take some time before the number of adults is reduced. Adults can be effectively controlled with labeled aerosols or sprays. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

NEMATODES

Foliar nematodes

Leaf, or foliar, nematodes cause deformity of young plant growth, leaf spots, and defoliation. Spots are first visible on the lower leaf surface as yellowish or brownish areas, which eventually turn almost black. Lesions are small at first, but, with favorable temperature and moisture, they may spread until much of the leaf is destroyed. Unlike other nematodes, foliar nematodes do not persist in the soil in the absence of living host-crop tissues.

On chrysanthemum plants, the leaf veins retard the spread of the nematodes through the leaf, causing V-shaped or angular lesions. Infection begins on the lower leaves and progresses upwards. On Peperomia, gloxinia, African violet, and Elatior begonias, the lesions are less definite in outline and infection may occur on any leaf.

Foliar nematodes can be effectively controlled by foliar or soil applications of labelled pesticides. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific pesticide materials.

Root-knot nematodes

Nematode problems affecting plant root systems are quite rare, except in cases where soil is used as a component of the growing medium.

Root-knot nematodes may cause plants to appear stunted and unthrifty and to wilt on warm days. When

the root system is examined, galls are generally conspicuous and easily recognized. On some crops, root-knot nematodes may cause crop loss even when only a few galls are evident. The presence of root-knot nematodes may also increase the amount of plant injury from bacterial and fungal diseases, or they may reduce the resistance of plants to these diseases. Galled plants will not perform as well as healthy ones, but adequate moisture and fertility may mask the difference in vigor between nematode-infested and healthy plants. Six kinds of root-knot nematodes are recognized in the United States today. All have been identified on greenhouse crops, although only the northern root-knot nematode, *Meloidogyne hapla*, survives outdoors. Thus, the other five kinds are shipped into the state on plant material. The host ranges and host-parasite relationships may vary, but all have essentially the same life history.



Eggs of *Meloidogyne* are about twice as long as they are wide. They are usually found in a gelatinous mass about the posterior end of the female. Eggs hatch into small, slender worms (larvae) about 1/50 inch long. The larvae migrate through the soil seeking new roots, which they enter near the tip. Once inside the root, the nematode does not change position. Stimulated by the nematode's saliva, nearby root cells develop into giant cells, which provide nourishment to the nematode. Other cells adjacent to the nematode enlarge and increase in number, forming the familiar gall or knot. After the giant cells are functioning, the nematode goes through three molts before becoming an adult. A female can lay as many as 2,000 eggs during her life, but the average is probably 200 to 500.

The temperature of the soil is critical in the development of the nematode. It takes about 17 days at 85°F for females to develop from larvae to egg-laying adults, 21 to 30 days at 76°F, and 57 days at 60°F. Females fail to reach maturity at temperatures above 92°F or below 59°F.

Nematode spread within a greenhouse occurs when infested soil or plant debris is moved by people, water, or possibly wind. Migration of larvae through the soil is limited to a few feet per year. There is no known cure for root-knot nematodes. With continued care, infected bed or bench plants can produce a good crop. Discard infected plants carefully to prevent spreading the nematode. Preplanting treatments of steam or fumigants effectively eliminate nematodes from soil, but be sure that infested crop residues are thoroughly decomposed. In general, chemical treatment will control nematodes even after above ground symptoms are evident.

Other nematodes affecting roots

Other root-attacking nematodes can cause chlorosis, as well as stunted and unthrifty growth of above ground parts of the plant. Affected roots may be shortened, thickened, excessively branched to the point of becoming matted, and are occasionally killed.

SECTION 9 - REVIEW QUESTIONS

Greenhouse Pests

1. Pesticides used in greenhouses must be labeled specifically for greenhouse use.

_____ True _____ False

2. Which is the most common greenhouse aphid species?

- a. melon aphids *Aphis gossypii*
- b. green peach aphids *Myzus persicae*
- c. greenhouse aphid *Aphis greenypii*

3. Aphids are most reliably identified using color characteristics.

_____ True _____ False

4. How often must you inspect plant foliage to successfully monitor aphid populations?

- a. once a week
- b. once a month
- c. once every two weeks

5. Blue sticky cards provide early warning of aphids in greenhouses.

_____ True _____ False

6. Which methods should be used to control aphid problems?

- a. eliminate weeds in or near the greenhouse
- b. inspection of plant material brought into growing areas
- c. regular scouting and monitoring
- d. all of these

7. Aphid resistance to pesticide applications should be carefully evaluated.

_____ True _____ False

8. Two-spotted spider mites are the most commonly encountered mites in greenhouses.

_____ True _____ False

9. In severe infestations, spider mites cover plants with:

- a. honeydew
- b. frass
- c. webbing

10. High temperatures (over 80°F) allow mite populations to increase rapidly.

_____ True _____ False

11. Many strains of spider mites are resistant to miticides.

_____ True _____ False

12. Which is a microscopic pest that causes damage similar to thrips?

- a. spider mites
- b. cyclamen mites
- c. green peach aphids

13. Cyclamen mites can be controlled by immersing infested plants into water heated to 110°F for 30 minutes.

_____ True _____ False

14. Which life stage should be used to differentiate between greenhouse whitefly and silverleaf whitefly?

- a. nymphs
- b. pupae
- c. adults

15. Which insect(s) secrete honeydew?

- a. whiteflies
- b. aphids
- c. mealybugs
- d. all of these

16. Most whitefly growth stages are found on the upper sides of leaves.

_____ True _____ False

17. Yellow sticky cards can be used to monitor for the presence of whitefly adults.

_____ True _____ False

18. What part of the plant should be treated with pesticides to control whiteflies?

19. Whitefly resistance to pesticides can vary from one greenhouse to the next.

_____ True _____ False

20. Scales and mealybugs can be hard to control because:

- a. they are covered by waxy secretions
- b. they occur on leaf undersides, in leaf axils or on roots
- c. all life stages may be present at one time
- d. all of these

21. Insecticidal oils and soaps can kill all life stages of scales and mealy bugs.

_____ True _____ False

22. Armored scales do not produce honeydew.

_____ True _____ False

23. Which insect produces a white cottony wax?

- a. fern scale
- b. brown soft scale
- c. Niger scale
- d. mealybugs

24. Which disease is spread by thrips?

- a. leafspot
- b. tomato spotted wilt virus
- c. pythium

25. Thrips are hard to control because they live in protected areas e.g., inside flower and terminal foliage.

_____ True _____ False

26. Weed control is critical to thrips control.

_____ True _____ False

27. What color(s) should greenhouse workers avoid wearing to reduce the spread of thrips?

- a. blue
- b. green
- c. yellow

28. To help prevent resistance development, how long should you apply an effective insecticide to control thrips before switching to an insecticide from another class of chemicals?

- a. 1 to 2 weeks
- b. 2 to 3 weeks
- c. 3 to 4 weeks

29. The first signs of leafminer damage may give leaves a speckled appearance.

_____ True _____ False

30. The best initial defense against leafminers is to inspect incoming plant material for leaf stipples and active mines.

_____ True _____ False

31. Most caterpillars overwinter inside greenhouses and become a persistent problem.

_____ True _____ False

32. Which insect attacks plant roots and may introduce bacterial or fungal pathogens?

- a. fungus gnats
- b. shore flies
- c. beet armyworm
- d. none of these

33. Shorefly larvae have a distinctive blackhead capsule.

_____ True _____ False

34. What can be used to monitor for fungus gnat larvae?

35. Nematode problems are associated with the use of soil as a component in the growing medium.

_____ True _____ False

36. There is no known cure for root-knot nematodes.

_____ True _____ False

MANAGEMENT OF GREENHOUSE DISEASES

It is beyond the scope of this manual to deal with every crop disease that occurs in the greenhouse. Information is given on the identification, symptoms, life cycles, and management strategies for a few of the more common diseases. Your county Cooperative Extension office can help you to identify these and other diseases and recommend appropriate control measures. If you have identified a disease and are familiar with its biology and the available management strategies, then you are ready to decide what type of control tactics (biological, cultural or chemical) to apply.

The most successful disease control programs rely on strategies that are planned before crop production begins. Successful growers are familiar with the most common disease problems and can identify their symptoms. They also keep informed about new developments in disease management.

A greenhouse management disease program begins with crop production in a greenhouse that is as free of pathogens as possible. Weeds and plant debris should be eliminated at the beginning and throughout the production of the crop. Incoming plant material should be inspected for disease symptoms before placement into the production area. Diseased plants should be refused or isolated for pest control before placement into the production area. Whenever possible, plants should be purchased from reliable dealers who index their crops to ensure they are not infected with specific diseases. Culture indexing is performed by specialists and involves removing thin slices from the base of a cutting and placing the slices in a nutrient medium. Cultures of nutrient media showing any fungus or bacterial growth are discarded along with the cuttings from which the slices were removed.

Pathogenic disease outbreaks occur in a variety of ways. Disease propagules can be carried on air currents, through the movement of contaminated potting media or plant material, in water droplets splashed during watering, on infested pots or tools, or by insect vectors such as aphids, thrips, or whiteflies. Crop stress from

improper heating, ventilation or watering should be avoided because stress can make an otherwise healthy or resistant crop susceptible to disease.

A weekly routine of scouting plant material throughout all growing areas for symptoms or signs of disease (a 10x hand lens can be helpful for identification) can help detect problems when they are small and manageable. Control efforts should be implemented in a timely fashion.

This manual does not list specific chemical pesticides for controlling greenhouse diseases. For current recommendations see the latest version of the New England Floricultural Crop Pest Management and Growth Regulation Guide.

DAMPING-OFF

Damping-off occurs when seeds and seedlings are infected by soil-inhabiting fungi. In pre-emergence damping-off, the seed is killed before it germinates, or before the seedling emerges from the soil. This may be misdiagnosed as “poor seed”. Postemergence damping-off occurs when emerged seedlings are attacked near the soil line, or at the roots. The seedling wilts, the stem collapses and the plant dies. Infections near the soil line often result in a spindly stem known as “wire stem” that cannot support the top of the plant, causing it to topple.

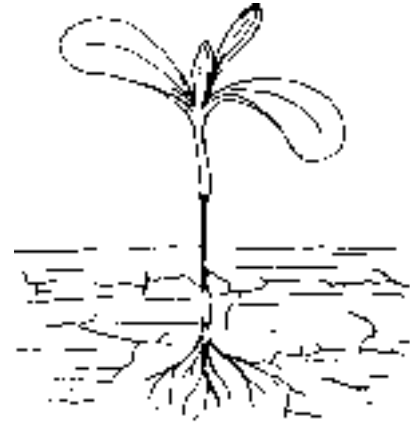
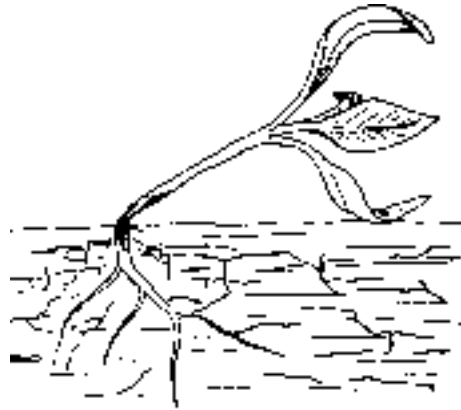
Rhizoctonia and *Pythium* are the most common causes of damping-off, although *Phytophthora*, *Fusarium*, *Botrytis* and *Sclerotinia* are occasionally responsible. *Rhizoctonia* causes pre-emergence damping-off, stem rot at the soil line, and wire stem. *Pythium* generally infects the seed, and the tips of rootlets.

When tender young tissue is infected, the plant usually dies from damping-off. Older plants may become stunted due to infection of the fine roots, or they may develop small stem lesions that could cause girdling.



↑ The root tips of young plants are frequently invaded by *Pythium* and the fungus usually progresses up the stem, eventually killing the young plant.

↓ Young plants may rot near the soil and fall over. Either *Rhizoctonia* or *Pythium* can cause this type of damping-off.



↑ Young plants may partially rot near the soil surface but they do not fall over. They remain stunted and eventually die. *Rhizoctonia* usually causes this type of damping off.

Chemical control requires using a registered product as a post-emergence soil drench to help prevent the disease from spreading.

Prevention

- Use pasteurized or sterilized media.
- Prevent any contamination of growing media.
- Use clean equipment.
- Use a porous, well-drained, seedling mix.
- Maintain adequate heat for germination.
- Do not sow seeds too densely or too deeply.
- Treat seeds or buy treated seeds.
- Avoid over watering.
- Avoid overhead watering if possible.
- Ensure pH and soluble salt levels are suitable to promote seedling growth.

LEAF SPOTS, FLOWER SPOTS AND BLIGHTS (GENERAL)

Leaf and flower spots can be caused by fungi, bacteria, viruses, or physiological disorders. Spots can vary in size from a pinpoint to lesions encompassing the en-

tire leaf (a blight). Most spots are tan to dark brown, and may be circular, angular or irregular in shape.

