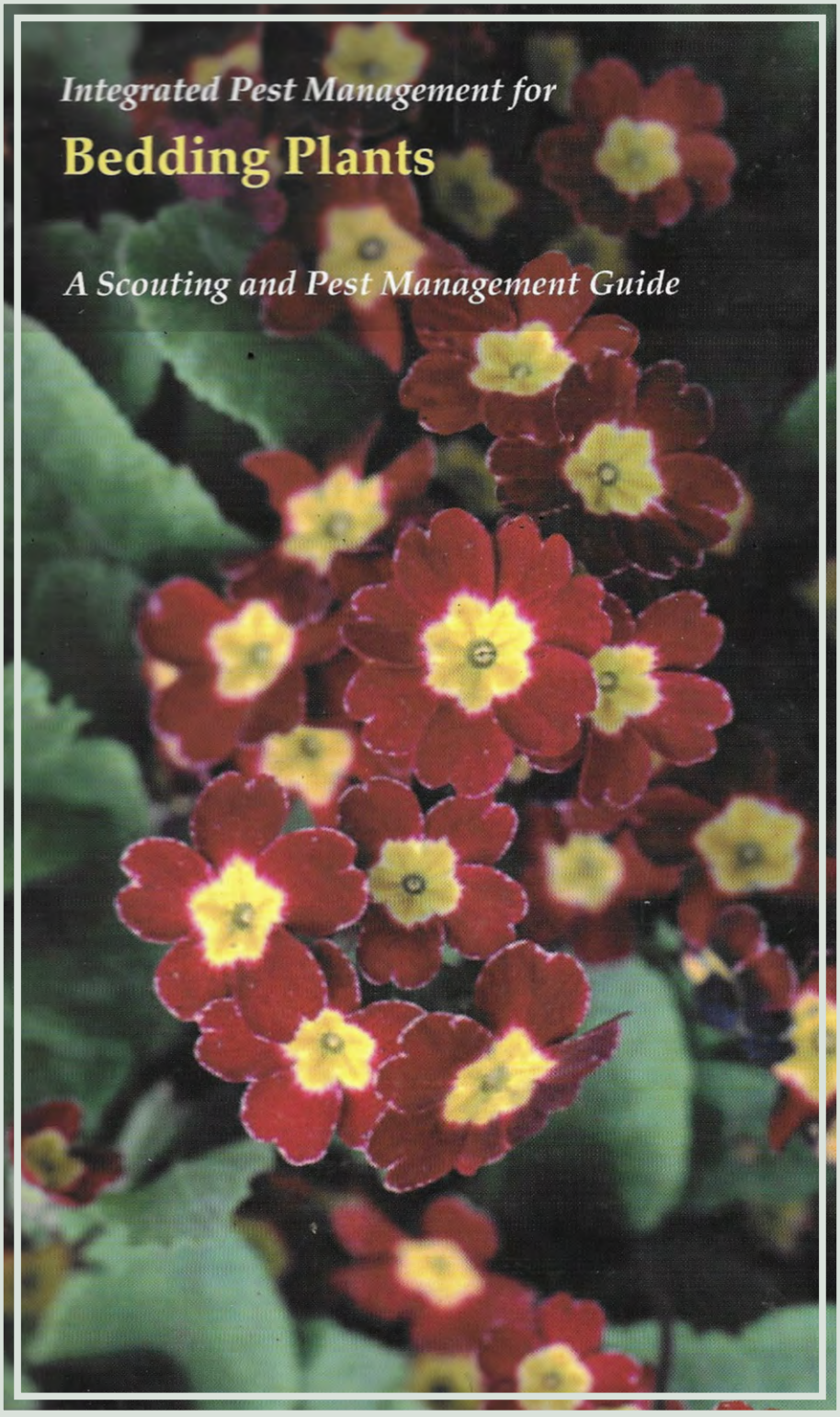


New York State
Integrated Pest Management
Program

IPM Publication No. 407, 2nd Edition

I. INTRODUCTION

The techniques of integrated pest management (IPM) offer a practical way for growers to maintain profitable crop production while effectively managing pests. Using IPM, growers can improve plant protection of annuals, perennials, herbs, vegetable transplants, foliage plants, and flowering potted plants, while minimizing reliance on chemical pesticides.

Integrated Pest Management for Bedding Plants: A Scouting and Pest Management Guide explains how to monitor for the presence of pests during all phases of production. This guide covers the crops that are commonly produced in the greenhouse between January and July. Although this publication is intended primarily as a training guide for scouts, it will also be useful for private consultants, growers, greenhouse managers, pesticide applicators, and students. Everyone associated with pest management in a greenhouse can benefit from understanding the basics of scouting and how it contributes to economically sound pest management practices.

How to Use this Publication

This guide provides a foundation in greenhouse scouting that can be used to develop a program for any given greenhouse. Use this publication with *Cornell Guidelines for the Integrated Management of Greenhouse Florist Crops: Management of Pests and Crop Growth*, which offers specific, up-to-date information on pest control strategies and pesticides (Media Services Resource Center, Cornell University, 607-255-2080).

II. THE ESSENTIALS OF IPM

Growers with a successful IPM program develop a site-specific strategy that includes careful assessment of pest problems. By inspecting their crops, they discover pest and cultural problems while these are still minor and can be easily and inexpensively managed. This early detection and intervention is the foundation of any IPM program.

Intervention occurs only when necessary, and relies on the use of a combination of compatible, effective management tactics—cultural, physical, mechanical, chemical, and biological. The IPM approach to pest management enables growers to produce a profitable, high-quality crop at minimal risk to themselves and the environment.

IPM has traditionally focused on improving crop quality through management of crop pests. As the importance of the relationship between plant health and pest injury has become more clearly defined, the emphasis of IPM programs has evolved to *total crop management.* Scouting has been expanded to include regular monitoring of soil and irrigation water chemistry; such vigilance alerts the scout to stressful growing environments that need correcting.

A successful IPM program includes monitoring, accurate problem identification, timely implementation, and evaluation of the appropriate management strategy. Information gathered by the scout is recorded on scouting forms (see appendix) and presented to the person responsible for pest management. This person decides upon and carries out an appropriate course of action, which is evaluated by the scout at the next monitoring visit.

Start with a Clean Greenhouse

At the end of a cropping season, the plant debris and spilled potting soil on the bench are likely to contain insects (especially eggs and pupae), bacteria, and plant pathogens. Remove all debris, including weeds on or under the benches. Thoroughly clean: sweep or vacuum the benches and floor, hose everything down with water or soapy water in a forceful spray, and then disinfest with an appropriate product labeled for greenhouse use (e.g., GreenShield, ZeroTol, or Physan 20). Disinfest the inside greenhouse walls and certain electrical fixtures (turn off electricity before treatment). For an additional margin of safety, leave the wet greenhouse sealed up and heated for a few days, then keep it empty for two to four weeks.

Monitor and Identify Problems

Monitoring, or scouting, is the basis of any IPM program. Monitoring is the regular, systematic inspection of the crops, benches, greenhouse floors, and exteriors to identify and assess insect, disease, weed, and cultural problems. It includes inspection of foliage, flowers, and root systems, determination of soil pH and conductivity, and the use of insect traps. Other monitoring tools include sentinel and indicator plants, disease detection kits, and the submission of plant or soil samples to diagnostic labs for analysis. Furthermore, monitoring includes an overall inspection of the greenhouse for production practices and greenhouse conditions that contribute to pest problems, such as watering nozzles left on floors or areas of standing water, or poor air movement.

This information is then used to decide whether action is needed and which techniques to use. Accurate information gathered through scouting is the basis for sound pest management decisions.

Your ability to accurately identify plant problems is critical to the success of an IPM program. The charts in this manual and the references listed in the bibliography will assist you in identifying plant problems. Samples should be

submitted to a university or private lab if they cannot be accurately diagnosed at the greenhouse. IPM strategies should be timely and pest specific, because a missed diagnosis can delay implementation of the proper set of controls. Scouting methods are explained in section III.

Develop a Management Plan

After each scouting session, record and summarize your observations. This information includes insect identification and counts, disease incidence and severity, and location of weeds. Also make notes about cultural aspects of the crop (such as crop height and plant development) and management of soil fertility and water. Give this information to the grower along with an evaluation of the effectiveness of past controls. This information is used to formulate management recommendations, which are discussed in subsequent sections.

Consider Best Management Practices

Best management practices, which include integrated pest management strategies, are standard rules and routines that reduce environmental impacts. In greenhouses, following best management practices means managing fertilizers and pesticides to minimize contamination of water runoff. For example, greenhouse managers can practice good sanitation and detect pests early. They can prevent spills of concentrated chemicals by purchasing waterproof tubs and using them for secondary containment of bagged fertilizers or concentrated solutions. They can provide a locked metal cabinet for pesticides, and update the list of contents regularly.

Many municipalities require businesses to avoid situations that could pollute the water table. Some logical improvements in the ways we handle chemicals in greenhouses can reduce the potential problems and the need for regulations.

III. SCOUTING METHODS

Setting Up a Scouting Program

Scouts might be growers, other greenhouse employees, or private consultants. Most growers find hiring a consultant to be worth the cost. This person is experienced in problem identification, brings an unbiased outlook to the greenhouse, and cannot be diverted to other activities.

On the other hand, an employee scout has more flexibility to change the scouting schedule to accommodate pesticide applications or shipping schedules. This means that incoming plants could be inspected immediately as they arrive at the greenhouse, helping to prevent unwanted pest entry. This person would also be at the greenhouse every day, so problems detected as the crops are handled could be quickly diagnosed.

The grower must first decide whether to use an independent scout or a greenhouse employee. Once a scout is selected, the grower and scout should agree on several topics before the program begins. The amount of time to be spent scouting, when scouting will take place, and (for independent scouts) what the scout will charge, are all important subjects. Some scouts charge by the hour, while others receive a flat fee per visit.

Establish an isolated area where plants will be left and examined by the grower after rogueing, or receive permission from the grower to discard them directly. Other details, such as responsibility for sending plants to diagnostic labs (and who will pay for this) as well as purchase of sticky cards, also need to be discussed.

The scout and grower should consider the type of information to be left at the end of each session. How much detail does the grower want, and are management recommendations desired? Finally, it is important to establish good

communication with the person in charge of pest management decisions and other employees who regularly work with the plants; they will often notice the development of new problems during the time between scouting sessions.

Follow the sanitation protocol outlined in table 1 to reduce the possibility of spreading insects or diseases and to minimize contact with pesticide residues. Before leaving one business or house to scout another, wipe off your clothing and wash your hands. Treat plants gently as you inspect them.

Another part of being a responsible scout is continuing education. Attend trade and educational shows, read trade journals, and stay in contact with other scouts. New pest problems will always develop, as will new ways to manage them. To remain effective, you need to be aware of these changes.

Finally, remember that at times the grower's priorities will be different from yours. Patience and good communication will be essential at these times. Don't expect to see all management recommendations implemented every week, but be prepared to prioritize problems and alert the grower to those that are urgent.

The Scouting Process

Gather background information

The next step before the scouting season begins is to gather background information about historical problem areas, the greenhouse layout, irrigation, pesticide application equipment, and media and fertilizer. All of these factors can interact to affect the development and management of pest problems.

Historical Problem Areas and Crops. Find out which crops tend to have pest problems so you can pay particular attention to those plants while scouting. In addition, many greenhouses have spots that have environmental problems, such as poor drainage, limited air movement, or cold spots that can lead to pest problems. These areas should also be noted when gathering background information.

Table 1. Scouting sanitation protocol

Procedure	Justification
Avoid wearing yellow, blue, or light-colored clothing.	Light colors attract many insects, which could then be carried on your clothing to another area.
Wear disposable gloves.	Disposing of gloves helps prevent pathogens from being transferred among plants. Wash or change gloves after contact with contaminated material. Gloves will help protect against contact with pesticide residue on plants.
Check the pest control record before entering an area.	Reduces your risk of pesticide exposure and points you to possible problem areas.
Monitor least-infested first, heavily infested areas last. Base this judgment on conversations with the grower and your previous visit.	Minimizes the possibility of inadvertently carrying insects or pathogens from one area to another or from older to younger plants.
Examine stock plants first, then cuttings.	Reduces the chance of infesting stock plants.
Don't carry infected plants to a clean area or another greenhouse.	Minimizes the spread of insects and diseases. When rogueing plants or removing dead leaves, place the material in a plastic bag, then remove it from the greenhouse.
After encountering bacterial blight on geraniums, wash hands and shoe soles immediately. DO NOT continue to handle the plants. DO NOT visit another greenhouse that day.	Minimizes the possibility that this disease, for which there is no control, will be spread as you scout.

Greenhouse Layout. At the first visit, inspect each greenhouse for situations that may lead to pest problems, such as watering nozzles left on the floor, areas of standing water, weeds, algae, and plants left from a previous crop. Look for whiteflies and thrips on the weeds, and for shore flies on the algae. Check for weeds outside the greenhouse that will need to be controlled in the spring. A 15-foot border around the greenhouse should be kept free of weeds.

Determine patterns of plant movement during a normal production cycle. For example, do plants move from propagation to a holding house, from which they are distributed throughout all greenhouses? If so, inspect plants carefully before they leave the holding area. Do all greenhouses share a common headhouse through which all plants pass as they are moved from one range to another? This means that a problem in one house could quickly be distributed to all greenhouses.

Irrigation. Several types of irrigation systems are used in greenhouses. These include hand watering, drip irrigation, overhead spray watering, capillary mats, and subirrigation (troughs or ebb and flow benches).

Hand watering and drip irrigation can lead to dry spots, either where the person watering missed an area (often in the center of the bench), or where a drip tube is clogged or has been knocked out of the pot. Dry plants may not grow fully or may show phytotoxicity from pesticides more readily than healthy plants would. Splashing from hand overhead spray watering can spread pathogens and exacerbate foliar diseases when there is poor air movement or insufficient drying time before nightfall.

Fungus gnat and shore fly populations may be higher on capillary mats, which remain continuously wet. The flood trays used in ebb and flow systems can inhibit good air circulation, thus contributing to foliar disease. There is little evidence, however, that this type of system causes a significant increase in root system disease.

Pesticide Application Equipment. Greenhouse growers apply pesticides in both dry and liquid forms. To do so, they use three main types of applicators: hydraulic sprayers, low-volume sprayers, and granular applicators.

Hydraulic sprayers depend on pressure derived from a pump. In greenhouses, applicators use either a backpack sprayer, a small portable sprayer, or a large, stationary unit. These sprayers typically create small droplets (10–400 microns in diam.) that are propelled forward.

Small hydraulic sprayers are useful when only a few plants need to be treated, but the low pressure they deliver can make adequate coverage difficult. Large hydraulic sprayers put out a high volume of material at higher pres-

sures, making thorough coverage easier to achieve. This type of machine is ideal for reaching insects that feed in concealed areas, such as leaf axils.

Low-volume sprayers, such as mist blowers, foggers, and electrostatic sprayers, provide coverage that is equal to or better than that of hydraulic sprayers with less pesticide. Sometimes called aerosols, they produce tiny droplets (10–80 microns in diam.) that are subject to drift; for this reason they are best used indoors.

The mist blower's small engine and fan create an air stream into which pesticide is injected. People applying products with low-volume equipment must verify that the product being used is labeled for low-volume application. Operators must also ensure that the air stream doesn't damage the plants or create drift that might harm natural enemies in areas adjacent to those being sprayed.

Foggers can be thermal or mechanical. Thermal foggers vaporize the pesticide into a fog, which hangs in the atmosphere of the greenhouse. Applicators should wear hearing protection and respirators. Mechanical foggers have a small compressor that makes fine droplets and a small, hand-held fan that distributes them as a fog.

Some pesticides are sold in aerosol cans that are opened in the greenhouse to disperse the chemical in a fine mist. These tend to provide variable coverage and are most effective against mobile adult pests on upper leaf surfaces.

Electrostatic sprayers use either water or compressed air as a propellant. As the liquid passes through the nozzle, a static electric charge is induced into the flow. Charged particles are attracted to the plants, which are grounded. Electrostatic sprayers produce uniform coverage, often with less pesticide or carrier than hydraulic sprayers. Like foggers, they work well indoors.

Granular applicators spread dry granules of pesticide across a given area. Obtaining uniform distribution of granules with granular applicators can be difficult. Growers who are treating individual pots should use a teaspoon or other volume measure and distribute the granules evenly across the soil. Work the granules into the soil and water, but do not float the granules off the bench soil surface or out of the pots.

Media and Fertilizer. Media type and fertilizer can also play a role in the development of pest problems. For example,

fungus gnat larvae prefer media high in organic matter. Poorly drained soil can favor the growth of root rot pathogens. Highly soluble nitrogen fertilizers tend to favor aphid reproduction, and micronutrient deficiencies or excesses can lead to noncontagious diseases. High levels of soluble salts may injure roots, making them more susceptible to disease development.

Create an IPM Notebook

The IPM notebook serves as a resource center at each greenhouse. It will contain information used weekly, such as blank scouting forms, greenhouse maps, and all scouting records. This book, which is always kept in the same place, should also contain pesticide recommendations, spray records, MSDS sheets, pesticide labels, and fact sheets or trade journal articles pertaining to pest problems. Other relevant information, such as fertilizer inputs, should also be included here. Establish this notebook before scouting begins, as you are preparing scouting forms and greenhouse maps. Continue to add new information to keep everyone on the IPM team up-to-date.

Develop a scouting strategy

Base your scouting strategy on the grower's schedule for the crop and the pests you expect to encounter (see table 2). To determine the date that the crop should be pest-free, project backwards from the expected sale date. The pest-free date is affected by the capacity of the insect, disease, or mite to injure a plant at a certain stage, as well as how difficult it is to detect the problem and the likelihood of the problem to spread.

To illustrate, fungus gnat larvae can seriously injure root systems that are less than three weeks old. Older roots, however, can tolerate a higher population of larvae. As a second example, even a small number of aphids—because of their great capacity for reproduction—is a concern on young plants, whereas on mature plants, one or two aphids could be washed off before sale. Thus, scouting for these two insects would be a priority during the first few weeks of the crop.

Whiteflies mature from eggs to adults in about one month, so these insects should be under control at least one month before sale. A few geraniums with Botrytis blight can be managed by removing the infected leaves and improving air circu

lation, yet if a few geraniums have rust lesions, a fungicide is needed. Rust lesions are also more difficult to see than Botrytis blight, so individual plants will need to be examined for rust, whereas Botrytis will usually be visible as you move through the crop.

Sometimes apparent injury is not necessarily related to current pest levels. For example, injury from thrips feeding early in the crop cycle may not be noticeable until several weeks later, when flowers and leaves have expanded.