The more common fungi causing leaf spots are *Alternaria*, *Ascochyta*, *Cercospora*, *Gloeosporium*, *Helminthosporium*, *Phyllosticta*, *Ramularia*, and *Septoria*. Bacteria such as *Pseudomonas* and *Xanthomonas* may also cause leaf spots. The spots caused by bacteria are often sunken, water-soaked, and angular in outline. Tomato spotted wilt virus and impatiens necrotic spot virus can cause brown leaf spots. It is difficult to determine the cause of leaf spots by symptoms alone. However, proper identification is essential to select the best control measures. See the sections on bacterial and virus diseases for a discussion of these diseases. Note that while a fungicide will not cure an established leaf spot, it will protect plants from new fungal infections.

Prevention

- Use disease-free propagating material.
- Water carefully, keep foliage and flowers as dry as possible.
- Remove infected plant parts from the greenhouse and bury or remove from the greenhouse site.
- Provide good air circulation.

WILT DISEASES (GENERAL)

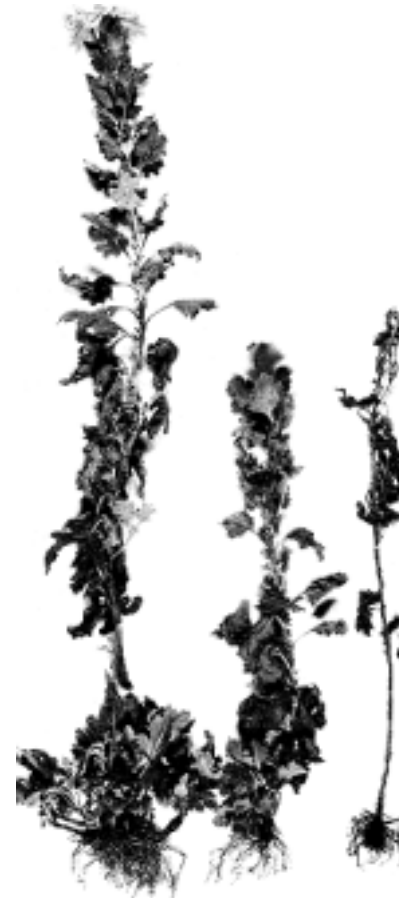
Wilt symptoms can develop slowly or suddenly; they may be temporary, as on hot days, or they may be permanent. Wilt occurs when the water flow to affected plant parts is stopped or slowed. Wilt can be caused by moisture stress which is usually temporary, except where water has been withheld for long periods. Wilt can also be caused from soil media that is too wet which results in an oxygen deficient root zone. Other causes of wilting are high soluble salt levels in the media, root rot organisms, and chewing insects.

There are several species of fungi and bacteria which cause diseases whose symptoms include plant wilt. When plants are infected by a wilt organism, they wilt because the organism and/or its by-products block the water conducting vessels. Symptoms include the wilting of part of a leaf, an entire leaf, one side of the plant, or the whole plant. Affected plants may be yellow, stunted, and have discolored vascular tissue in the stem.

The fungi most often involved in wilt diseases are *Fusarium oxysporum*, *Verticillium dahliae*, and *Verticillium albo-atrum*. The *Verticillium* fungi infect many types of ornamental plants, while special forms of *Fusarium oxysporum* infect specific host plants. For example, *Fusarium oxysporum* f.sp. *cyclaminis* infects only cyclamen, and *Fusarium oxysporum* f.sp. *dianthi* infects only carnations.

Verticillium is a fungus capable of infecting a wide variety of ornamental plants. Symptoms vary with the host. The most characteristic symptoms are one-sided development, wilting and yellowing of leaf margins progressing upward from the lowest leaves, lack of leaf and stem lesions, and normal appearing roots. These symptoms, however, can be quite different depending on the crop. The fungus causing the disease invades the soil and may persist there for many years. Initial infection usually occurs through normal roots, and the fungus grows upward through the water-conducting (xylem) tissues. Infected plants of some types (for example, chrysanthemums) are usually not killed by the fungus and, during periods of rapid vegetative growth, can appear to be without symptoms. Cuttings taken from diseased plants without symptoms can carry the fungus internally and introduce the disease to new areas.

Snapdragons can appear completely healthy until blossoms develop; then the foliage can suddenly wilt completely. The conductive tissues of some varieties can turn brown or purple, particularly the woody stem tissues.



Verticillium wilt of chrysanthemum. The plant at left shows typical killing of lower leaves of the older flower stalk from the base upward, and development of a number of apparently healthy basal shoots. The center plant shows similar symptoms plus stunting. The plant at right was killed before flowering.



Verticillium wilt of strawflower. The two short, wilted plants are shown 5 weeks after artificial infection in the greenhouse. The tall plant is healthy.

With chrysanthemums, there is usually a marginal wilting of the leaves, followed by chlorosis and eventually death. The brown leaves remain attached and hang down against the stem. These symptoms often begin on only one side of the plant and not until after flower buds have formed. Young, vigorous plants usually have no symptoms.

The buds on one or two branches of red-flowered greenhouse rose varieties may turn blue and fail to open; the leaves and the green stem tissues may become mottled, and when the stem is shaken, the leaves fall from the plant. Eventually the stem dies. Additional shoots can develop from basal buds and go through the same sequence, and, eventually, a shoot may remain healthy. Usually there is no vascular discoloration.

With semituberous rooted begonias, some yellowing of leaf margins can occur, but the most distinctive symptom is the development of an extremely shiny lower leaf surface.

The most important bacterial wilt pathogen in Connecticut is *Xanthomonas campestris*. Various forms (pathovars) of *Xanthomonas campestris* exist which attack specific hosts. For example, *Xanthomonas campestris* pv. *pelargonii* causes bacterial blight of Pelargonium species, and *Xanthomonas campestris* pv. *syngonii* causes bacterial blight of Syngonium. See the section on bacterial diseases for more information on *Xanthomonas* blight of geraniums. Wilt diseases may also be caused by three other bacteria, *Erwinia carotovora*, *Erwinia chrysanthemi*, and *Pseudomonas solanacearum*. They are usually serious only at temperatures above 27°C.

Bacteria require wounds or natural openings, usually on leaves and stems, to enter plants. Fungal wilt pathogens enter plants primarily through the roots. They do not require wounds. Both bacteria and fungi can be spread in propagative material, by water movement through soil, by soil movement, by equipment (especially cutting knives), by contaminated flats, and by splashing water. Wilt fungi can survive free in the soil for several years, whereas bacterial wilt pathogens generally survive for only one to six months in soil. Both have good survival rates in infected plant debris.

High temperatures and high relative humidity generally favor the wilt diseases. Conditions which contribute to plant stress will also increase disease severity. There are no effective fungicides or bactericides available for the control of wilt diseases. Infected plants must usually be rogued-out and destroyed.

Prevention

- Minimize heat stress by shading or ventilating.
- Avoid high salts caused by overfeeding and/or underwatering.
- Monitor the crop's E.C. Levels.
- Minimize soil pathogen contamination of crops by keeping hose ends and pots off the ground.
- Where possible, grow varieties that have been selected for resistance to wilt diseases.
- Use disease free propagating material.
- Use sterile or pasteurized growing media

ROOT ROTS

Most root rots are caused by the following fungi: *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Thielaviopsis*. Plants of all ages can be infected, and the degree of infection can vary from light to severe depending on environmental conditions and susceptibility of the plant.

These fungi are soil-borne. The presence of plant root exudates stimulates *Pythium* and *Phytophthora* spores to move toward and infect the roots. Infected plants have discolored roots that are reduced in number and lack healthy, white rootlets.



Root rot of *Ranunculus*, caused by *Pythium*. A healthy plant is shown on the right.

Environmental conditions play an important role in root rot diseases. Factors which stress plants can damage roots. These include over or under watering, too high or too low temperatures, high salts, and chemical damage. Secondary organisms that might not cause diseases on their own may then invade the injured tissue and cause further damage. Insects, such as fungus gnat larvae, can spread the fungi and provide an entry site through feeding wounds. Maintaining conditions that are favorable for plant growth and promoting overall plant health will reduce disease severity.

Root rot pathogens are common, naturally occurring organisms. Irrigation water from storage ponds that has been collected from run-off water may contain root rot pathogens, whereas water from municipal treatment systems, or deep wells is normally pathogen-free. Most natural soils contain a diverse population of microorganisms, including those that cause root rot. Artificial growing media such as perlite, vermiculite, and rockwool start off sterile and slowly build up low populations of microorganisms during the crop cycle. If a pathogenic organism is accidentally introduced into this sterile media, there are few naturally antagonistic fungi or bacteria to suppress it. This gives the pathogen the opportunity to spread. Naturally occurring media components, for example peat moss, may contain pathogenic fungi, such as *Pythium*.

Prevention

- Use pasteurized or sterile media.
- Use porous, well-drained media.
- Avoid watering with cold water.
- Don't overwater.
- Maintain optimum root temperatures.
- Maintain proper soil pH for the crop.
- Don't propagate from diseased plant material.
- Handle plants carefully and use proper sanitation during transplanting.
- Control fungus gnats (see Section 9).
- Clean tools, hoses, walkways, benches, pots, and tables between crops.

Pythium and *Phytophthora* Root Rots

The cortex, the outer covering of roots infected with *Pythium* or *Phytophthora* is usually rotted, and slides off easily leaving the string-like vascular bundles behind. Roots are generally soft, mushy, and various shades of brown. Above-ground symptoms of infected plants include stunting, wilting, and yellowing as a result of nutri-



Stem rot caused by *Rhizoctonia solani* on an unrooted poinsettia cutting.



Above, stems from young poinsettia plants showing *Rhizoctonia* stem-rot lesions, and roots rotted off by *Thielviopsis*. Below, poinsettia stems with swollen and cracked bark caused by *Thielviopsis* infection.



ent deficiencies occurring from root loss. Most ornamental crops are susceptible to at least one of these fungi. High soil moisture favors *Pythium* and *Phytophthora*.

Rhizoctonia Root Rot

Infected roots are often reddish-brown, with a dry rot. Cool, moderately wet conditions encourage *Rhizoctonia*. This disease can cause infections of the stem as well as the roots. Above ground symptoms include stunting and yellowing.

Thielaviopsis Root Rot

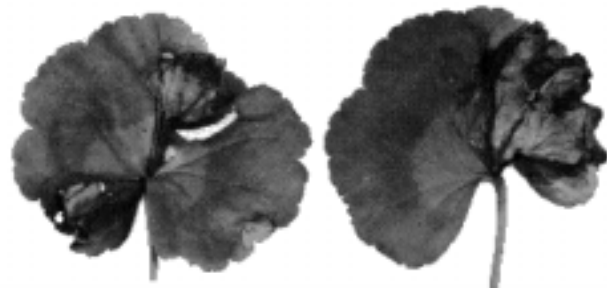
Thielaviopsis causes black root rot on cyclamen, fuchsias, geraniums, impatiens, kalanchoes, pansies, petunias, poinsettias, primulas and other crops. Infected roots may have black lesions covering all or part of the root. This can be observed after the growing mix has been washed off with water. Above ground plant parts are stunted and have yellow leaves.

Wet soils, and neutral or alkaline pH levels favor black root rot. Plant stress arising from factors such as high soluble salts or excessive fungicide applications can also promote disease development. Prevention is the best method of controlling black root rot.

BOTRYTIS (GREY MOLD)

Botrytis infects the immature, senescent, and wounded tissues of many crops. It can also infect healthy tissue if conditions are well suited to the fungus, or if a piece of infected plant material such as a flower petal comes in contact with healthy leaves or stems. Optimum conditions for *Botrytis* growth are 18 - 28°C, and high humidity or free moisture. Free moisture occurs when plant tissue temperature drops and relative humidity is high. The temperature drop may be only one or two degrees, but if the dewpoint is reached, water condenses on plant parts. It occurs most often just after sunset when plant tissue temperatures drop more rapidly than air temperatures, or in the morning when air temperatures rise quickly. If the greenhouse environmental controls are not quick enough to respond to these changes, *Botrytis* can become established.

Infected tissue first appears as tan or brown water-soaked areas that may become grey upon drying out. Infected flower petals usually show small water-soaked areas which enlarge rapidly and then turn brown or black. The characteristic signs of *Botrytis* are the fuzzy gray spore masses that develop on infected tissue.



Above, geranium leaves with lesions caused by Botrytis blight. Such lesions develop where infected petals fall on healthy leaves. Below, blighted terminals of rose plants caused by infection with botrytis blight.



Botrytis is almost always present in greenhouses. New infections occur when conditions are optimum for spore spread and germination. Spores are spread by air currents and splashing water. *Botrytis* overwinters in soil and plant debris.

Prevention

- Ensure adequate air circulation through the plants. The disease will not be controlled by chemicals until the circulation problem is corrected.
- Keep relative humidity below 90% by heating or venting of moist air.
- Don't overcrowd plants.
- Minimize dripping of water onto plants from roof condensation or overhead sprinklers.
- Remove dead or diseased plant material from the green house site.