Scouting Procedures

Scouting Equipment

Table 2 lists the equipment used by a greenhouse scout. A supplier list is included in the bibliography.

Scouting Route and Schedule

Establish a sampling route that will allow you to visit all areas of the greenhouse and inspect different plants each week. The pests that commonly attack bedding plants do not distribute themselves evenly throughout the crop. For example, whiteflies tend to have a clumped distribution; contagious diseases are usually spread by water or air movement, which are rarely uniform.

In a typical greenhouse layout, the most efficient route is a zig-zag pattern down the aisle between two benches (figure 1). Stop at about 10 locations in an area of 1000 ft^2, examining a plant or flat on each side of the aisle as well as any baskets overhead. Start this pattern at a slightly different location each week. The number and density of plants will affect the scouting pattern, as will the location and size of benches in the greenhouse.

Table 2. Greenhouse scouting equipment and use

Equipment	Use
Hand lens of at least 10x power	Examine suspected arthropod or disease problems under magnification.
Optivisor® (a hands-free magnifier)	Optivisor® allows you to keep both hands free as you inspect plants.
Blank scouting and report forms with clipboard and pen	Record scouting observations on forms and report findings to grower. Pen attached to clipboard is useful.
Colored survey flags and flagging tape	Mark sentinel plants or problem areas.
Sticky cards, stakes, and clothespins	Monitor adult insect flight activity.
Potato disks	Monitor immature fungus gnat activity.
Hand counter (tally meter)	Fast, accurate way to count large numbers of insects.
Plastic gloves	Protect scout from pesticide residues and prevent disease transmission during root system inspection.
Garbage bags	Isolate plants that are rogued or sent out for diagnosis.
Small plastic and paper bags	Attach plastic bag to belt while scouting to discard leaves and sticky cards. Use paper bags for transporting soil or tissue samples.
Plastic wrap	Wrap sticky cards for later ID or counting
Vials of alcohol, small artist's brush, and tweezers	Collect and preserve insects and mites for identification.
QTA Tospo™ detection kit	Test performed by the scout to determine if a plant is infected with INSV or TSWV.
Bleach solution (10%) or other disinfectant and rag. Prepare fresh solution weekly and store out of direct light.	Wash plastic gloves between root inspections to prevent disease transmission. Wipe gloves after applying bleach. Disinfest shoe soles after visiting a greenhouse with a suspect bacterial blight infestation on geraniums.

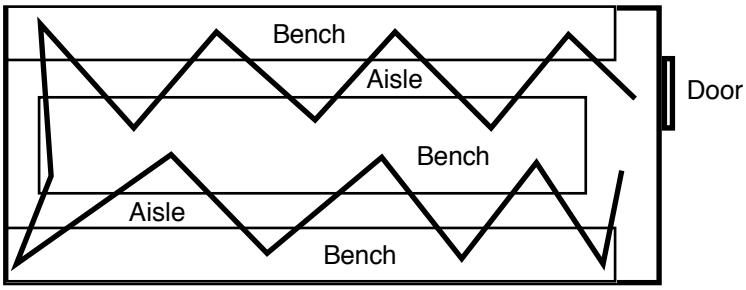


Figure 1. Scouting pattern down aisles and between benches

Scout the greenhouse once a week by inspecting plants and assessing root system health. Leave information in the IPM Notebook at the end of each session. A consistent schedule is necessary to accurately observe pest activity and trends. Scouting should take place on the same day of each week, and at the same time each week. This way the grower knows when you are coming and can prepare questions or schedule pesticide applications accordingly.

It is possible that before a scouting visit, an area of the greenhouse will have been treated with pesticide or plant growth regulator. Always check pesticide application records in the IPM Notebook for the reentry intervals specified by the Worker Protection Standards before entering a greenhouse. Be sure the grower keeps up-to-date records about the materials sprayed, the date, and the location. Knowledge about these applications will help scouts to evaluate the current pest situation and to protect their personal safety.

The time it takes to scout bedding plants depends on the experience and skill of the scout, the level of pest infestation, the size of the greenhouse(s), and the number and kind of plant species. A new scout may require an average of 20-25 minutes to inspect every 1,000 sq. ft. Once the scout is comfortable with pest identification, experienced at making pest counts, and familiar with the greenhouse layout, the time needed for scouting generally drops to an average of 10–15 minutes per 1,000 sq. ft.

As a rule of thumb, allot four hours per week for a greenhouse of approximately 1.5 acres. An additional one to two hours per range each week is optimal but may not be feasible. Allow time to discuss your work with the grower before and after scouting. Growers can guide your scouting by telling you

what they've seen or news of problems in other greenhouse operations.

Greenhouse Overview

Each time you enter a greenhouse to begin scouting, scan the entire crop for plants that are off-color, of uneven height, or abnormal in some other way. Make a note of the bench location and be sure to examine that area in detail as you work along your scouting route. Look under the benches for weeds, and check those weeds for insects. Note on the data sheet any presence of insects on weeds. A small weed population can be pulled by hand as you scout.

Do the same outside, noting the presence of weeds and ornamental plantings and any insects on them. Usually these weeds are too numerous for hand removal. They should be killed with an herbicide and replaced with a gravel border over weed barrier fabric.

Using Sticky Cards

Use colored sticky cards to monitor changes in adult insect populations and to detect pest populations in new shipments of plant material that has just arrived at the greenhouse. The color of the trap is attractive to a particular insect, which is caught on the adhesive surface. Sticky traps do not, however, significantly reduce insect populations.

Yellow cards are used to detect winged aphids, fungus gnats, shore flies, whiteflies, leafminer flies, and thrips. They will not pick up mites or wingless aphids. They also attract many natural enemies of insects, so try not to release beneficials near yellow sticky cards. Blue sticky cards also attract thrips, although it is more difficult to see the thrips against the blue background (photos 1, 2).

Examine sticky cards weekly as part of the scouting routine. Identify and count insects, then record this information with the other scouting data. Weekly changes in insect counts indicate general levels and trends of insect activity in a greenhouse. Because there are no guidelines for relating the number of insects on a trap to the population on the crop, you should use plant inspections as the primary source of information for pest management decisions.

Place traps in hanging baskets, at bench level, or on the floor (if the greenhouse has soil floors). Place one card per 1,000 sq. ft. Number each card. Correlate the number to a spe-

1. Monitoring for thrips with blue and yellow sticky cards, J. Sanderson

2. A winged aphid, J. Sanderson

cific location; that location will have a card (or replacement card) for the life of the crop. Use both sides of the card each week. If only a few insects are caught in a week, the card may be reused. Circle the insects with a waterproof marker so they are not counted again. Place cards at the level of the crop canopy, moving them each week as the plants grow.

Sometimes a different approach is used if a specific insect is of primary concern. For example, cards placed horizontally above the soil may be more effective for fungus gnat and shore fly monitoring. For thrips, cards should be placed in areas of air movement because thrips move around the greenhouse primarily on air currents. Attach cards near vents or other openings, on the eastern and western ends of the greenhouse, and near floors and ceilings until you are able to determine the most "popular" spots; continue to place cards in only the spots that collect thrips.

In hanging baskets, suspend cards from the support used to hang the baskets. At bench level, clip a card to a stake with double clothespins and place the stake in a pot. At the basket or bench level, set cards vertically. Choose whether cards will be oriented with the short or long side parallel to the ground, and maintain this orientation for the life of the crop. Keep the bottom third of the card below the crop canopy.

At the floor level, cards should be placed *horizontally,* since the purpose of these cards is to catch insects as they emerge from the soil. Another technique that may be used is to coat the inside of a clear plastic shoe box or sweater box with sticky material so the insects are caught as they emerge from the soil. These traps can help to determine the need for soil treatment.

Research in California has shown that the time spent counting yellow sticky cards for thrips and whiteflies can be cut by 80 percent if the scout counts only a one-inch *vertical* strip in the center of the card. This method is not effective for aphids and was not tested for fungus gnats or shoreflies.

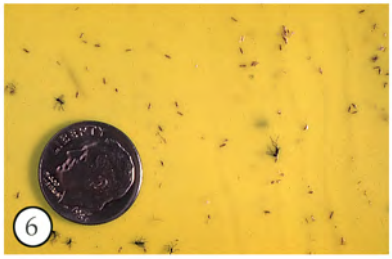
Unusual insects may occasionally be found on these cards. Several species of parasitic wasps may be seen in greenhouses where few pesticide applications are made. Insects not normally seen in the greenhouse may enter from outside through open vents or doors. If an unknown species is trapped more than twice, it should be identified. Always be alert to the arrival of a new pest. Sticky cards covered with insects can be wrapped in plastic to be saved for identification.

2. A winged aphid, J. Sanderson

3. Fungus gnat, J. Sanderson

4. Leaf miner flies, J. Sanderson

5. Shore fly, J. Sanderson



6. Thrips, J. Sanderson

Descriptions of Insects on Sticky Cards

Aphid. (varied species) Family Aphididae. These are small (1/8 inch) insects that vary in color from black to green. Only the winged forms will be caught on sticky traps (photo 2). They tend to shrivel after a few days on the trap, but if fresh will appear stout with cornicles visible near the tip of the abdomen. The wings are often spread out on the trap and a large dark vein will be visible near the front of the forewing. Nymphs may be seen near the body of the adult.

Fungus gnat. (*Bradysia* spp.) Family Sciaridae. These are small (1/16 inch) slender flies that resemble small mosquitoes. Distinguish them by their long legs and antennae (photo 3). They appear to be hunchbacked and have one pair of clear wings with a Y-shaped vein in the center.

Leafminer. (*Liriomyza* spp.) Family Agromyzidae. These are small (1/16 inch) stout-bodied flies that are mostly black with areas of bright yellow. There is typically a bright yellow patch on the thorax. Being flies (order Diptera), they have only one pair of wings (photo 4).

Moth fly; drain fly. (varied species) Family Psychodidae. These are small (1/16 inch) flies that appear fuzzy due to a covering of fine hairs. They are often trapped in wet or poorly drained growing areas.

Shore fly. (*Scatella stagnalis*) Family Ephydridae. These are medium (1/8 inch) stout-bodied flies that are dark in color (photo 5). They have bristle-like antennae that are shorter than the head and not always visible. The wings (one pair) are dark gray and have three to five distinct white spots.

Thrips. (varied species, typically *Frankliniella occidentalis*) Family Thripidae. Thrips are very small (1/32 to 1/16 inch) slender, elongated insects. They are usually the smallest insect on a trap and may be confused with specks of dirt (photo 6). Thrips are black to yellow and have hair fringes on their wings. These fringes are not always visible on traps because the wings of the thrips tend to fold over its body.

Whitefly. (varied species) Family Aleurodidae. These are small (1/16 to 1/8 inch) insects with white wings and yellow to orange bodies (photo 7). The white wings disintegrate quickly, leaving behind only the body, which can easily be confused with thrips. The wingless whitefly body tends to be shorter and stouter than the thrips.

Parasitic wasp. (varied species) Order Hymenoptera. Many parasitic wasps in the order Hymenoptera may be seen on yellow sticky traps (photo 8). They are generally small (1/16 to 1/8 inch) with bodies that range from slender to stout. They often have long, elbowed antennae. Their abdomens tend to be pointed at the rear. Parasitoid wings tend to be clear, with only one large vein on the forewing. The hindwings are usually without veins and much smaller than the front wings.

Other Insect Monitoring Tools

Occasionally other types of insect monitoring devices are used in greenhouse scouting. Potato disks may be placed on the soil surface to monitor for fungus gnat larvae. Cut a potato into 1- to 2-inch cubes and press the raw surface lightly into the soil. If larvae are present, they may be seen feeding on the potato when it is lifted from the soil after 24 hours.

Duct tape or packing tape may be wrapped sticky side out on bench legs to determine if slugs feeding on benches are moving up from the greenhouse floor; look for their slime trails on the tape.

Pheromone traps are occasionally used in greenhouses to detect European corn borer.

Plant Inspections

This section explains how to inspect plant tops and root systems for arthropods, diseases, and cultural problems. Descriptions of specific arthropod and disease problems can be found in subsequent sections.

Scout by Key Pests, Plants, and Locations

Be familiar with the key pests, plants, and locations for the crops grown in your greenhouses. Key pests are the insects, mites, and diseases most likely to cause problems on a plant

(table 3). Key plants are the species or varieties most likely to have pest problems. Key locations are areas of a greenhouse that are most likely to be the site of pest problems, such as spots with poor floor drainage, benches near vents, or production areas near stock plants.

Table 3. Some key pests of greenhouse bedding plants

Plant	Cultivar(s)	Pest(s)[1]
Ageratum	All	Whiteflies, WFT, aphids, TSSM
Alyssum	All	Whiteflies, WFT, aphids, Rhizoctonia
Basil	All	Fusarium wilt, INSV/TSWV
Begonia	All	WFT, damping off (*Rhizoctonia solani; Pythium* spp.), Botrytis, INSV, TSWV
Begonia	Tuberous	WFT, INSV/TSWV, bacterial leaf spot of begonia (*Xanthomonas campestris* pv. *begoniae*), powdery mildew
Celosia	All	WFT, aphids, damping off
Cyclamen	All	WFT, aphids, TSSM, cyclamen mite, INSV/TSWV, Fusarium wilt, Botrytis
Chrysanthemum	All	WFT, leaf miners, aphids, whiteflies, European corn borer, cabbage looper, Pseudomonas leaf spot, Fusarium wilt, Rhizoctonia, Pythium root rot, INSV/TSWV, Leafminers
Dahlia	Seed-grown	Aphid, WFT, Botrytis blight, INSV

[1]INSV = impatiens necrotic spot virus; TSSM = two-spotted spider mite; TSWV = tomato spotted wilt virus; WFT = western flower thrips, AMV = alfalfa mosaic virus, PVY = potato virus y, TMV = tobacco mosaic virus

7. Whiteflies on yellow sticky card, J. Sanderson

8. Parasitoids (5) and shore flies (2), J. Sanderson

Table 3—*Continued*

Plant	Cultivar(s)	Pest(s)[1]
Dahlia	Tuber-grown	WFT, TSWV
Dianthus	All	WFT, Botrytis blight
Dracaena (spike)	All	WFT, TSSM
Easter lily	All	Aphid, lily symptomless virus, cucumber mosaic virus, Pythium root rot, Rhizoctonia
Gazania	All	WFT
Geraniums	Cutting-grown zonals	Fungus gnats, whiteflies (esp. 'Aurora,' 'Snow Mass'), Botrytis blight, foxglove aphid, bacterial blight*(Xanthomonas campestris* pv. *pelargonii)*, root rot *(Pythium*spp.), rust, Fe/Mn toxicity at low (esp. 'Aurora'), Southern wilt (*Ralstonia solanacearum)*
Geraniums	Ivy types (cutting-grown)	WFT (especially flowers of 'Sybil Holmes' and foliage of certain cultivars), TSSM, whiteflies, bacterial blight of geraniums *(Xanthomonas campestris* pv. *pelargonii)*, oedema

Table 3—*Continued*

Plant	Cultivar(s)	Pest(s)[1]
Geraniums	Seed-grown zonals	Whiteflies, Botrytis blight, Pythium root rot, bacterial blight *(Xanthomonas campestris* pv. *pelargonii)* if near infested cuttings, Pseudomonas leaf spot, Acidovorax leaf spot
Gerbera Daisies		WFT, aphids, whiteflies, TSSM, INSV, TSWV, Pythium root rot, Pseudomonas leaf spot, powdery mildew, leafminers
Herbs	All, esp. vegetatively propagated	Whiteflies, aphids, WFT, TSSM, mealybugs, Rhizoctonia, Pythium
Hydrangea	All	Aphid, whiteflies, TSSM, powdery mildew, hydrangea virescence phytoplasma
Impatiens	All *wallerana (sultani)* and hybrid varieties	WFT, aphids, broad mites, TSSM, TSWV/ INSV, Pseudomonas leaf spot, Alternaria leaf spot, crown rot *(Rhizoctonia solani)*, *(Pythium* spp.), Botrytis stem & leaf blight
Kale, flowering	All	Imported cabbage worm, diamondback moth,
Marigolds	All	WFT, leaf miners, aphids, Botrytis blight, TSSM, Alternaria leaf spot, micronutrient toxicity (Hi Fe or Mn), Leafminers

[1]INSV = impatiens necrotic spot virus; TSSM = two-spotted spider mite; TSWV = tomato spotted wilt virus; WFT = western flower thrips, AMV = alfalfa mosaic virus, PVY = potato virus y, TMV = tobacco mosaic virus

Table 3—*Continued*

Plant	Cultivar(s)	Pest(s)[1]
New Guinea Impatiens	All	WFT, broad mites, INSV/TSWV, crown rot *(Rhizoctonia solani)*, crown rot *(Pythium irregulare)*, Botrytis stem and leaf blight, Myrothecium leaf spot, Phyllosticta leaf spot, powdery mildew
Pansy	All	Aphids, WFT, black root rot *(Thielaviopsis basicola)*, downy mildew, crown rot *(Phytophthora parasitica)*, downy mildew, Cercospora leaf spot, anthracnose, powdery mildew
Petunia	Vegetatively propagated	INSV/TSWV, powdery mildew, AMV, PVY, TMV
Petunia	All	WFT, damping off, *(Rhizoctonia solani)*, Leafminers
Pepper	All	WFT, aphids, TSWV/INSV, bacterial leaf spot
Portulaca	All	WFT, INSV, Papaya mosaic virus
Primula	All	Aphids, WFT, whiteflies, Botrytis, INSV/TSWV, Pythium root rot
Ranunculus	All	Aphids, WFT, INSV/TSWV, powdery mildew

Table 3—*Continued*

Plant	Cultivar(s)	Pest(s)[1]
Rosemary	All	Pythium, Fusarium, Rhizoctonia root rot, powdery mildew
Salvia	All	Aphids, whiteflies, downy mildew, Rhizoctonia
Snapdragon	All	WFT, aphids, Pythium root rot, downy mildew, rust
Tomato	All	Whiteflies, aphids, WFT, TSWV/INSV, bacterial leaf spot, bacterial canker, Rhizoctonia, Leafminers
Verbena	Flowering annuals (seed-grown)	WFT, aphids, potyvirus, TSWV/INSV, Phytophthora crown rot
Vinca vine		TSSM, Rhizoctonia
Vinca (Catharanthus)	All	WFT, broad mites, damping off and crown rot, *Phytophthora parasitica*, Rhizoctonia
Zinnia	All	Whiteflies, WFT, melon and green peach aphids, bacterial leaf spot *(Xanthomonas campestris)*, Alternaria leaf spot

[1]INSV = impatiens necrotic spot virus; TSSM = two-spotted spider mite; TSWV = tomato spotted wilt virus; WFT = western flower thrips, AMV = alfalfa mosaic virus, PVY = potato virus y, TMV = tobacco mosaic virus

Crop Plants

In general, inspect 10 to 20 plants or plug trays per 1,000 sq. ft. Be sure to inspect a few plants of each cultivar or species each week. Base the number of plants inspected on the number of different species or varieties being grown, the size of each plant's key pest complex, and the specific part of the production cycle. For example, geraniums are pestered by thrips, whiteflies, Botrytis, Bacterial blight, rust, and oedema, all of which can develop at any point in the crop production cycle. Therefore, you will want to check for these pests at every scouting visit.