- Don't leave large stubs or joints on stock plants after taking cuttings.
- Remove senescent flowers and leaves before they drop onto other plant parts.

POWDERY MILDEW

Powdery mildew is sometimes confused with spray residue because it causes whitish-grey patches of fungal growth on the upper leaf surface. Lower leaf surfaces, flowers, and stems may also be infected. Many ornamental crops are infected by powdery mildew fungi. It causes serious economic losses through loss of plant vigor, a reduction in the number of blooms, and reduced aesthetic appeal.

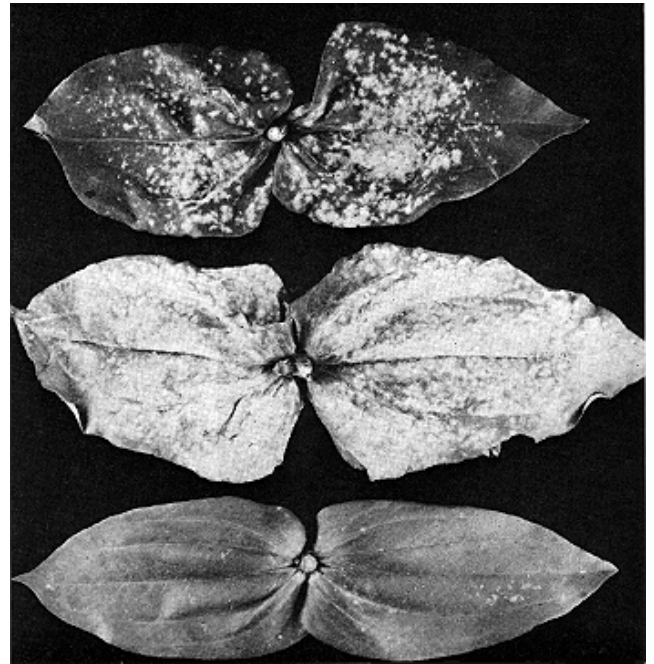
Powdery mildews can occur in a warm, dry environment, or in a cool to warm, humid environment. Spores will release, germinate, and cause infection without a film of water on the plant surface. A fairly high relative humidity is all that is required for the initial infection. Once the plant is infected, the fungus can continue to grow regardless of the relative humidity. Spores of the powdery mildew fungus are spread by air movement. The fungus grows on the leaf surface but obtains nutrients from the plant by penetrating into leaf cells with specialized structures called haustoria. Dead mildew can remain visible on the plant surface for many days so check the efficacy of control by examining new growth for signs of fresh mildew outbreaks.

Prevention

- Eliminate weeds in and around the outside perimeter of the greenhouse. Some may be hosts for powdery mildew.
- Carefully monitor humidity levels to avoid high humidities or large swings in humidity.
- Maintain optimum plant growing temperatures.

DOWNY MILDEW

Roses, snapdragons, cineraria, and violas may be infected by downy mildew during periods of cool temperatures and high humidity. The fungus, which is related to *Pythium* and *Phytophthora*, actually grows inside the plant tissue. It may produce reddish-purple leaf splotches on the top surface of the leaf. When humidity



Two zinnia leaves affected by powdery mildew, top and center; healthy leaf below. The center leaf is severely infected; individual infections can be distinguished on the top leaf.

levels are high, a mauve-grey, felt-like mat appears, usually on the bottom surface of the leaf. Many spores are present in the mat and can be spread from plant to plant via air movement. The fungus carries over to new crops on dead plant material or through persistence in the soil.

Prevention

- Monitor for infections.
- Control humidity to prevent condensation on the crop.
- Clean up all crop debris at the end of the season and remove from the greenhouse site.
- Alternate crops, if possible.

RUSTS

Rust diseases appear initially as small, yellow swellings. These grow and produce rusty blisters which will contain either white, yellow, orange, brown or black spores. The pustules are often on the underside of the leaves, but may occur on the top surface and/or stems depending on the rust species and the stage in the life cycle. The leaf surface directly above the pustule is fre-

quently yellow. Many rusts have complex life cycles, requiring two different plant species as hosts. Some rusts can cause systemic infections in their hosts so the plant may be infected but not show any symptoms.

Spores are spread by moving air currents or splashing water or moving air, and require wet conditions for infection. There are several important rust diseases of greenhouse ornamentals, notably on asters, carnations, chrysanthemums, fuchsias, geraniums, and snapdragons.

Rusts are obligate pathogens and usually are host specific, although several species from the same family may be infected.

Prevention

- Inspect new plant materials carefully before bringing them into the greenhouse.
- Avoid wetting foliage.
- Remove and destroy infected plant parts where possible.

BACTERIAL DISEASES

Bacterial diseases are not as common as fungal diseases, but they can be very destructive and are difficult to control in the greenhouse. It is not easy to visually differentiate between bacterial and fungal infections, so an early accurate diagnosis is essential in choosing the correct management technique.

Bacteria can cause leaf spots, wilts, rots, and blights. Bacterial leaf spots usually appear as circular or angular water soaked areas. They may be light green or yellow, becoming brown or black as the disease progresses. Sometimes a halo can be observed around the center of the lesion when held to the light. Some leaf spots may exude ooze of various colors, and the spots may eventually coalesce. The veins leading from these lesions may be discolored as bacteria spread through the vascular system.

On above-ground plant parts, bacteria require free moisture for infection, which can be provided by condensation, overhead watering or splashing water. Bacteria are spread during pruning, propagating, and by splashing water. Pruning and propagating are particularly effective means of spreading disease, as bacteria require wounds or natural openings to enter the plant. Begonias, chrysanthemums, geraniums, hibiscus and foliage plants all have recognized bacterial diseases. Most fungicides have no effect on bacterial diseases. Prevention is the only effective control of bacterial diseases.



Geranium leaf affected by bacterial leaf spot.

Prevention

- Use disease-free propagative stock.
- Avoid wetting foliage.
- Minimize plant wounding.
- Space plants to provide good air circulation.
- Disinfect cutting tools and propagating areas.

Xanthomonas Blight of Geraniums

Bacterial blight caused by *Xanthomonas campestris* pv *pelargonii* is the single most important disease of geraniums. This disease becomes systemic in the plant and can quickly kill it. Bacterial blight may occur wherever geraniums are grown and is a continual threat to production.

Xanthomonas bacterial blight infects all varieties of zonal, ivy, seedling, florist, and regal geraniums. Ivy leaf geraniums (*Pelargonium peltatum*) are especially susceptible while Lady and Martha Washington types (*P. domesticum*), and specialty types (*P. acerfolium*, *P. 'Toronto'*, *P. tomentosum*, and *P. scarboroviae*) have a tolerance to the disease but can act as carriers.

Xanthomonas can survive on the leaves or wounded stems of several ornamental species such as tuberous begonia, chrysanthemum, coleus, fuschia, impatiens, lantana, verbena and vinca.

Steps to Early Detection of Bacterial Blight

Routinely check geraniums for symptoms and be very suspicious of any signs of wilting. Symptoms develop very slowly when the temperature is below 21°C.

- 1) Look for dark brown, sunken leaf spots 1.5 - 3 mm in diameter. Notice: Not all geranium varieties will show leaf spot symptoms.



Geranium cuttings affected by bacterial stem rot caused by *Xanthomonas pelargonii*. Some of the cuttings in this lot had been attacked by *Pythium* also, as sometimes occurs.



Geranium plant affected by bacterial stem rot. Tissues of stem and upper roots are blackened.

- 2) Look for V-shaped yellow wedges that form at the leaf margin and taper down to the base of the leaf. The wedge is usually bound by leaf veins on both sides. Botrytis can cause similar symptoms, but these infections usually do not taper down to the leaf base and are not restricted by leaf veins.
- 3) Cut the leaf petiole at the base and the stem in half to check for a dark discoloration in the vascular tissue.

There is no effective chemical control for geranium bacterial blight. Fungicides will not control a bacterial disease. Fixed copper may suppress disease spread but will have no effect on plants that are already infected with bacteria that spread systemically throughout the plant.

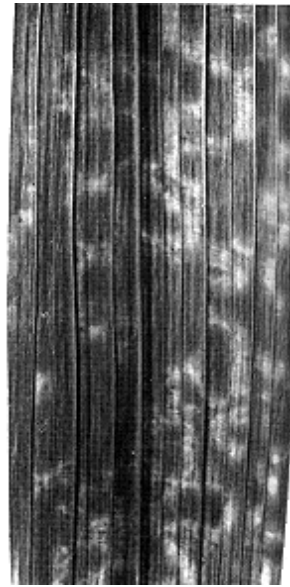
Strict sanitation combined with the exclusive use of culture virus indexed (CVI) stock from reputable propagators is the only way to minimize losses from bacterial blight.

Avoid, as much as possible, splashing the plants during watering. Bacterial blight is readily disseminated by splashing water which spreads bacteria to leaf surfaces where infection occurs through the leaf stomata. Pesticide spraying for insects or other diseases that cause water splashing that may spread bacterial blight. Bacterial blight is readily spread by the use of common rooting beds and water films including capillary mats, ebb and flow benches, and trough irrigation systems.

Sanitizing the Greenhouse After a Bacterial Blight Outbreak

- 1) Discard all geraniums at the end of the season and wash down all bench surfaces with bleach, Formalin(formaldehyde, 1:40 dilution) or quaternary ammonium compounds (follow label directions). *Do not mix these compounds as hazardous gases can result.*
- 2) Purchase CVI disease-free plants each year and use a sterile, soilless mix.
- 3) Do not save outdoor-grown geranium plants for use as stock plants.
- 4) Discard all plants returned by customers and do not allow such plants to be brought into the growing areas.
- 5) Break off branches from stock plants for propagation rather than using cutting knives.

- 6) Avoid splashing when watering.
- 7) Immediately discard all plants found to be infected, wash down benches and disinfect all tools, flats, pots, etc., used to handle the plant.
- 8) Keep hoses off the ground.
- 9) Limit entry into stock and production areas.
- 10) Avoid plant-to-plant contact, common water films (capillary mats, ebb and flow benches, trough irrigation systems) and overhead watering particularly for stock plants.
- 11) Keep exact records of plant sources when taking cuttings so that batches can be traced back to an infected source and all infected material can be destroyed.
- 12) Dispose of infected plants away from the green house site. *Do not compost diseased plant material.*
- 13) Start work from the cleanest production area to the dirtiest, i.e. stock plants to propagation area to production area and ending at the cull pile. Do not work in the reverse direction from the cull pile.



Necrotic ring spot on gladiolus leaf infected with the tobacco ring-spot virus.

Tomato Spotted Wilt Virus/Impatiens Necrotic Spot Virus

The two strains of tomato spotted wilt virus (impatiens and lettuce) are now recognized as two separate diseases. The impatiens strain has been renamed ‘impatiens necrotic spot virus’ (INSV) while the lettuce strain has retained the original name ‘tomato spotted wilt virus’ (TSWV). INSV infects floriculture crops more frequently than TSWV.

Both these viruses cause stunting, leaf distortion, mosaic mottling of leaves, leaf vein clearing, necrotic areas on leaves, wavy lines on foliage, chlorotic spots, concentric rings on foliage or flowers, and stem necrosis. The necrotic lesions on leaves can easily be mistaken for pesticide damage. The symptoms vary depending on host age, host species, cultivar, the level of nutrition, temperature, and the virus strain.

Method of Spread

Both western flower thrips (*Frankliniella occidentalis*) and the onion thrips (*Thrips tabaci*) can spread TSWV/INSV. The western flower thrips is the most dangerous vector due to its ability to develop insecticide resistance faster than other thrips species.

Thrips are small (2 - 3 mm long), narrow, light to dark brown insects with long fringed wings. They are not strong fliers but due to their fringed wings and small size can be carried long distances by wind and move from outside into greenhouses through open doors and vents. Thrips must feed on infected tissue while they

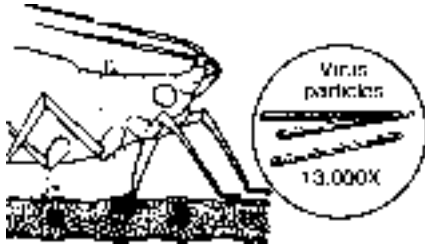
VIRAL DISEASES

Viral diseases are usually first observed as color changes, spots, streaks, rings, and mottling on leaves. Leaves may also exhibit distorted growth. Flower symptoms include dwarfing, streaking, deformities, and color changes. Virus infected plants may be stunted, particularly if infected when young.

Symptoms can be masked, and plants may appear to grow out of the infection under certain conditions, such as warmer temperatures. However, once a plant is infected with a virus, it remains so indefinitely. There are no pesticides to cure virus infections.

Viruses may be transmitted by insect feeding, crop handling, and infected propagation material. Each virus disease has different requirements for control so it is important to have the virus identified.

Tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV) can infect over 300 plant species, including many ornamentals. They are spread by thrips and infected plant material, but not easily by crop handling.



are larvae to acquire the virus. They introduce the virus into plants when their stylet pierces the leaf tissue. Once a thrips picks up the virus it remains infected for the rest of its life. During this period many plants can be infected. There is a direct relationship between the number of thrips and incidence of the virus.

Thrips must feed on infected plants for 15 minutes to acquire the virus. There is a latent period of at least four days after picking up the virus during which thrips cannot transmit the virus.

TSWV/INSV is also reportedly transmissible through the seed of cineraria.

Prevention

- Control insect pests, particularly aphids and thrips.
- Use virus-free or virus-resistant propagation material.
- Have suspicious looking plants tested for the presence of TSWV/INSV.
- Destroy plants showing obvious virus symptoms.
- Keep stock plants in an area separate from growing plants.

Control Strategies

An effective insecticide program is an essential component in the control of TSWV/INSV, but sole reliance on insecticides to control western flower thrips is a short-term solution due to the development of resistance. An integrated approach must be used.

1. Start with clean stock. Plants infected with TSWV/INSV usually have a latent period during which they show no symptoms. Also, some hosts may be infected but remain symptomless and are a threat to more susceptible host that may be present in the greenhouse. When purchasing cuttings or seedlings ensure there are no thrips on the plant that may have already infected them, or that may be a source of infection for the crops already in your greenhouse. Keep in-coming stock isolated from production areas until it is certain they are insect and virus free.



The geranium leaf on the left is affected by a viral disease; the other leaf is healthy.



Cineraria leaves with symptoms of mosaic virus.

2. Monitor western flower thrips populations with yellow or blue sticky traps. Place cards at the crop level to monitor any population changes and near doorways and vents to detect movement of thrips into the greenhouse.
3. Screen vents and cover open doorways with heavy plastic strips to reduce movement into the greenhouse.
4. Ensure that greenhouses are weed-free and that a weed-free border 10 - 20 feet wide around the greenhouse is maintained. Many weeds are host for the western flower thrips and TSWV/INSV. The ground next to doors and vents should have a weed-free border at least 20 feet wide. Avoid planting susceptible bedding plants around the greenhouse.

5. Place potted petunia plants ('pink beauty' or 'min-strel') among your crop along with non-sticky blue cards as attractant to determine if TSWV/INSV is present. Leaf spot symptoms will appear on petunias within 3 - 5 days after infection.
6. Destroy all infected plants. If the virus has been confirmed in one or two plants of a certain batch or cultivar you must presume all these plants are potentially infected. Spray all diseased plants with an insecticide to kill thrips on the plants. This prevents viruliferous thrips from flying to healthy crops when their host is disturbed. Infected plants should be placed in plastic bags at the bench or bed site to prevent thrips from spreading through the green house as they are carried outside.
7. Bio-control agents are generally not effective for virus infected thrips on ornamentals because a low population of the pest remains, and even a low number of virus carrying thrips can cause severe economic damage.
8. Planting beds should be steam treated or fumigated to kill thrips and larvae. Larvae are found in the top few centimeters of soil, so they may be treated with a soil spray. Apply as a coarse spray to the soil surface to kill larvae that drop to pupate, as well as adults emerging from the soil. Apply 2 sprays: the first when damage is noticed and the second two to three weeks later. Repeat if new infestations occur. See label for mixing and pH requirements. Use extra caution when spraying close to cynara, coleus, episcia, and gloxinias. Crop control may damage open blooms.
9. If the greenhouse is cleared out before a new crop begins, increasing the temperature to 35°C for 5 days or 40°C for 2 - 3 days will help control thrips pupae. The pupal stage will be shortened at these temperatures and emerging adults will starve because there is no food source.
10. Educate your staff so that they can identify the symptoms of TSWV/INSV.

Tomato Spotted Wilt Virus & Impatiens Necrotic Spot Virus Crop Symptoms	
Calceolaria	TSWV and INSV cause symptoms on calceolaria which resemble a fungal wilt disease. Central areas, or one-sided wilt patterns develop on leaves with a greasy grey color and plants eventually collapse without recovery.
Chrysanthemum	Susceptible chrysanthemum cultivars such as Polaris develop necrotic stem lesions and leaves become necrotic and collapse. Flowering plants have a blighted appearance and look as though they were infected with Fusarium wilt.
Cineraria	Young cineraria may develop symptoms similar to those on gloxinia (see gloxinia) while older plants develop ring spots and line patterns on leaves. Dark purple to brown sunken lesions develop on petioles, frequently at the leaf junction. The petiole may be girdled or the lesions may move into the stem.
Cyclamen	Initial symptoms on cyclamen include necrotic leaf spots and vein necrosis. Occasionally, lesions initiated at the base of the leaf blade radiate along several veins causing an oak-leaf pattern. Chlorotic leaf lesions develop into necrotic spots or concentric rings. Leaf collapse can result from petiole necrosis or coalescence of numerous ring spots. Necrosis in the vascular bundles of the corm has been observed in some plants. Symptom development is optimum at 13°C. When the temperature is increased to 22°C infected plants tend to be symptomless. Symptoms develop approximately 3 to 4 months after infection when plants are grown at 13°C.
Exacum	TSWV and INSV cause straw-colored necrotic leaf lesions 7 to 14 mm in diameter on exacum. Leaves may become completely necrotic and collapse. Lesions on the stem become slightly sunken and light to dark grey or straw colored. On larger plants, one branch or the entire plant may collapse and die.
Gloxinia	Infected plants less than six weeks old develop symptoms resembling Phytophthora root rot. The base and central part of lower leaves darken and plants collapse. Older plants develop spots and line patterns on upper and lower leaf surfaces which begin as chlorotic patterns that become necrotic. Necrotic areas may coalesce and plants develop a ragged appearance. Flowers may become distorted.
Marigold	Infected marigolds exhibit leaf strapping symptoms, particularly on the youngest leaves. Marigolds planted outside the greenhouse should be examined for symptoms.
New Guinea Impatiens	TSWV and INSV cause local lesions on impatiens that include ring spots and papery necrotic areas on leaves. The virus becomes systemic and causes faint purplish ring patterns or a mottle on newer leaves. Growing points may abort. Susceptible cultivars may die, or more often, some branches will die back while others survive. Mojave, in the Indian series, produces some leaves with necrotic ring and spotting symptoms, but many leaves on the plant are symptomless while cultivars in the Sunshine series are often killed.
Pepper	Fruit ripens unevenly if infected after fruit set. If infected before fruit set, fruit develops unevenly and becomes misshapen. Dark brown soft spots may develop on fruit and ring patterns may occur. Look for stem lesions, petiole, and peduncle necrosis, loss of leaders and branch dieback.
Tomato	The most common symptoms are rapid browning of the young leaves followed by cessation of growth. The leaves later become distorted with necrotic spotting and fruit formed after infection may develop blotches or mottling. None of the cultivars currently being grown exhibit resistance.

SECTION 10 - REVIEW QUESTIONS

Management of Greenhouse Diseases

1. What tactic(s) should be used to prevent disease problems in greenhouses?
- a. remove weeds and plant debris
 - b. inspect incoming plants for disease symptoms
 - c. purchase plants from dealers that index their crops
 - d. all of these
2. Plant diseases may be spread on infested pots or tools.
- _____ True _____ False
3. Damping-off is caused by soil-inhabiting fungi.
- _____ True _____ False
4. Older plants usually die from damping-off infection.
- _____ True _____ False
5. Which plant maintenance practice(s) reduce leaf spot problems?
- a. over-the-top watering
 - b. reduced air circulation
 - c. soil surface watering
 - d. none of these
6. High soluble salt levels in the rooting media may cause plant wilting.
- _____ True _____ False
7. Verticillium may persist in the soil for many years.
- _____ True _____ False
8. How do bacteria enter plants?
- a. through the roots
 - b. through wounds
 - c. through buds
9. Plants infected with a wilt disease can be treated using systemic fungicides.
- _____ True _____ False
10. How do you prevent root rot?
- a. use pasteurized or sterile media
 - b. avoid watering with cold water
 - c. don't over water
 - d. all of these
11. High soil moisture favors Rhizoctonia root rot.
- _____ True _____ False
12. Greenhouse environmental controls must be constantly controlled to prevent development of free moisture which leads to grey mold.
- _____ True _____ False
13. List four factors that will reduce or prevent grey mold problems.
- a.
 - b.
 - c.
 - d.

14. Which disease problem is commonly confused with spray residue?

- a. leaf spot
- b. powdery mildew
- c. rust
- d. botrytis

15. Once a plant is infected, powdery mildew can continue to grow when the relative humidity drops very low.

_____ True _____ False

16. Downy mildew actually grows inside the plant tissues.

_____ True _____ False

17. Which disease symptoms appear as a mauve-gray, felt-like mat on the undersides of the leaves?

- a. botrytis
- b. Xanthomonas blight
- c. tomato spotted wilt virus
- d. downy mildew

18. Rust diseases appear initially as small, yellow swellings.

_____ True _____ False

19. How are bacterial diseases often spread?

- a. by splashing water
- b. during pruning
- c. during propagation
- d. all of these

20. What is the most important disease affecting geraniums?

- a. tomato spotted wilt virus
- b. leaf rust
- c. damping-off
- d. none of these

21. Strict sanitation combined with exclusive use of culture virus indexed stock is the only way to minimize losses from bacterial blight.

_____ True _____ False

22. List six of the thirteen steps to sanitize a greenhouse after a bacterial blight outbreak.

- a.
- b.
- c.
- d.
- e.
- f.

23. Viral diseases can be cured with fungicide treatments.

_____ True _____ False

24. What insect generally causes the spread of tomato spotted wilt virus and impatiens necrotic spot virus?

- a. green peach aphid
- b. soft shell scale
- c. thrips

25. Thrips acquire the TSW virus when feeding as adults.

_____ True _____ False

26. An effective insecticide program is a long-term solution to wilt virus disease prevention.

_____ True _____ False

27. List four of the ten TSWV/INSV control strategies.

- a.
- b.
- c.
- d.

GREENHOUSE WEED MANAGEMENT

Weed control is an important part of greenhouse management. A typical management plan for greenhouse weeds includes a variety of cultural, mechanical and chemical methods to promote crop growth while reducing weed problems. Understanding plant growth habits will aid in selecting the best weed management methods.

Weeds can enter the greenhouse as seeds in the growing medium of plants, on tools, pots and machinery, or in any other propagation material. Light seeds are easily blown by the wind through ventilation systems.

An integrated weed control program is encouraged. This should include control of weeds in and around greenhouses by mowing or cultivating and applying chemicals, steam pasteurization or fumigation when appropriate.

REASONS FOR WEED CONTROL

Vigorous, healthy crop plants are the best defense against insect and disease damage. Unfortunately, practices that promote development of the crop also encourage the growth of weeds. Weeds adversely affect the yield of greenhouse crops in several ways:

- Weeds directly compete for soil moisture and nutrients.
- Weed growth can shade young crop plants, delaying their development.
- Dense weed growth impedes harvest, creates a poor impression on customers and reduces sales.
- Many weeds harbor diseases, with or without evident symptoms, that can infect crop plants.
- Weeds may be primary or alternate hosts for insects and related pests.
- Heavy weed growth can interfere with pesticide applications, preventing adequate protection.

WEEDS OUTSIDE THE GREENHOUSE

Control of weeds growing outside the greenhouse will eliminate a major source of airborne weed seed. Perennial weeds such as quackgrass or bindweed may grow under the foundation and into the greenhouse.

Several options are available for controlling weeds outside the greenhouse. These include mowing, herbicide application, mulches, steam pasteurization, fumigation and hand weeding.

Some growers maintain a bare, plant-free area surrounding the greenhouse. Other growers use mowed grass. Mowing regularly will prevent a majority of weeds from forming seed. Thrips will develop in grass and weed flowers so a regular mowing schedule is important.

Registered postemergent and soil residual herbicides may be used in areas immediately adjacent to the greenhouse. When applying herbicides around the greenhouse, avoid drift into the structure through the vents. Those herbicides considered safest to use are also labeled for use within the greenhouse.

Mulches can effectively control weeds by preventing seed germination at or near the soil surface. Mulches are generally used for long-term crops such as roses, outdoor cut flower crops, or as bed preparation. Organic mulches, like sawdust, shredded bark or other plant residue should be applied to weed free soil to a minimum depth of two inches. Inorganic materials, such as sand, gravel, polypropylene ground covers, or perforated black polyethylene film, may also be used. These materials provide a weed-resistant surface while allowing water penetration. New plastic products have been specifically designed for mulching purposes.

Steam pasteurization and soil fumigants will provide significant weed control. In the case of steam, proper temperature and treatment are necessary. Soil fumigants

are used prior to adding fertilizers to the soil, to kill weed seeds that are present (see Section 7 - Fumigation).

Supplement other weed management methods with hand weeding. By integrating sanitation, preemergent herbicides, postemergent herbicides, fumigation, mowing and manual weed removal in a total weed management program, weed pressure will be greatly reduced.

WEEDS INSIDE THE GREENHOUSE



Yellow wood sorrel (*Oxalis stricta* or *O. europaea*), a perennial greenhouse weed that seeds profusely.

Cultural and mechanical controls

The most important control measure for a weed-free greenhouse is sanitation. Limit the introduction of weeds by keeping weed seed out of the greenhouse, using sterile growing mixes, introducing only clean plant materials, and managing weeds outside the greenhouse. Weeds that enter the greenhouse should be removed by hand or treated with a registered herbicide before they go to seed.

If weeds are already established in the greenhouse, they can be eliminated by:

- Manual removal
- Emptying the greenhouse and allowing it to dry up
- Emptying the greenhouse and using a postemergent herbicide.

Each of these methods will remove the vegetation that is present but will do nothing to prevent reestablishment from seed that is present. If continuous removal is too expensive and time consuming, try applying a registered residual herbicide.

Chemical control of weeds

Restrictions on the use of herbicides in greenhouses are very specific. No currently registered herbicides may

be used in pots or on benches. The herbicides labeled for use in greenhouses may only be applied on the floor or underneath benches. Some herbicides can only be applied in an empty greenhouse. Plants can usually be brought into the treated area almost immediately after treatment. Other herbicides can be applied in a greenhouse while a crop is present. REI and PPE requirements vary with the material being used. Be sure to read the entire product label before mixing or applying herbicides. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific herbicide recommendations.

ALGAE

The greenhouse provides an ideal environment for algal growth. Left unchecked, algae will grow on walks, water pipes, equipment, greenhouse coverings and, on or under benches. It can reduce light levels to the crop, provide a breeding ground for insect pests like fungus gnats, harbor disease organisms, reduce efficiency of irrigation and cooling equipment, and be a liability risk for workers and customers using slippery walkways.

The primary control is through environmental modification and sanitation. Foremost is the reduction of moisture on the floors, benches, and structural surfaces. Proper ventilation will also reduce the amount of moisture in the greenhouse. Exchanging the internal moist air with external dry air is an effective method of lowering greenhouse moisture. Horizontal Air Flow (HAF) will help keep the internal greenhouse surfaces dry. Watering should be directed to the growing containers. The greenhouse floor should be level and drain properly to prevent pooling of water. The use of porous concrete or sand in construction will prevent puddling if surfaces are kept free of dirt and debris.

Sanitation is very important in algae control. All surfaces should be kept clean of plant debris and weeds. Algae control on capillary watering mats can be achieved by excluding light with a barrier, such as perforated black plastic film. On the greenhouse floor, black polypropylene ground cover fabrics will curtail algal growth.

Currently there are several registered chemicals that may be used for algae control. These products are also useful biocides that may control bacteria, fungi, and viruses on greenhouse surfaces. See the current New England Greenhouse Floricultural Crop Pest Management and Growth Regulation Guide for specific recommendations.

SECTION 11- REVIEW QUESTIONS

Greenhouse Weed Management

1. A major method of controlling weeds in greenhouses is elimination of weeds around the perimeter of the greenhouse.

_____ True _____ False

2. Regular mowing of plants around greenhouses helps discourage thrips populations.

_____ True _____ False

3. List four ways to manage weeds outside the greenhouse.

a.

b.

c.

d.

4. Sanitation is the most important measure for a weed free greenhouse.

_____ True _____ False

5. How can established weeds be eliminated from a greenhouse?

a. manual removal

b. emptying the greenhouse and allowing it to dry up

c. emptying the greenhouse and using a postemergent herbicide

d. all of these

6. Most herbicides registered for greenhouse use may be applied in pots or on benches.

_____ True _____ False

7. Algae can be controlled by reducing moisture on floors, benches and structural surfaces.

_____ True _____ False

8. List three methods for reducing algae problems.

a.

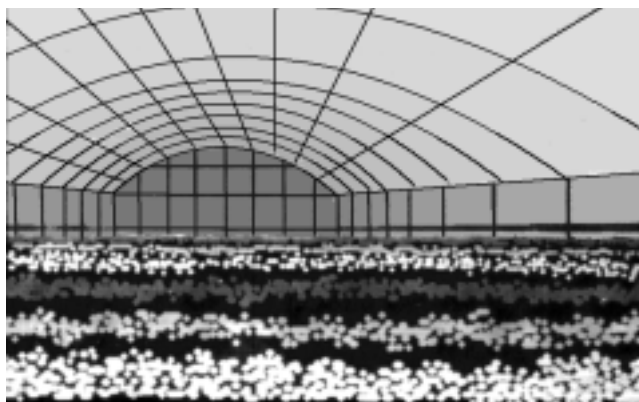
b.

c.

APPENDIX A

GREENHOUSE REFERENCES

PRODUCTION REFERENCES



The following crop production and greenhouse management reference books are available from several horticultural industry clearinghouses or from bookstores, unless otherwise noted. Prices and availability are current September 1994.

Armitage, A. A. 1993. *Specialty Cut Flowers*. 372 pp. Varsity Press, Portland, OR.

Ball, Vic, ed. 1991. *Ball Red Book*. (15th ed.). From GrowerTalks Bookshelf, 1-800-456-0132. \$60.00. Practical grower's manual with 15 sections on greenhouse structures, heating, computerization, mechanization, etc.; 5 sections on plug production; 6 sections on pest management, and 12 sections on general crop culture. Includes details on 120 crops.

Bedding Plants III. 1985. 560 pages. This manual covers all aspects of bedding plant production, and includes information about plug production. \$24.95.

Chase, A.R. 1987. *Compendium of Ornamental Foliage Plant Diseases*. A.P.S. Press, St. Paul, MN., 92 pages. 1-800-328-7560. \$35.00.

Chase, A. R., M. Daughtrey, and G. W. Simone. 1995. *Diseases of Annuals and Perennials*. Ball Publishing, Batavia, IL. 202 pp.

Daughtrey, M. and Chase, A.R. 1992. *Ball Field Guide to Diseases of Greenhouse Ornamentals*. 218 pp. GrowerTalks Bookshelf, 1-800-456-0132. Over 500 color photos for quick grower ID.

Daughtrey, M., R. Wick and J. Peterson. 1995. *Compendium of Flowering Potted Plant Diseases*. APS Press, 3340 Pilot Knob Rd., St. Paul, MN 55121. 1-800-328-7560. \$35.00.

De Hertogh, A. *Holland Bulb Forcer's Guide*. 4th ed. Available from Professional Plant Growers Assn., Attn. Deborah Norton, 1980 North College Road, Mason, MI 48854. \$30.00, complete reference for cut and potted bulb production in the greenhouse.

Ecke, P., Jr., O.A. Matkin, and D.E. Hartley. 1990. *The Poinsettia Manual*. 3rd ed. Encinitas CA: Paul Ecke Poinsettias. 267 pages. \$49.95 incl UPS shipping. Available from Paul Ecke Poinsettias, Encinitas CA; 619-753-1134. Complete and well-indexed manual on production and marketing of poinsettias.

Gentile, A.G. & D. T. Scanlon. 1992. *A Guide to Insects and Related Pests of Floricultural Crops in New England*. Revised in 1992 by Tina M. Smith. Descriptions, color photos, lifecycles and habits of insects and related pests of floriculture crops. Available for \$10 from University of Massachusetts Cooperative Extension System, Bulletin Distribution Center, Cottage A, Thatcher Way, Amherst, MA 01003-0051.

Holcomb, E.J., ed. *Bedding Plants IV*. 1994. 4th ed. will be available from GrowerTalks Bookshelf, 1-800-456-0132, \$55.00. Complete production guide to bedding plant production, including plug production.

1994 Integrated Pest Management for Florist Crops. Part of the Cornell Recommendations series. Publication #141RGFC2. Available from Cornell University Resource Center, 607-255-2080. \$14.00

Jarvis, W.R. 1992. Managing Diseases in Greenhouse Crops. A.P.S. Press, St. Paul, MN, 288 pp. 1-800-328-7560. \$79.00.

Larson, Roy, A. 1992. Introduction to Floriculture. 2nd ed. New York: Academic Press. 636 pages. \$50.00. Crop production manual with 22 chapters cover 22 major crops, including foliage plants, bedding plants, several cut flowers and several potted flowering plants.

Nelson, Paul. 1991. Greenhouse Operation and Management. Englewood Cliffs, NJ: Prentice-Hall. 612 pages. \$56.00. Basic reference book on greenhouse operation and management. A standard textbook for greenhouse management courses.

New England Greenhouse Floricultural Recommendations, A Management Guide for Insects, Diseases, Weeds and Growth Regulators. 1997-8. 156 pages. A collaborative effort among the six New England states; this guide contains information on IPM, pesticides, biocontrol, biorationals, etc. \$15.00. (Replaces New England Greenhouse Floricultural Crop Pest Management and Growth Regulator Guide 1995-1996.)

Ohio State "Tips" Series: Poinsettias; Potted Easter Lilies; Zonal Geraniums; Bedding Plants; Potted Perennials and / Biennials; and Potted Chrysanthemums. Approx. 80 pages each. Available from Ohio State University Cooperative Extension Bulletin Office, 614-292-1607. \$ 12 each.

Powell, C.C. and R.K. Lindquist. The Ball Pest and Disease Manual. 1992. 332 pp. Ball Publishing, Batavia, IL 60510. All aspects covered from ID to controls.

Strider, David, L. 1985. Diseases of Floral Crops, Volumes 1 & 2, Praeger Publishers, New York, N.Y., 1212 pages.

White, John., W., ed. Geraniums IV. 1993. 4th ed. Publ. formerly by Pennsylvania Flower Growers. 412 pages \$53.00, available from GrowerTalks Bookshelf, 1-800 4564132. Complete production guide to zonal geraniums.

FLORICULTURAL ASSOCIATIONS

Association of Specialty Cut Flower Growers (ASCFG)

ASCFG was formed to unite growers engaged in the production and marketing of specialty floral crops. The group is dedicated to improving the industry by fostering friendship and sharing through conferences, tours, seminars and shows; publishing information pertinent to the industry through a bulletin; generating research on producing, handling and marketing specialty cut flowers; and educating distributors and the general public about specialty cut flowers. For more information about ASCFG, contact Judy Laushman, Executive Director, 155 Elm Street, Oberlin, Ohio 44074.

Perennial Plant Association (PPA)

PPA member benefits include a quarterly newsletter, proceedings from the group's annual Symposium, and a membership directory. PPA sponsors seminars, regional meetings, and research on perennials. For more information, contact Dr. Steven Still, Executive Secretary, PPA, 3383 Schirtzinger Road, Hilliard, Ohio 43026.

Professional Plant Growers Association (PPGA)

PPGA represents primarily greenhouse growers of container plants — flowering potted plants, foliage plants and bedding plants. The association sponsors several educational programs each year, publishes a newsletter and produces educational materials for growers, including videos and written crop manuals. For more information, contact PPGA, PO Box 27517, Lansing, Michigan 48909.

The Herbal Connection

The Herbal Connection offers a bimonthly newsletter, an annual resource guide, and an information service to answer members' herb production/marketing questions. For more information, contact The Herbal Connection, 3343 Nolt Road, Lancaster, PA 17601.

JOURNALS



Greenhouse Grower. 14 issues/yr. \$25. Meister Publishing Co., 37733 Euclid Avenue, Willoughby OH 44094.

Greenhouse Manager. 12 issues/yr. \$24. Branch-Smith Publishing, 120 St. Louis Ave., Fort Worth, TX 76104.

Grower Talks. 12 issues/yr. \$22. PO Box 532, Geneva, IL 60134-0532.

Greenhouse Product News. 6 issues/yr. \$24. Scranton Gillette Communications, Inc. 380 E. Northwest Hwy., Des Plaines, IL 60016-2282.

The IPM Practitioner. 10 issues/yr. \$35. PO Box 7414, Berkeley, CA 94707.

INTERNET RESOURCES



There are a few sites on the world wide web with useful information. The following locations may be useful.

Commercial Greenhouse Programs:
<http://aggie-horticulture.tamu.edu/greenhouse/comgreen.html>

North Carolina State University Floriculture Page:
http://ww2.ncsu.edu/ncsu/cals/hort_sci/floriculture/

PlantNet.Com:
<http://www.plantnet.com>

Information on floriculture research.

Texas Plant Disease Handbook:
<http://cygnus.tamu.edu/texlab/table.html>

The African Violet Page:
<http://aggie-horticulture.tamu.edu/violet/violet.html>

The Horticultural Web:
<http://www.webdev.com>

Provides interactive databases on varieties, research, government regulations, and products.