9. Scouting for whiteflies, J. Lamboy

10. Greenhouse whitefly adults, eggs, and crawlers, J. Sanderson

Many plants are affected by fungus gnat larvae and damping off, which are a concern primarily during the first few weeks of production. Crop history also plays a role; check for a problem that has occurred regularly in the past until you are certain it is not present. Be vigilant with problems resulting from ongoing environmental circumstances, such as poor air circulation or standing water.

Systematically examine the tops and bottoms of leaves. Some arthropod pests, such as mites and whiteflies, are found primarily on leaf undersides, whereas aphids are most commonly seen on tender new growth. Most disease symptoms will be visible on the upper leaf surface, although downy mildew and powdery mildew can appear first on leaf undersides. For plants with six or fewer leaves, examine the entire plant. For larger plants, look over the entire plant, holding it above your head to see the leaf undersides (photos 9, 10). An Optivisor® is useful for this purpose. Select six leaves from all parts of the plant (upper, middle, lower) and examine them individually.

Examine the length of all stems and branches for insects, mites, and disease symptoms. Many arthropod and disease problems are specific to certain parts of the plant. Some aphids prefer terminal growth, whereas mealybugs may be located at any point, although often they are visible in leaf axils or where branches and stems meet. Western flower thrips adults and larvae are most commonly found in flowers. Sometimes they are visible on leaves and in leaf axils, or hidden within buds. Check stems and branches carefully for diseased areas—primarily at the root-stem junction, or where branches and stems meet. Leaf spots develop first on the older, lower leaves of seedlings.

Sentinel plants. Sentinel plants are individual plants within the crop that are monitored to provide information about the development of a problem. They can be marked crop plants that you check each week (usually for insect development) or non-crop plants that you place and check (usually for viruses). Sentinel plants can help you determine how quickly a problem is developing, whether control is necessary, and whether previous controls were effective. On crop plants used to follow insect development, wrap flagging tape around a branch where a problem is observed. Write the date and a description of the problem on the tape. Examine this plant at

the next visit. If a treatment was used, assess the effectiveness of the treatment. If no treatment was applied, check for continued development of the problem.

Indicator plants. Indicator plants are of a different species than the crop and are used because they have distinctive symptoms of a pest or are especially attractive to that pest. For example, they would be used to show the presence of thrips carrying the tospoviruses INSV or TSWV. These plants will develop viral symptoms within one week if fed on by infected thrips (photo 11). The petunia cultivars 'Red Cloud,' 'Summer Madness,' and 'Super Magic Coral' have all been shown to work as indicators for tospoviruses, while any variety of fava bean may be used (photo 14). See section VII for more information on using indicator plants for tospoviruses.

Tomatoes are sometimes used as indicators of ethylene gas, which can cause plants to become stunted and distorted. These plants react quickly to the presence of ethylene, which can be released into the greenhouse if a gas heater is not functioning properly. Yellowing leaves on ivy geraniums may be an indication of ethylene.

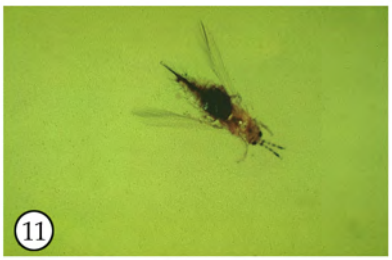
Root System Health. Inspect 10 plants per 1,000 sq. ft. for root system health, which is based on the size of the root ball and the color and disease status of the root system. Test a soil sample from two plants of the same species for pH and conductivity. A description of the techniques and a root health rating system are shown in table 4.

Preparation of the Scouting Report

At the end of each scouting visit, summarize your findings on the Scouting Summary Report Form (see Appendix). Leave this in the IPM notebook. Provide any other information not specified on this form (such as management suggestions) that the grower has requested. It is also a good idea to speak with the grower before you leave the greenhouse to provide a verbal summary of your observations.

Table 4. Monitoring root system health

Parameter	How to Measure	Interpreting the Results
Size of root ball	Y = root ball is filling the pot N = root ball is not filling the pot	A small root system is normal during the first few weeks of the crop. If a full root system is not seen by about the fourth week, the health of the plant is probably compromised.
Root system color	1 = healthy white with noticeable root hairs 2 = some brown roots, many lacking root hairs 3 = majority of the roots dead	Average the values for 10 plants. An average greater than 2 indicates poor root system health. Look for evidence of root rots, especially in the bottom of containers.
Soil pH	Take 2 level tablespoons of soil at least 1/4" below soil surface from each of two pots. Combine with 4 tablespoons of distilled water. Keep the volume ratio 1:2 (soil:water). Mix and allow to sit for 45 minutes. Pour off extract liquid and test.	A pH value below 5.0 or above 6.5 is cause for concern. Check references for optimum levels for specific crops. A pH value below 6.0 is sometimes a problem for marigold or geranium cultivars sensitive to iron/manganese toxicity.
Soil conductivity	Use same sample extract liquid as for pH.	This value should be between 0.5 and 1.5 µS (micro siemens; 1 µs = 1 mmhos). It is normal for this value to rise as the crop grows. Lower values are appropriate for young seedlings and plants ready for sale. Check references for optimum levels for specific crops.



11. Thrips on yellow sticky card, S. Gill

14. INSV symptoms on fava bean indicator plant, M. Daughtrey

IV. DEVELOPING, IMPLEMENTING, AND EVALUATING A MANAGEMENT PLAN

IPM growers use a variety of cost-effective methods to keep pests at acceptable levels. Some of these strategies are listed in table 5. Those appropriate to specific insects and diseases will be mentioned as those pests are discussed. A management technique for a specific problem aims to reduce its severity as well as prevent its recurrence.

Table 5. IPM approaches for bedding plants

Approach	Examples
Cultural	Adjust incorrect pH or salts to promote root health. Eliminate weeds and standing water. Use HAF fans to improve air movement.
Mechanical	Remove diseased leaves or plants. Remove plants infested with insects or mites. Screening, which prevents insects from entering the greenhouse, may be cost effective.
Biological	Apply biopesticides (insect toxins or pathogens sold as pesticides). Use fungal antagonists (naturally occurring soil fungi that displace plant pathogenic fungi). Release natural enemies.
Chemical	Use pesticides judiciously. Spot-treat in a timely fashion.
Resistant plant varieties	Limited use in bedding plant production at present

The short-term need is to reduce a problem to acceptable levels as quickly as possible. Doing so usually involves disposing of severely infested plant material and using pesticides. The least toxic materials that will be effective are used first, applied as spot treatments whenever possible.

Over the long term, there are several steps that should be taken to help prevent a problem from recurring. Whenever

possible, use a reputable supplier of clean plant material and develop a plan to prevent pests from entering and spreading in the greenhouse. For example, establish an isolation area in which incoming plants can be held and inspected for arthropod and disease problems before they enter the greenhouse, and keep the plants isolated until these problems have been treated. To help prevent the spread of problems, keep doors to bays off a common headhouse closed.

Change growing conditions that lead to pest problems, such as incorrect pH of irrigation water, algae around benches, or weeds in and around the greenhouse. The most obvious step is to simply stay on top of small problems before they become big ones.

Developing a Management Plan

Management strategies are developed before the bedding plant season so that the necessary management tools can be readied; these tactics are then modified as needed during the season.

Pest biology, production practices and equipment, and economics all need to be considered when management strategies are formulated. A pest present in high numbers that can spread or reproduce quickly will need to be controlled quickly, whereas a pest detected early at low levels could be managed with an insect growth regulator or biological control, which act more slowly.

Greenhouse style and pesticide application equipment will also determine what management approaches will be effective. For example, a crop in a large gutter-connected greenhouse that contains varied crops may not be a suitable candidate for biological control if pesticides are to be used on other nearby crops. Capillary mats or flood trays that block spray coverage from underneath could limit the effective use of contact insecticides, as could small, low-pressure sprayers that do not provide adequate coverage. Areas with frequent worker activity will need to be managed with techniques that have limited or no worker re-entry intervals.

Economics also play an important role in a management strategy. Important considerations are the cost of pesticides or natural enemies (including the labor to apply or release them) and the labor cost to rogue dead plants or plant parts.

It may be less costly to discard heavily infested plants than to apply pesticides and risk spread to clean plants. The value of the crop and impact of a pest on that value are also important. Botrytis on geranium flowers is not as urgent a problem as thrips on cyclamen.

Implementing a Management Plan

After each scouting session, record and summarize your observations. This information includes insect identification and counts, disease incidence and severity, location of weeds, and an evaluation of the effectiveness of previous control measures. Also make notes about cultural aspects of the crop (crop height, plant development, etc.) and management of soil fertility and water. A final part of an implementation plan is to have a clear understanding of whose responsibility it is develop and implement the management strategy. The information gathered during scouting should be given to this person as soon as the monitoring session is finished.