The Sun Room:
<http://www.prairienet.org/ag/garden/sunroom.htm>

University of Minnesota Commercial Floriculture Services:
<http://134.84.58.52/ComFlor.html>

OTHER INFORMATION SOURCES

Department of Environmental Protection (DEP)
Waste Management Bureau
Pesticide Management Division
79 Elm Street
Hartford, CT 06106
Phone: (860) 424-3369 FAX: (860) 424-4060

Department of Agriculture
165 Capitol Avenue
Hartford, CT 06106
Phone: (860) 566-4667 FAX: (860) 566-6576

PAT Office
Northern District Cooperative Extension Centers
West Hartford Campus
The University of Connecticut
1800 Asylum Avenue
West Hartford, CT 06117
Phone: (860) 241-4940 FAX: (860) 241-4960

COOPERATIVE EXTENSION OFFICES

Eastern District Cooperative Extension Offices

562 New London Tnpk
Norwich, CT 06360
Phone: (860) 887-1608 FAX: (860) 886-1164

139 Wolf Den Road
Brooklyn, CT 06234
Phone: (860) 774-9600 FAX: (860) 774-9280

1066 Saybrook Road, Box 70
Haddam, CT
Phone: (860) 345-4511 FAX: (860) 345-3357

Sea Grant Marine Advisory Program
The University of Connecticut at Avery Point
1084 Shennecossett Road
Groton, CT 06340-6097
Phone: (860) 445-8664 FAX: (860) 445-3458

Northern District Cooperative Extension Centers

West Hartford Campus
The University of Connecticut
1800 Asylum Avenue
West Hartford, CT 06117
Phone: (860) 241-4940 FAX: (860) 241-4960

1305 Winstead Road
Torrington, CT 06790
Phone: (860) 626-6240 FAX: (860) 626-8849

24 Hyde Avenue
Vernon, CT 06066
Phone: (860) 875-3331 FAX: (860) 875-0220

Southern District Cooperative Extension Centers

305 Skiff Street
North Haven, CT 06473
Phone: (203) 789-7865 FAX: (203) 789-6461

Bridgeport Expanded Food and Nutrition, Urban Gardening, and 4-H/Youth Development Education Programs

1374 Barum Avenue
Bridgeport, CT 06610
Phone: (203) 579-6302 FAX: (203) 579-6037

State Administrative Office

Cooperative Extension System
College of Agriculture and Natural Resources
The University of Connecticut
1376 Storrs Road
Storrs, CT 06269-4036
Phone: (860) 486-4128



APPENDIX B

BIOLOGICAL CONTROL

DIRECTORY OF BENEFICIAL ORGANISMS

This appendix has been adapted from "Suppliers of Beneficial Organisms in North America," Edited by Charles D. Hunter, California Environmental Protection Agency, Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1994 Edition. One free copy per request is available from:

California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring and Pest Management
Branch
1020 N Street, Room 161
Sacramento, California 95814-5604
Telephone (916) 324-4100

It is also available on the internet at <http://www.cdpr.ca.gov/docs/dprdocs/goodbug/organism.htm>.

This listing is confined to beneficial organisms used for the biological control of pest organisms in greenhouses and excludes other commercially available useful organisms such as honey bees, earthworms, or butterflies as indexed listings.

Biological controls that are single-celled organisms such as bacteria, fungi, protozoans, and viruses are defined as pesticides by the United States Environmental Protection Agency (USEPA). In the United States of America (USA), the sale and use of these organisms is governed by USEPA and state laws, and regulations applicable to chemical pesticides. These organisms are widely available commercially and are not listed in this publication.

This appendix lists some 50 different organisms available from 81 suppliers. Only private commercial suppliers are listed. The suppliers of each country have been listed separately.

In each section, the suppliers are listed alphabetically with each listing preceded by a supplier number. Each supplier number begins with the first letter of the



***Encarsia formosa* - whitefly parasite**

country in which the supplier is located (C=Canada, M=Mexico, U=USA). Each listing includes the name, address, telephone, and FAX numbers of the supplier along with a retail/wholesale notation. Under the retail/wholesale notation, there may also be a brief comment submitted by the supplier on its specialties and/or the services it can provide. All the information on Mexican suppliers was obtained from Ing. Enrique Garza Gonzalez, Centro Nacional de Referencia de Control Biologico (Sanidad Vegetal).

Scientific names are used because most beneficial organisms do not have common names.

This listing gives only a general description of the beneficial organisms and makes no recommendations nor implies their effectiveness in controlling any pest. The beneficial organisms listed may attack other organisms that are not listed. Before using any type of pest control, be sure of the identity of the pest(s). Sometimes, beneficial organisms are confused with pests, especially in their immature stages, and control measures are mistakenly applied.

In addition to offering biological controls, some of the companies listed can provide consultation services. These services can be extremely valuable in establishing integrated pest management (IPM) programs of which biological controls are a major part. Many of the suppliers also have literature available about beneficial organisms and how to use them.

IMPORTANT NOTICE

With the proper permits, most of the organisms listed in this booklet can be shipped interstate and in many cases between countries. The suppliers should be aware of the permits required and may often have the permits on hand to ship to your area. In some cases, suppliers may require assistance in obtaining permits. In some situations, the importation or transport of certain species is prohibited.

The importation and transportation of live insects or microbial agents may require a permit. For further information contact: Louis Magnarelli, Connecticut Agricultural Experiment Station, 123 Huntington Street, New Haven, CT 065211,
Phone: (203) 789-7241, FAX: (203) 789-7232.



**An *Encarsia* sp. wasp.
Actual size 0.75 mm.**

CANADA- Commercial Suppliers

C01 Applied Bio-Nomics Ltd.

11074 West Saanich Road
Sidney, British Columbia
CANADA V8L SP5

Telephones: (604) 656-2123 (Insectary) (604) 940-0290 (BC) (416) 793-7000 (ONT)

FAX: (604) 656-3844

Retail and wholesale. Distributor list available. Free literature and price list.

C02 Better Yield Insects

RR3

Belle River, Ontario
CANADA NOR 1A0

Telephone: (519) 727-6108

FAX: (519) 727-5989

Retail and wholesale. Free consultation. Catalog \$ 1

C03 Canadian Insectaries

5 Alderwood Road
Winnipeg, Manitoba
CANADA R2J 2K7

Telephone: (204) 257-3775

FAX: (204) 256-2206

Retail and wholesale. Price list available. FAX/Mail orders preferable. Permit needed for U.S.A. import.

C04 Coast Agri Ltd.

464 Riverside Road South RR#2
Abbotsford, British Columbia
CANADA V2S 4N2

Telephone: (604) 853-4836

FAX: (604) 853-8419

Retail and wholesale. IPM consulting. Free catalog. Need permit for U.S.A. import.

- C05 Koppert Canada Ltd.**
3 Pullman Court
Scarborough, Ontario
CANADA M1X 1E4
Telephones: (416) 291-0040, (800) 567-4195
FAX: (416) 219-0902
Retail and wholesale. Free literature and pricing available upon request.
- C06 Manbico Biological**
Box 17, GRP 242, RR2
Winnipeg, Manitoba
CANADA R3C 2E6
Telephones: (204) 697-0863, (800) 665-2494 (Canada)
FAX: (204) 697-0887
Retail and wholesale. Free catalog. Consulting.
- C07 Natural Insect Control**
RR #2
Stevensville, Ontario
CANADA L0S 1S0
Telephone: (905) 382-2904
FAX: (905) 382-4418
Retail and wholesale. 36 page catalog. Permit for N.Y., other states pending.
- C08 Nature's Alternative Insectary Ltd.**
Box 19 Dawson Road,
1636 East Island Highway
NanOOSE Bay, British Columbia
CANADA V0R 2S0
Telephones: (604) 468-7912, (604) 468-7911
FAX: (604) 468-7912
Retail and wholesale.
Producer. Available year round.
Weekly shipments within U.S.A. Phone/FAX for brochure.
- C09 Richters**
357 Highway 47
Goodwood, Ontario
CANADA L0C 1A0
Telephone: (905) 640-6677 FAX: (905) 640-6641
Retail only. Years of experience using beneficials for pests on herbs. Catalog \$2.
- C10 Westgro Sales Inc.**
7333 Progress Way
Delta, British Columbia
CANADA V4G 1E7
Telephone: (604) 940-0290
FAX: (604) 940-0258
Retail and wholesale. Literature and price list available upon request.

MEXICO - Commercial Suppliers

CREROB - Centro Regional de Reproductores de Organismos Beneficos. Son insectarios que fueron transferidos de manos del gobierno a compaffias privadas y que ahora vendee al publico = “ Regional Center of Reproducers of Beneficial Organisms.”

These are insectaries that were transferred from the Mexican Government to private ownership and now sell to the public.

M01 CREROB - Caborca

Av. “P” y Calle Obregon
Caborca, Sonora
MEXICO
Telephone: (637) 2-08-71
Retail and wholesale.

M02 CREROB - Matamoros

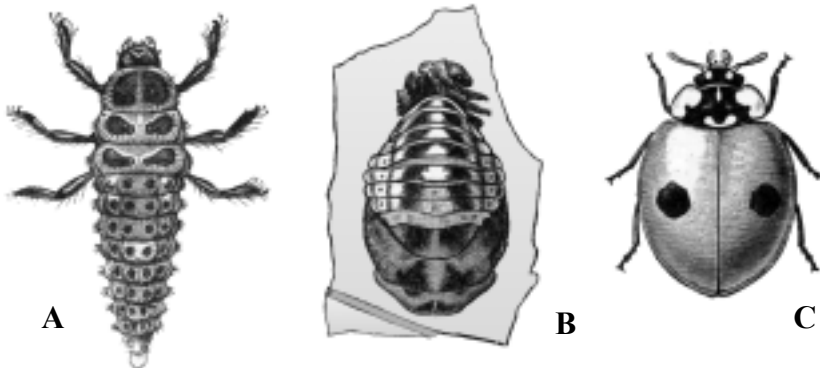
Sendero Nacional Km. 1
Apartado Postal No. 550 Matamoros, Tamaulipas
MEXICO
Telephone: (891) 2-12-02
Retail and wholesale.

M03 CREROB - Mexicali

Km. 1.5 Carretera a Mexicali-San Felipe, CP 21230
Mexicali, Baja California Norte
MEXICO
Telephone: (65) 61-70-80
FAX: (65) 61-94-28
Retail and wholesale.

M04 Unifrut

Calzada 16 de Septiembre y M. Jimenez
Apartado Postal 676
Ciudad Cuauhtemoc, Chihuanua
MEXICO
Telephones: (158) 2-00-95, (158) 2-00-41
FAXes: (158) 2-01-21, (158) 2-06-41
Retail and wholesale.



The two-spotted lady beetle, *Adalia bipunctata*, an aphid predator. A, larva; B, pupa; C, adult

UNITED STATES - Commercial Suppliers

- U01 A-I Unique Insect Control**
5504 Sperry Drive
Citrus Heights, California
U.S.A. 95621
Telephone: (916) 961-7945
FAX: (916) 967-7082
Retail and wholesale. Free brochure. Formerly Unique Insect Control. A primary source of ladybugs.
- U02 Agricultural Supply, Inc.**
1435 Simpson Way
Escondido, California
U.S.A. 92029
Telephones: (800) 527-6699, (619) 741-0066
FAX: (619) 741-9412
Retail and wholesale. Licensed Pest Control Advior's available.
- U03 American Insectaries, Inc.**
30805 Rodriguez Road
Escondido, California
U.S.A. 92026-5312
Telephone: (619) 751-1436
FAX: (619) 749-7061
Retail and wholesale. Se habla Español. Wide variety of beneficial insects and mites available.
- U04 Applied Bio-Control**
P.O. Box 118
Waterford, California
U.S.A. 95386
Telephone: (209) 874-1862
FAX: (209) 874-1808
Retail and wholesale. Consultation service available both within and outside of California.
- U05 ARBICO, Inc.**
P.O. Box 4247 CRB
Tucson, Arizona
U.S.A. 85738-1247
Telephones: (602) 825-9785, (800) 827-2847
FAX: (602) 825-2038
Retail and wholesale. Free catalog and consulting
- U06 Beneficial Insectary**
14751 Oak Run Road
Oak Run, California
U.S.A. 96069
Telephones: (800) 477-3715, (916) 472-3715
FAX: (916) 472-3523
Retail and wholesale. Producer and supplier. FREE literature, consulting, and training available.

- U07 Beneficial Insects Etc.**
P.O. Box 154
Banta, California
U.S.A. 95304
Telephone: (209) 835-6158
Retail only. Lacewings April-July.
- U08 Beneficial Ladybugs**
15010 Merchants Bar Road
Magalia, California
U.S.A. 95954
Telephone: (916) 873-6729
Wholesale only.
- U09 Beneficial Resources Inc.**
P.O. Box 327
Danville, Pennsylvania
U.S.A. 17821
Telephones: (800) 268-4377, (717) 271-1741
FAX: (717) 271-1187
Retail and wholesale. Exclusive distributor of Biobest® beneficials and bumble bees.
- U10 Bio-Agronomics**
P.O. Box 1013
Clovis, California
U.S.A. 93613
Telephone: (209) 297-9288
Retail and wholesale. Consulting services available. Information available on products and services.
- U11 Bio AG Services**
4218 West Muscat
Fresno, California
U.S.A. 93706
Telephone: (209) 268-2835
Retail and wholesale. Biological control specialists.
- U12 Bio AG Supply**
710 South Columbia
Plainview, Texas
U.S.A. 79072
Telephones: (806) 293-5861, (800) 746-9900
FAX: (806) 293-0712
Retail and wholesale. Consulting. Food for beneficials. Price list.
- U13 Bio-Control Company**
Box 337
Berry Creek, California
U.S.A. 95916
Telephone: (916) 589-5227
Retail and wholesale. Free catalog available.

- U14 Binfac, Inc.**
P.O. Box 87
Mathis, Texas
U.S.A. 78368
Telephone: (512) 547-3259
FAX: (512) 547-9660
Retail and wholesale. Complete advisory and consulting services within 400 miles or with substantial business.
- U15 BioTactics, Inc.**
425 La Cadena Drive, West Unit #12
Riverside, California
U.S.A. 92501
Telephone: (909) 320-1366
FAX: (909) 781 -6572
Retail and wholesale. Mail order only. No retail store.
- U16 Bo-Biotrol, Inc.**
9538 Lupin
Winton, California
U.S.A. 95388
Telephones: (209) 358-1488 (800) 622-9045
FAX: (209) 358-1127
Retail and wholesale. Beneficials, consulting, and products for the home and farm. Free catalog available.
- U17 Bountiful Gardens**
18001 Shafer Ranch Road
Willits, California
U.S.A. 95490
Telephone: (707) 459-6410
FAX: (707) 459-6410 (6-10 PM - PST)
Retail only. Beneficials and other IPM materials. Also biointensive books and supplies.
- U18 Bozeman Bio-Tech**
P.O. Box 3146
Bozeman, Montana
U.S.A. 59772
Telephones: (800) 289-6656 (Orders only), (406) 587-5891 (Free consulting)
FAX: (406) 587-0223
Retail and wholesale. Free catalog and consulting.
- U19 Buena Biosystems**
P.O. Box 4008
Ventura, California
U.S.A. 93007
Telephones: (805) 525-2525, (805) 525-2526
FAX: (805) 525-6058
Retail and wholesale. International consulting. Se habla Español. IPM system design.

- U20 Bunting Biological North America**
P.O. Box 2430
Oxnard, California
U.S.A. 93034-2430
Telephone: (805) 986-8265
Wholesale only. Brochure on request.
- U21 Burpee Seed Company**
300 Park Avenue
Warminster, Pennsylvania
U.S.A. 18974
Telephone: (215) 674-4900
FAX: (805) 986-8267
Retail and wholesale. Free catalog.
- U22 CalTec Agri Marketing Services**
P.O. Box 576155
Modesto, California
U.S.A. 95357
Telephone: (800) 491 -2847
Wholesale only.
- U23 Central Coast Insectary**
391 Hames Road
Watsonville, California
U.S.A. 95076
Telephone: (408) 726-1853
FAX: (408) 726-5123
Retail and wholesale. Producer. Se habla Español. Free guidebook for control of twospotted spider mites.
- U24 CropKing Inc.**
P.O. Box 310
Medina, Ohio
U.S.A. 44258
Telephone: (216) 725-5656
FAX: (216) 722-3958
Retail and wholesale. Training and consulting. Free catalog.
- U25 Cyline Biotic**
P.O. Box 48
Goodyears Bar, California
U.S.A. 95944-0048
Telephone: (916)289-3122
FAX: (916) 289-3122
Retail and wholesale. Free brochure. Retail plan for nurseries. Ladybugs available all year long.

- U26 Down To Earth Distributors, Inc.**
345 Lincoln Street Alley
P.O. Box 1419
Eugene, Oregon
U.S.A. 97440
Telephone: (503) 485-5932
FAX: (503) 485-7141
Wholesale only.
Call for free catalog of organic gardening supplies.
- U27 FAR, Inc.**
510½ Chase Drive
Corona, California
U.S.A. 91720
Telephones: (909) 371-0120, (800) 640-2FAR (Central Valley)
FAX: (909) 279-5150
Retail and wholesale. Free literature.
- U28 Gardener's Supply Company.**
128 Intervale Road
Burlington, Vermont
U.S.A. 05401
Telephone: (802) 863-1700
FAX: (802) 660-4600
Retail and wholesale. Mail order catalog. Free catalog and free gardening consultation.
- U29 Gardens Alive!**
5100 Schenley Place
Lawrenceburg, Indiana
U.S.A. 47025
Telephone: (812) 537-8650
FAX: (812) 537-5108
Retail only. Free catalog.
- U30 Garden-Ville of Austin**
8648 Old Bee Caves Road
Austin, Texas
U.S.A. 78735
Telephone: (512) 288-6115
FAX: (512) 288-6114
Retail only. Call, write or FAX for free catalog. USA and Canada only.
- U31 Great Lakes IPM**
10220 Church Road NE
Vestaburg, Michigan
U.S.A. 48891
Telephone: (517) 268-5693 or (517) 268-5911
FAX: (517) 268-5311
Retail only.

- U32 Greenfire Inc.**
347 Nord Avenue #1
Chico, California
U.S.A. 95926
Telephone: (916) 895-8301
FAX: (916) 895-8317
Retail only. Free catalog.
- U33 Gurney Seed & Nursery Company**
110 Capital Street
Yankton, South Dakota
U.S.A. 57079
Telephone: (605) 665-1930
Retail only. Free catalog.
- U34 Harmony Farm Supply**
P.O. Box 460
Graton, California
U.S.A. 95444
Telephone: (707) 823 -9125
FAX: (707) 823-1734
Retail only. Send \$2 for catalog (refunded with 1st order). Consulting available.
- U35 Helena Chemical Company**
2589 North Air-Fresno Dr. #105
Fresno, California
U.S.A. 93727
Telephone: (209) 453-9385
FAX: (209) 453-0655
Retail and wholesale. IPM consulting available.
- U36 Henry Field's Seed & Nursery Co.**
415 North Bumett Street
Shenandoah, Iowa
U.S.A. 51602
Telephone: (605) 665-4491
Retail only. Free catalog.
- U37 Hydro-Gardens, Inc.**
P.O. Box 25845
Colorado Springs, Colorado
U.S.A. 80936
Telephones/FAXes: (719) 495-2266, (800) 634-6362
Retail and wholesale. Free catalog. Dealers welcome. Complete greenhouse supplies.
- U38 IFM - Integrated Fertility Mgmt.**
333 Ohme Gardens Road
Wenatchee, Washington
U.S.A. 98801
Telephones: (509) 662-3179, (800) 332-3179
Retail and wholesale. Free catalog.

- U39 Integrated Pest Management Services**
P.O. Box 989
Fresno, California
U.S.A. 93714
Telephones: (209) 456-0990, (209) 284-1538 (Cellular phone)
FAX: (209) 456-1156
Retail and wholesale.
- U40 IPM Laboratories, Inc.**
Main Street
Locke, New York
U.S.A. 13092-0300
Telephone: (315) 497-2063
FAX: (315) 497-3129
Retail and wholesale. Free catalogs. Specialties: greenhouses, nurseries and NE U.S.A. manure fly control.
- U41 Koppert USA**
P.O. Box 39387
North Ridgeville, Ohio
U.S.A. 44039
Telephone: (216) 353-9437
FAX: (216) 353-9457
Retail and wholesale.
- U42 Kunafin Insectary**
Route 1, Box 39
Quemado, Texas
U.S.A. 78877
Telephones: (210) 757-1181, (800) 832-1113
FAX: (210) 757-1468
Retail and wholesale. Consulting entomologists. Se habla Español. German also spoken. We mass rear beneficials.
- U43 Ladybug Sales**
P.O. Box 903
Gridley, California
U.S.A. 95948-0903
Telephones: (916) 846-9907
FAX: (916) 846-2655
Retail and wholesale. Pest control consulting and co-ordination services.
- U44 Mellinger's, Inc.**
2310 West South Range Road
North Lima, Ohio
U.S.A. 44452
Telephones: (216) 549-9861, (800) 321-7444 (orders/catalog)
FAX: (216) 549-3716
Retail only. Free catalog.

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Parasites and Predators for Greenhouse Pests

- Adalia bipunctata* - twospotted lady beetle, a predator for aphids - U28
- Aphelinus abdominalis* - a parasite for aphids - C05, U24, U40, U41, U54
- Aphidoletes aphidimyza* - a predator for aphids - C01, C02, C04, C05, C06, C07, C09, C10, U03, U05, U09, U18, U19, U22, U24, U31, U32, U34, U37, U38, U39, U40, U41, U45, U46, U47, U48, U52, U54, U55, U56, U64, U65, U67
- Aphidius colemani* - a parasite for aphids - C05, U20, U31, U40, U41, U54
- Aphidius matricariae* - a parasite for aphids - C01, C04, C07, C10, U09, U24, U27, U31, U34, U37, U38, U39, U45, U47, U54, U55, U56, U64, U65
- Cryptolaemus montrouzieri* - mealy bug destroyer, a predator for various scales and mealybugs - C03, C04, C05, C06, C07, C09, C10, U01, U03, U05, U09, U10, U11, U12, U16, U18, U19, U20, U22, U24, U27, U34, U35, U37, U38, U39, U40, U41, U44, U45, U47, U50, U52, U54, U55, U56, U57, U58, U63, U64, U65, U67
- Dacnusa sibirica* - a parasite for leafminers - C05, C07, U09, U19, U20, U22, U24, U37, U39, U41, U46, U54, U55, U64
- Delphastus pusillus* - a predator for whiteflies - C01, C04, C05, C07, C10, U03, U05, U09, U12, U15, U18, U19, U24, U34, U37, U38, U39, U40, U41, U53, U54, U55, U56, U57, U60, U63, U64
- Delphastus spp.* - predators for whiteflies - C07, U39, U55, U64
- Diaeretiella rapae* - a parasite for aphids - C06, C07, U03, U39, U55
- Diglyphus isaea* - a parasite for leafminers - C05, C06, C07, U05, U09, U10, U19, U20, U22, U24, U34, U35, U37, U38, U39, U41, U46, U54, U55, U64
- Encarsia desert* (=luteola) - a parasite for whiteflies - U03
- Encarsia formosa* - a greenhouse whitefly parasite - C01, C02, C04, C05, C06, C07, C08, C09, C10, U01, U02, U03, U05, U09, U10, U12, U14, U16, U18, U19, U20, U22, U24, U27, U29, U30, U32, U34, U35, U37, U38, U39, U40, U41, U44, U45, U46, U47, U48, U52, U53, U54, U55, U56, U57, U58, U63, U64, U65, U67
- Encarsia spp.* - parasites for whiteflies - C07, U02, U03, U09, U15, U16, U39, U46, U55, U64
- Eretmocerus californicus* - a parasite for sweet potato whitefly - U40
- Eretmocerus spp.* - a parasite for whiteflies - C05, U05, U09, U20, U39, U41, U45, U55
- Hippodamia convergens* - convergent lady beetle, a general predator - C02, C04, C05, C06, C07, C09, C10, U01, U02, U03, U05, U08, U09, U10, U12, U13, U14, U18, U19, U21, U22, U24, U25, U26, U29, U30, U32, U33, U34, U35, U36, U37, U38, U39, U40, U43, U44, U45, U46, U47, U48, U49, U52, U54, U55, U56, U62, U63, U64, U67
- Hypoaspis* (=Stratiolaelaps) *miles* - a predatory mite for fungus gnats and flower thrips - C01, C06, C07, C10, U03, U05, U09, U19, U34, U37, U38, U40, U45, U54, U55, U56, U63, U64, U65
- Iphiseius* (=Amblyseius) *degenerans* - a predatory mite for western flower thrips and pest mites - U09, U15, U24, U40, U41, U54, U64
- Lysiphlebus testaceipes* - a parasite for aphids - U03, U12, U39, U55
- Orius insidiosus* - a general predator - C07, U40, U64, U67
- Orius tristicolor* - minute pirate bug, a general predator - C06, C07, U03, U10, U12, U22, U35, U39, U47, U55
- Orius spp.* - a general predator - C05, C07, U05, U06, U09, U12, U14, U16, U18, U19, U20, U24, U34, U37, U38, U39, U41, U45, U52, U54, U55, U56, U57, U65

Scolothrips sexmaculatus - sixspotted thrips, a predator for mites and thrips - U39

Thripobius semiluteus - a parasite for thrips - C04, C07, U03, U05, U19, U22, U27, U38, U39, U40, U47, U52, U55, U64, U67

Scale and Mealybug Parasites and Predators

Aphytis melinus - a parasite for red scale - C02, C05, C06, C07, U02, U03, U05, U09, U10, U11, U12, U16, U19, U22, U27, U31, U34, U35, U37, U38, U39, U40, U45, U46, U52, U55, U56, U58, U64