When a specific action needs to be taken, the grower should do so in a timely fashion. If pesticides are to be used, they should be applied as soon as possible after observing a problem, assuming the susceptible life stage is present. Apply a labeled pesticide correctly, using the appropriate equipment. Some control failures are the result of improper application techniques or equipment. Cryptic pests, such as thrips larvae or mealybugs, will need to be treated with a sprayer that provides excellent coverage with small particle sizes. A low-pressure backpack sprayer will not give adequate coverage in a dense crop with a large canopy.

Use of biological control requires commitment on the part of the grower. Because many biological controls are not compatible with many pesticides, the grower often has to be willing to use nonchemical methods to manage all pests found in the crop. Biological control agents act more slowly than chemical controls and cannot be expected to be a rescue treatment. Many biological controls are host-specific, and many operate only under specific environmental conditions. Essential to this method are 1) regular scouting to detect small problems that are more easily managed non-chemically, and 2) a reliable supplier of natural enemies. There are many

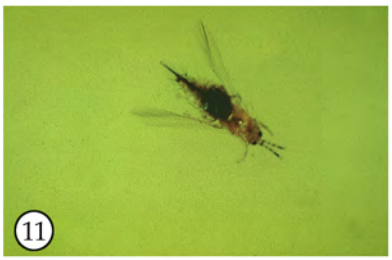
natural enemies of bedding plant arthropod and disease pests that are discussed in the biological control section.

Evaluation

Evaluation, a critical part of an IPM program, is accomplished during monitoring sessions. Because IPM is a dynamic process, management tactics are constantly evaluated and changed.

Begin an evaluation by checking the spray records before each scouting session. When scouting an area that received a pesticide application after your last visit, look for indications that it was effective. Signs of efficacy are dead, dried, or blackened insects and mites, a drop in trap catches or visual observations, or lack of disease progression. Indicator and sentinel plants, described in section III, are also important evaluation tools. Water-sensitive cards may be used to determine whether adequate coverage was obtained. Place these inconspicuously in the crop just before pesticides are applied. They will turn blue where water hits them, so a card with few blue areas indicates poor coverage.

There are several reasons why a pesticide application may not be effective (assuming a pesticide known to kill the insect, mite, or pathogen was used). Poor coverage of plant surfaces can result in incomplete contact with the pest. Water pH that is too high can cause pesticides to lose effectiveness. Also, pesticides that have been stored incorrectly, such as liquids that have been allowed to freeze, or dry materials that have become wet, can become less effective. Finally, some materials require irrigation. Too much or too little water will result in leaching or reduced plant uptake.



11. Thrips on yellow sticky card, S. Gill

VI. CASE STUDIES

12. Petunia indicator plant for thrips, M. Daughtrey

These case studies, drawn from actual experiences in New York greenhouses, show how pest management strategies are implemented and evaluated.

Case Study 1: Thrips and INSV on Impatiens

A grower who had experienced large losses for the past two years in his impatiens crop because of INSV decided to use indicator plants for early virus detection (table 6; photos 11-14).

13. Petunia 'Calypso' with thrips feeding injury, M. Daughtrey

Table 6. Thrips average in impatiens house

DATE	Trap Catch	AVG.	
Jan. 2	all 0	0	Petunias (indicator plant for INSV/ TSWV*) were placed December 26.
9	0, 2, 2, 4	2	
16	0, 0, 0, 2	0.5	No thrips controls have been used because populations are so low.
23	all 0	0	
30	all 0	0	
Feb. 6	all 0	0	
13	0, 0, 0, 4	1	
20	0, 0, 0, 4	1	
27	0, 1, 1, 0	0.5	On February 27, INSV symptoms appear on petunia indicator plants. QTA-Tospo™ kit confirms plant is infected.

*INSV=impatiens necrotic spot virus
TSWV=tomato spotted wilt virus

14. INSV symptoms on fava bean indicator plant, M. Daughtrey

Strategy Implemented on February 27

Even though thrips numbers were too low up to this point to warrant spraying, the presence of a virus means there are viruliferous thrips in the greenhouse (and therefore there is no tolerance for thrips).

- Remove indicator plant, taking it from the greenhouse in a sealed plastic bag. Replace it with non-infected indicator.
- Treat for thrips three times at 5-day intervals.
- Inspect at least twice as many plants as normal for INSV in this house for the next 3 to 4 weeks.
- Try to identify the reservoir of the virus.
- Do not move plants into or out of this house.

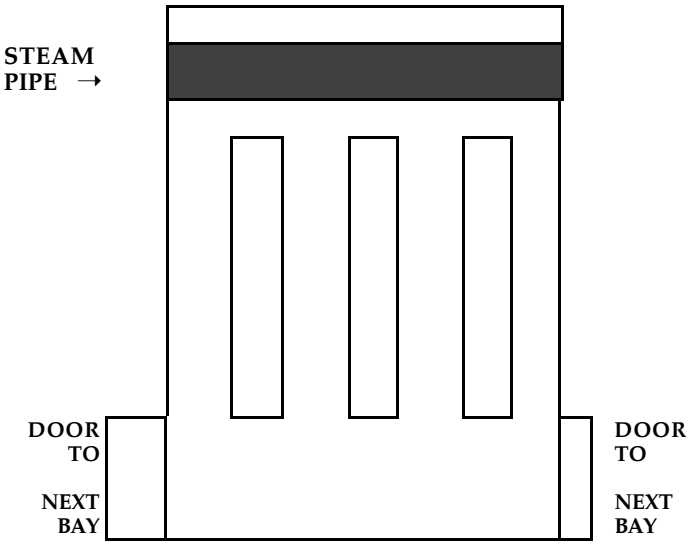
Results

- Use of indicator plants alerted the grower to the need to spray for thrips to control the spread of the virus. Only six plants out of 3,000 were lost to the virus.

Case Study 2: Whiteflies on Hidden Weeds

Shown in table 7 are the greenhouse map and yellow sticky card counts for the first eight weeks of a geranium crop grown in a gutter-connected greenhouse. An average of three whitefly-infested plants were observed each week in this 3,000 sq. ft. bay. The doors to the adjoining bays were kept closed, and pesticides were not applied until March 15. What was going on?

Table 7. Map of greenhouse and card counts



Whitefly Card Counts—House 3

Date	Card 1	Card 2	Card 3
7-Feb	0	0	4
14-Feb	0	0	5
21-Feb	0	0	7
28-Feb	0	0	15
7-Mar	0	1	18
14-Mar	0	1	20
21-Mar	3	5	5
28-Mar	0	0	0

On March 14, after he finished counting the cards, the scout looked behind the steam pipe near card 3 and saw a clump of about 20 weeds that were heavily infested with whiteflies. He pulled them and removed them from the greenhouse. He did not place them in a bag, so as he walked through the greenhouse, many of the insects were knocked off the weeds. Thus there were whitefly adults on all cards the following week. On March 15 the grower applied a wet spray to control

the adults, and no further card catches were recorded. (Remember, the insects counted on the 21st probably arrived there on the 14th, *after* the card was counted but before pesticides were applied.) This infestation might have been avoided if the scout had thoroughly inspected for weeds at the beginning of the season (photo 15).

Case Study 3: Importance of Early Intervention

This grower, as her poinsettia crop was finishing, brought 50 fuchsia cuttings into the greenhouse on December 12. The scout found the fuchsia cuttings to be infested with whiteflies. He also found weeds with whiteflies.

At this point, the cuttings should have been treated with a pesticide or discarded and replaced with clean plants, and the weeds should have been removed. Instead, nothing was done until December 19 to either the cuttings or the weeds (see table 8).

15. Whiteflies on greenhouse weed, J. Sanderson

Table 8. Whitefly counts and control measures used

Date	WF on YSC[1]	Whitefly Observations	Control Measures Used
12-5	18.5		
12-12	22.7	fuchsia cuttings and weeds infested with whitefly	
12-19	73.4	fuchsia cuttings infested with whitefly	12/19 Resmethrin
12-27	18.4		12/23 Resmethrin
1-2	11.6	many whitefly immatures seen on fuchsia	
1-9	-----		1/8 Marathon
1-16	8.0		
1-23	62.4		
1-30	95		
2-6	37		2/3 Plantfume 103
2-13	4		2/10 Plantfume 103
2-20	3.2		2/17 Plantfume 103
2-27	1.2		
3-5	4.2		
3-12	22		3-12 Threw out fuchsias

[1] WF = whiteflies; YSC = yellow sticky card

Results

The Resmethrin applications of December 19 and 23 caused some adult mortality, so the YSC count on December 27 was much lower than the previous week. The eggs laid by the high adult populations of December 12 and 19 were not affected by the Resmethrin. These are seen as immatures on plants on January 2, and as adults on the YSC on January 23. This scenario illustrates why pest management decisions should be based on *plant and YSC* observations. A small number of adults seen on cards January 2 and 16 did not mean the population was declining, only that immatures were the predominant life stage.

Marathon could not be applied earlier than January 8 because the cuttings did not have an adequate root system for uptake. It took four weeks for this application to noticeably reduce the adult whitefly population; a wet spray should have been used in the interim. The large number of adults still present in February, four weeks after the Marathon application, is due to the continued presence of weed hosts. Plantfume 103 did have an effect, although three applications were probably not necessary. The grower discarded the cuttings, on which many whiteflies could still be seen, on March 12. Whiteflies caught that day were moving up from the weeds on the floor.

If the grower had thrown out the infested cuttings and removed the weeds when they were first observed, several pesticide applications could have been avoided. Furthermore, the crop would not have to have been discarded because it was infested.