Chilocorus kuwanae - a predator for euonymus scale - U55

Chilocorus nigritus - a predator for various scales - U55

Cryptolaemus montrouzieri - mealy bug destroyer, a predator for various scales and mealybugs - C03, C04, C05, C06, C07, C09, C10, U01, U03, U05, U09, U10, U11, U12, U16, U18, U19, U20, U22, U24, U27, U34, U35, U37, U38, U39, U40, U41, U44, U45, U47, U50, U52, U54, U55, U56, U57, U58, U63, U64, U65, U67

Leptomastix dactylopii - a parasite for citrus mealybug - C03, C04, C05, C07, C08, C10, U12, U19, U24, U38, U40, U41, U55, U56, U64

Metaphycus helvolus - a parasite for black scale - C02, C06, C07, C10, U03, U05, U10, U19, U34, U38, U40, U45, U46, U52, U55, U56, U64

Microterys nietneri (=flavus) - a parasite for brown scale -U46, U55

Rhycobius (=Lindorus) *lophanthae* - a predator for various scales - C03, C04, C05, C07, U18, U34, U37, U38, U40, U55, U56, U64

Aphid Parasites and Predators

Adalia bipunctata - twospotted lady beetle, a predator - U28

Aphelinus abdominalis - a parasite - C05, U24, U40, U41, U54

Aphidoletes aphidimyza - a predator - C01, C02, C04, C05, C06, C07, C09, C10, U03, U05, U09, U18, U19, U22, U24, U31, U32, U34, U37, U38, U39, U40, U41, U45, U46, U47, U48, U52, U54, U55, U56, U64, U65, U67

Aphidius colemani - a parasite - C05, U20, U31, U40, U41, U54

Aphidius matricariae - a parasite - C01, C04, C07, C10, U09, U24, U27, U31, U34, U37, U38, U39, U45, U47, U54, U55, U56, U64, U65

Chrysoperla (=Chrysopa) *carnea* - common green lacewing, a predator - C02, C04, C05, C06, C07, C09, C10, M03, U02, U03, U05, U09, U10, U12, U16, U19, U22, U24, U27, U29, U30, U31, U34, U37, U38, U39, U42, U44, U46, U48, U52, U55, U56, U57, U58, U64, U65, U67

Chrysoperla (=Chrysopa) *comanche* - Comanche lacewing, a predator - U10, U11, U12, U16, U19, U22, U34, U38, U39, U46, U55, U56, U57, U58, U64, U65

Chrysoperla (= Chrysopa) *rufilabris* - a green lacewing, a predator - C02, C06, C07, U03, U05, U06, U10, U12, U14, U16, U17, U18, U19, U20, U22, U29, U34, U37, U38, U39, U40, U42, U45, U46, U47, U52, U55, U56, U57, U58, U62, U63, U64, U65, U67

Chrysoperla & *Chrysopa* spp. - green lacewings, predators - C07, M01, M02, M04, U01, U04, U06, U07, U12, U13, U16, U21, U32, U33, U35, U36, U38, U39, U46, U55, U57, U58, U64, U65

Coccinella septempunctata - sevenspotted lady beetle, a predator - U29
Deraeocoris brevis - a true bug, a predator - C01, U56, U64
Diaeretiella rapae - a parasite - C06, C07, U03, U39, U55
Hippodamia convergens - convergent lady beetle, a predator - C02, C04, C05, C06, C07, C09, C10, U01, U02, U03, U05, U08, U09, U10, U12, U13, U14, U18, U19, U21, U22, U24vU25, U26, U29, U30, U32, U33, U34, U35, U36, U37, U38, U39, U40, U43, U44, U45, U46, U47, U48, U49, U52, U54, U55, U56, U62, U63, U64, U67
Lysiphlebus testaceipes - a parasite - U03, U12, U39, U55
Macrolophus caliginosus - a predator - C05, U09, U41, U54
Orius insidiosus - a predator - C07, U40, U64, U67
Orius tristicolor - minute pirate bug, a predator - C06, C07, U03, U10, U12, U22, U35, U39, U47, U55
Orius spp. - a predator - C05, C07, U05, U06, U09, U12, U14, U16, U18, U19, U20, U24, U34, U37, U38, U39, U41, U45, U52, U54, U55, U56, U57, U65

Whitefly Parasites and Predators

Chrysoperla (= *Chrysopa*) *carnea* - common green lacewing, a predator - C02, C04, C05, C06, C07, C09, C10, M03, U02, U03, U05, U09, U10, U12, U16, U19, U22, U24, U27, U29, U30, U31, U34, U37, U38, U39, U42, U44, U46, U48, U52, U55, U56, U57, U58, U64, U65, U67
Chrysoperla (= *Chrysopa*) *comanche* - Comanche lacewing, a predator - U10, U11, U12, U16, U19, U22, U34, U38, U39, U46, U55, U56, U57, U58, U64, U65
Chrysoperla (= *Chrysopa*) *rufilabris* - a green lacewing, a predator - C02, C06, C07, U03, U05, U06, U10, U12, U14, U16, U17, U18, U19, U20, U22, U29, U34, U37, U38, U39, U40, U42, U45, U46, U47, U52, U55, U56, U57, U58, U62, U63, U64, U65, U67
Chrysoperla & *Chrysopa spp.* - green lacewings, predators - C07, M01, M02, M04, U01, U04, U06, U07, U12, U13, U16, U21, U32, U33, U35, U36, U38, U39, U46, U55, U57, U58, U64, U65
Delphastus pusillus - a predator for sweet potato whitefly - C01, C04, C05, C07, C10, U03, U05, U09, U12, U15, U18, U19, U24, U34, U37, U38, U39, U40, U41, U53, U54, U55, U56, U57, U60, U63, U64
Delphastus spp. - predators - C07, U39, U55, U64
Deraeocoris brevis - a true bug, a predator - C0 1, U56, U64
Encarsia deserti (= *luteola*) - a parasite for sweet potato whitefly - U03
Encarsia formosa - a parasite for greenhouse whitefly - C01, C02, C04, C05, C06, C07, C08, C09, C10, U01, U02, U03, U05, U09, U10, U12, U14, U16, U18, U19, U20, U22, U24, U27, U29, U30, U32, U34, U35, U37, U38, U39, U40, U41, U44, U45, U46, U47, U48, U52, U53, U54, U55, U56, U57, U58, U63, U64, U65, U67
Encarsia spp. - parasites - C07, U02, U03, U09, U15, U16, U39, U46, U55, U64
Eretmocerus californicus - a parasite for sweet potato whitefly - U40
Eretmocerus spp. - parasites - C05, U05, U09, U20, U39, U41, U45, U55
Macrolophus caliginosus - a predator - C05, U09, U41, U54

Predatory Mites

Galendromus annectans - for pest mites - U03, U15, U19

Galendromus (= *Metaseiulus*, = *Typhlodromus*) *occidentalis* - western predatory mite for spider mites - C01, C04, C05, C06, C07, C10, U01, U03, U05, U06, U10, U11, U12, U15, U16, U18, U19, U22, U23, U27, U32, U34, U35, U37, U38, U39, U40, U41, U44, U45, U46, U47, U51, U52, U54, U55, U56, U57, U58, U63, U64, U65, U66

Hypoaspis (= *Stratiolaelaps*) *miles* - for fungus gnats and flower thrips - C01, C06, C07, C10, U03, U05, U09, U19, U34, U37, U38, U40, U45, U54, U55, U56, U63, U64, U65

Iphiseius (= *Amblyseius*) *degenerans* - for western flower thrips and pest mites - U09, U15, U24, U40, U41, U54, U64

Mesoseiulus (= *Phytoseiulus*) *longipes* - for spider mites - C07, C10, U03, U05, U10, U12, U15, U18, U27, U29, U32, U34, U37, U38, U40, U46, U47, U48, U51, U52, U55, U56, U63, U64, U65, U67

Neoseiulus (= *Amblyseius*, = *Phytoseiulus*) *barkeri* (= *mckenziei*) - for thrips - C06, C07, U03, U05, U24, U27, U37, U40, U45, U46, U53, U55, U57, U63, U65

Neoseiulus (= *Amblyseius*) *californicus* - for spider mites - C05, C06, C07, C10, U01, U03, U05, U06, U10, U12, U15, U18, U22, U27, U29, U31, U32, U34, U35, U37, U38, U40, U46, U47, U48, U51, U52, U53, U55, U56, U57, U57, U63, U64, U65, U67

Neoseiulus (= *Amblyseius*) *cucumeris* - for thrips, cyclamen and broad mites - C01, C02, C04, C05, C06, C07, C08, C09, C10, U03, U05, U09, U16, U18, U19, U20, U22, U24, U31, U32, U34, U35, U37, U38, U40, U41, U45, U46, U47, U48, U51, U52, U53, U54, U55, U56, U57, U63, U64, U65

Neoseiulus (= *Amblyseius*) *fallacis* - for European red and twospotted spider mites - C01, C07, C10, U11, U12, U31, U40, U53, U55, U56, U60, U63, U64, U65

Phytoseiulus macropilis - for spider mites - U15, U40

Phytoseiulus persimilis - for spider mites - C01, C02, C04, C05, C06, C07, C08, C09, C10, U01, U02, U03, U05, U06, U09, U10, U11, U12, U14, U15, U16, U18, U19, U20, U22, U23, U24, U27, U29, U31, U32, U34, U35, U37, U38, U39, U40, U41, U45, U46, U47, U48, U52, U53, U54, U55, U56, U58, U61, U63, U64, U65, U67

Various species of predatory mites - U04, U49



***Aphidius testaceipes*, a braconid wasp parasite of aphids**

APPENDIX C

ANSWERS TO REVIEW QUESTIONS

Section 1

1. True
 2. d
 3. True
 4. biological, cultural, mechanical
 5. True
 6. True
 7. d
 8. True
-
-

Section 2

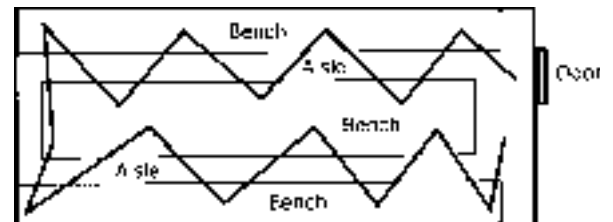
1. True
2. True
3. d
4. False
5. take down hanging plants before treatment, do not use highly toxic pesticides in hanging baskets, only treat overhead plants in the next aisle not directly above you, apply the pesticide while backing away and use the least toxic methods available
6. False
7. False
8. they are unaware of the routine hazards inside greenhouses
9. d
10. by establishing a totally separate display and sales area where no pesticides are applied
11. False

Section 3

1. False
 2. temperature, humidity, ventilation, heating systems and volatilization
 3. True
 4. d
 5. an irrigation water containment and recycling system, prevents escape of pesticides and nutrients from the greenhouse.
 6. c
 7. False
 8. b
 9. True
-
-

Section 4

1. scouting, pest identification, timing treatments and record keeping
2. b
3. False



- 4.
5. False
6. d
7. True
8. c
9. b

10. True
 11. Sanitation
 12. To reduce insect, weed and disease pest reinfestation
 13. False
 14. a
 15. screens, vacuuming, pruning and roging
 16. False
 17. False
 18. d
 19. b
 20. nonspecific, broad mode of action
-
-

Section 5

1. True
 2. False
 3. c
 4. True
 5. False
-
-

Section 6

1. d
 2. True
 3. False
 4. b
 5. True
 6. False
 7. c
 8. True
 9. False
 10. False
 11. d
-
-

Section 7

1. True
2. False
3. chloropicrin, Vorlex, Vapam, Telone and Basamid
4. a & c
5. False
6. True
7. c

Section 8

1. b & c
 2. True
 3. b
 4. False
 5. d
 6. gradual change in light intensity and duration of light
 7. d
 8. c
 9. True
 10. True
 11. c
 12. False
 13. Botrytis & Chrysanthemum leafminers
 14. b
 15. False
 16. False
 17. True
 18. d
-
-

Section 9

1. True
2. b
3. False
4. a
5. False
6. d
7. True
8. True
9. c
10. True
11. True
12. b
13. True
14. b
15. d
16. False
17. True
18. undersides of leaves
19. True
20. d
21. True

22. True
 23. d
 24. b
 25. True
 26. True
 27. a & c
 28. b
 29. True
 30. True
 31. False
 32. a
 33. False
 34. cube of potato tuber on the soil
 35. True
 36. True
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Section 10

1. d
2. True
3. True
4. False
5. c
6. True
7. True
8. b
9. False
10. d
11. False
12. True
13. adequate air circulation, relative humidity below 90%, don't over crowd plants, remove dead or diseased plant material, don't leave large stubs or joints and remove senescent flowers
14. b
15. True
16. True
17. b
18. True
19. d
20. d
21. True
22. See pages 91 and 92
23. False
24. c

25. False
 26. False
 27. See pages 93 and 94
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Section 11

1. True
2. True
3. mowing, herbicide application, mulches, steam pasteurization, fumigation and hand weeding
4. True
5. d
6. False
7. True
8. improved horizontal air flow, sanitation (cleaning benches), ground cover fabrics