Case Study 4: Root Rot Management

A grower noted a few collapsing poinsettia cuttings during propagation and thought no more of it. Several weeks later, however, she began to lose dozens of transplants. The roots were soft and discolored, and brown cankers showed at the base of some stems (photo 16).

Determining the Source of the Problem

The grower took the following steps:

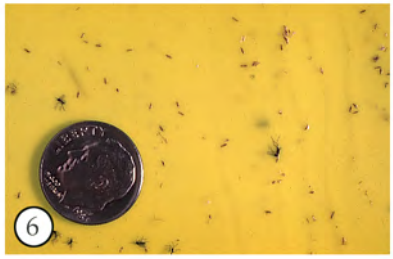
- Sent a sample to the diagnostic lab. Results showed that *Pythium aphanidermatum* was causing the transplant losses.
- Checked soluble salts in the media using a saturated media extract. Results indicated that salts were at EC 5.7 (excessively high).
- Examined sticky card counts, which showed that fungus gnat populations had quadrupled since the last count (1 month earlier).

16. Pythium root rot on poinsettia, J. Lamboy

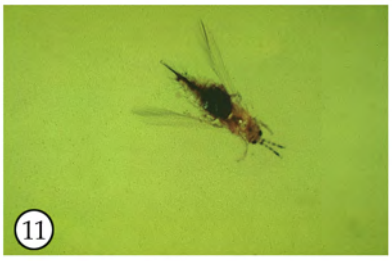
Addressing the Problem

Then the grower

- discarded plants with symptoms;
- irrigated poinsettias with only water for one week to reduce salt levels before resuming the regular fertilization program, thus making the root system less susceptible to *Pythium* attack. She tested the soil and, two weeks later, performed a foliar analysis to check the status of the micronutrients.
- treated the crop with a fungicide drench to protect against *Pythium;*
- drenched onto the surface of the growing medium a material effective against fungus gnat larvae. The reason? So adult fungus gnats would not be moving about the greenhouse spreading *Pythium.*
- permanently reconfigured the propagation area to eliminate puddling around the base of rooting strips. (Puddling would facilitate the spread of a fungus with swimming spores such as *Pythium aphanidermatum*).
- decided to make fungus gnat card counts on a weekly basis during poinsettia propagation, beginning two weeks before receiving cuttings;
- resolved to inspect the root health of the poinsettia crop regularly, sending in samples for diagnosis when appropriate.



6. Thrips, J. Sanderson



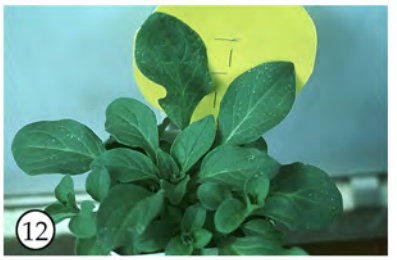
11. Thrips on yellow sticky card, S. Gill

VII. ARTHROPOD PESTS

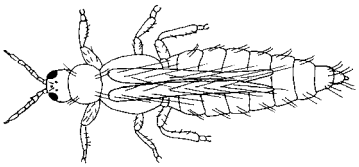
Table 9 summarizes how to monitor for and manage the arthropod pests found most often in the greenhouse. Details about each pest can be found in separate sections below, presented in the same order as in the table. We also encourage you to consult the references in the bibliography.

Western Flower Thrips *(Frankliniella occidentalis)*

The western flower thrips (WFT) is one of the most common pests in greenhouses (photo 6). It attacks chrysanthemums, cyclamen, African violet, portulaca, cineraria, impatiens, ivy geraniums, and many other crops (photos 11–13, 17). WFT can transmit impatiens necrotic spot tospovirus (INSV) and tomato spotted wilt tospovirus (TSWV), two viruses with a wide host range that includes most bedding plants.



12. Petunia indicator plant for thrips, M. Daughtrey



Actual size: –

13. Petunia 'Calypso' with thrips feeding injury, M. Daughtrey

Thrips eggs are inserted into plant tissue, where they are protected from natural enemies and insecticides. Larvae are sometimes seen on leaves, but more often feed in the protection of buds and leaf axils, which hampers control of these stages. The majority of WFT pupae are found in the soil. Adult WFT are typically found on foliage or in flowers.

17. Western flower thrips feeding on plant tissue and pollen, D. Gilrein

Table 9. Monitoring and management of arthropod pests

Arthropod Pest	Monitoring	Signs or Symptoms	Management
Western Flower Thrips	YSC just above crop canopy will detect adults; check plants during the growing season by tapping new growth and flowers onto white paper. Blow into the flowers first. Look for small (1/16 in.) light brown cigar-shaped insects with feathery wing margins and smaller yellow larvae.	Distorted or stunted new growth; white feeding scars on new growth or flowers that sometimes have small black specks (frass) on them. Geraniums will develop a symptom similar to oedema.	Eliminate weeds inside and establish a 15-foot weed-free border around the greenhouse. Do not carry over thrips-infested stock plants. Use 3 pesticide applications at 5-day intervals (warm weather) or 7-day intervals (cool weather). Rotate insecticide classes monthly.
Fungus Gnats	YSC just above soil surface for adults; potato slices (1.5 in. x 1 in.) on soil surface for larvae; these may attract mice. Favored by damp areas and organic material. Larvae are white with shiny black heads. Adults resem-ble small mosquitoes.	Cuttings may develop poor root systems from larval feeding. Young plants will be stunted or dead in severe cases.	Avoid overwatering and wet floors. Eliminate weeds. Clean up spilled media. Keep compost piles and other sources of microbial activity far away from the greenhouse. Use biological or chemical control.
Shore Flies	YSC. Adults can be distinguished by white spots on wings. Favored by damp areas and algal growth, which they feed on. Adults resemble fruit flies.	They do not directly injure plants but may carry several plant patho-gens. High populations can leave unsightly droppings on plants.	Control algae by controlling excess water and fertilizer runoff. If this is not effective, use chemical control.
Green Peach Aphid	Visual inspection of plants, since only winged adults will come to YSC. 1/16-1/8-inch long green to pink adults occur mainly on growing tips, especially on leaf undersides. Cornicles are light green; slightly darker than the body. Look for white shed skins.	Honeydew and sooty mold; dis-torted new growth. Green peach aphid is usually spread throughout the crop.	Avoid high N fertilization. Eliminate weeds, and do not keep aphid-infested plants in the greenhouse. Wash aphids off plants. Use biological or chemical control.

Table 9—*Continued*

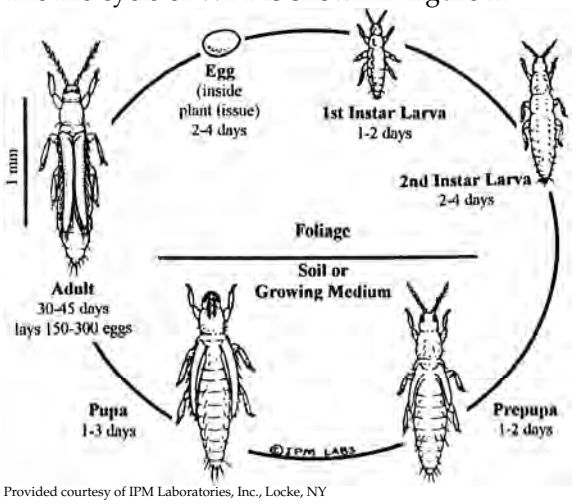
Arthropod Pest	Monitoring	Signs or Symptoms	Management
Melon/ Cotton Aphid	Small (1/16 inch) light yellow to dark green aphid with black cornicles. Usually seen on stems. Look for white shed skins.	Honeydew and sooty mold; distorted new growth. Melon/cotton aphid usually occurs in clumps within crop.	Avoid high N fertilization. Eliminate weeds, and do not keep aphid-infested plants in the greenhouse. Wash aphids off plants. Use biological or chemical control.
Two-Spotted Spider Mite	Visual inspection of plants, especially leaf undersides. Look first on plants in hot, dry areas or near doors and walkways.	Stippling on upper leaf surface, followed by yellowing and bronzing of foliage. Webbing may develop when high popula-tions are present. Ivy geran-iums will not exhibit stippling, but may develop oedema.	Avoid fertilizing plants that have mites. Wash leaves if air circulation will promote fast drying. Use biological or chemical controls.
Cycla-men Mite	Visual inspection of plants, primarily the growing tips. Mites are very small and are best seen with a dissecting microscope. This makes it difficult to detect them prior to onset of injury.	Distorted or stunted new growth. Blackened shoot tips. African violet, ivy, and clematis are common hosts.	Rogue out infested plants. Use chemical control.
Broad Mite	Same as cyclamen mite.	Bronzing of undersides of lower leaves and curling and stunting of new growth.	Rogue out infested plants. Use chemical control.

Table 9—*Continued*

Arthropod Pest	Monitoring	Signs or Symptoms	Management
Greenhouse White-fly (GHWF)	YSC for adults; visual inspection of plants for adults and immature stages. Turn leaves over to inspect for nymphs. Adults hold wings nearly flat over body.	Primarily a nuisance pest, but its presence detracts from the value of the plant. High populations can result in honeydew and sooty mold, and unmarketable plants.	Eliminate weeds and leftover poinsettias. Use chemical or biological control.
Silverleaf Whitefly	Same as greenhouse whitefly. Adults hold wings at an angle over body, giving them a narrower profile when viewed from above. Body color more yellow than GHWF.	Primarily a nuisance pest, but its presence detracts from the value of the plant. High populations can result in honeydew and sooty mold, and unmarketable plants.	Eliminate weeds and leftover poinsettias. Use chemical or biological control.
Mealybugs	Common on foliage plants. Visual inspection: Look for cottony white masses in leaf axils and on undersides of leaves.	Honeydew and sooty mold on leaves, followed by leaf yellowing and leaf drop at high populations.	Rogue severely infested plants. Wash off plants. Use biological or chemical control. Young nymphs are most susceptible to pesticides.

Western Flower Thrips, continued

The life cycle of WFT is shown in figure 2.

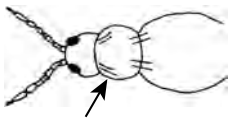
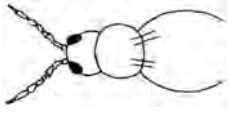


Provided courtesy of IPM Laboratories, Inc., Locke, NY

Figure 2. Thrips life cycle

The western flower thrips is generally the most abundant thrips species in the greenhouse. Occasionally other species may be present. It can be important to distinguish between these to know if the thrips present will vector tospoviruses. Although identifying thrips to species can be difficult, it *is* possible to separate *Frankliniella occidentalis* from thrips that are not in the genus *Frankliniella*. As shown in table 10, do so by examining the thrips body on the sticky trap, using a hand lens to look for setae (hairs) on the thorax.

Table 10. Comparison of Frankliniella and non-Frankliniella thrips

Frankliniella species	Non-Frankliniella species
	
Setae on the anterior (front) of the thorax	No setae on the anterior of the thorax

18. Western flower thrips with cast skin from pupal stage, D. Gilrein

19. Chrysanthemum daisy with thrips feeding damage, J. Sanderson

Plant Signs and Symptoms

Thrips damage usually appears as scarred, stunted, or distorted foliage or flowers, or as white areas on leaves or petals. Look for black fecal specks on damaged tissue (photo 19).

Monitoring

Inspect plants for signs of foliar or flower injury. This injury may have been caused by feeding on leaves or petals still in the bud stage, so injury can be apparent even though card catches are low.

Blow gently in flowers or on buds to draw out the hiding thrips. Tap sturdier plants over a white board or sheet of paper to check for an infestation. Use blue or yellow sticky cards to monitor adult activity. Adult thrips are attracted to open flowers and may be seen in much higher numbers there than on sticky cards. Thrips move through greenhouses on air currents, so cards should be placed in areas of air movement. Place them near openings, including ceiling vents. Cards can also be placed among plants suspected of harboring thrips.

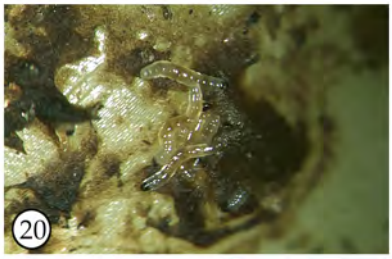
Management

- Adults are most active at the beginning and end of the day, so insecticides should be applied at either of these times for maximum effectiveness.
- Use a hydraulic sprayer that delivers a small particle size to reach thrips hidden in leaf axils or buds.
- Three applications seven days apart may be needed in cool weather, five days apart in warmer weather. Follow label directions.
- Rotate to a different class of insecticide each month.
- Eliminate weeds.
- Use biological controls.

Fungus Gnats (*Bradysia* spp.)

Organic-based growing media (including peat-lite or bark), compost piles, areas of high moisture, and weedy spots under greenhouse benches all favor fungus gnats. Adults are 1/8 inch long, black or dark brown, with long legs and antennae. Their clear wings have a distinctive Y-shaped vein. The adults

3. Fungus gnat, J. Sanderson



20. Fungus gnat larvae infesting Easter lily, D. Gilrein

may be mistaken for shore flies, which have short antennae and white spots on their wings. See table 10 for a comparison of fungus gnat and shore fly appearance (photo 3).

Fungus gnat larvae are usually found in the top inch of soil. They are legless and have a translucent body with a black head (photo 20). They grow to 1/4 inch in length before pupating. Larvae feed on fungi, organic matter, and the young roots and stems of cuttings, seedlings, and potted plants. The injury they cause can girdle young plants directly, as well as facilitate root and stem decay by fungi. Adult fungus gnats do no direct damage, but are annoying and can carry fungal spores between plants.

Plant Signs and Symptoms

Fungus gnat larvae can cause retarded plant development, wilted foliage (even with adequate watering), leaf yellowing, and leaf drop. Feeding injury will be visible on roots and stem bases.

Actual size: –

Provided courtesy of IPM Laboratories, Inc., Locke, NY

Monitoring

Place yellow sticky cards horizontally at soil level for maximum catch, or vertically just above the plant canopy for general monitoring. Inspect roots for feeding injury and disease. Insert slices of potato (approx. 1 sq. in.) far enough into the soil surface to cover the cut edges. This will attract larvae, which can be found feeding on the underside after about one day. You might see adult fungus gnats flying around the plants or media surface.

Management

- Keep floors as dry as possible; place gravel in low spots where water tends to accumulate.
- Keep compost piles away from the greenhouse.
- Clean up spilled growing media and eliminate weeds.
- Several biological or chemical management tools are available. Control larvae 3–5 days after cuttings are potted; control adults before propagating plants.

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Leafminers—Serpentine Leafminer, Pea Leafminer, and Vegetable Leafminer (*Liriomyza trifolii, Liriomyza huidobrensis, Liriomyza sativae*)

Three species of leafminer may infest bedding plants: the serpentine leafminer, the pea leafminer, and, less frequently, the vegetable leafminer. Chrysanthemum, marigold, petunia, and tomato are commonly affected. Leafminers tend to be more of a problem when the nitrogen level in plant tissue is high.

Plant Signs and Symptoms

The female deposits her eggs in leaf tissue, leaving small brown puncture wounds that may be mistaken for tospovirus lesions. Adults feed on plant fluids that exude from these wounds. The larvae of all leafminer species feed inside the leaves of their hosts, creating unsightly mines in the leaf tissue. Dark fecal material accumulates in the mine as the larva feeds. Larvae destroy cells as they feed, so heavily mined leaves can die and heavily infested plants can lose vigor.

Monitoring

Use yellow sticky cards for adults, and examine the foliage for oviposition punctures and larval mines (photos 4, 21). Sometimes the adults, which are small, black and yellow flies can be seen on the leaves.

Management

- Inspect incoming shipments of cuttings and destroy any that are infested.
- Use resistant varieties of chrysanthemum when feasible.
- Lay weed barrier fabric over soil floors to prevent adult leafminers from emerging after they have pupated in the soil). Cement floors also prevent some emergence.
- Use biological controls.

- Prevent resistance to chemicals. In many cases, Avid no longer effectively manages this pest. Use new materials in conjunction with nonchemical methods to help prevent resistance.
- Direct any chemical control at the larvae and spray when you observe them actively feeding in their mines. Leafminers drop out of the mine to pupate, so spraying mines after pupation will waste time and materials.
- Repeat any contact sprays used against adults every three to four days for about 10 days to kill those that emerge after the initial spray.

Shore Flies *(Scatella stagnalis)*

Adult shore flies spread pathogens within greenhouses and thrive in the same wet conditions that are attractive to fungus gnats. High populations of shore flies can be annoying. See table 10 for a comparison of shore flies and fungus gnats (photos 5, 22).

Table 11. Comparison of fungus gnats and shore flies

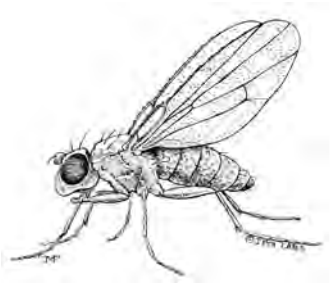
	Fungus Gnats	Shore Flies
Resemblance	tiny mosquito	tiny house fly or fruit fly
Legs and Antennae	long	short
Larva	clear to white; shiny black head	clear to white; no head capsule; forked air tube at posterior
Wings	clear, with a distinct Y-shaped vein	five light spots on each gray wing
Food Source	plants, organic material in soil; fungi	algae

4. Leaf miner flies, J. Sanderson

5. Shore fly, J. Sanderson

21. Serpentine leafmines on gerbera caused by Liriomyza leafminers, J. Sanderson

22. Adult shore fly showing whitish spots on wings, J. Sanderson



Provided courtesy of IPM Laboratories, Inc., Locke, NY

Actual size: –

Plant Signs and Symptoms

Large populations of shore flies leave quantities of unsightly dark specks (droppings) on flowers, foliage, and plant labels.

Monitoring

Watch for adults flying among plants or resting on leaves and flowers. Shore fly adults can be caught on yellow sticky cards placed horizontally just above the soil surface.

Management

- Adults and larvae feed on algae, so the best way to manage shore flies is to control algae.

Green Peach Aphid and Melon/Cotton Aphid *(Myzus persicae, Aphis gossypii)*

Two common species of aphids in greenhouses are the green peach aphid and the melon/cotton aphid. Other aphids occasionally found in greenhouses include the chrysanthemum aphid, the leaf-curling plum aphid, the cabbage aphid, the foxglove aphid, and the tulip bulb aphid. They commonly infest dahlia, impatiens, cineraria, chrysanthemum, lamium, and carnation (photos 23, 24). Aphids can vector viruses to their hosts.

Provided courtesy of IPM Laboratories, Inc., Locke, NY

Actual size: - to —

Aphids can blow into greenhouses through vents and doorways, be imported on clothing or infested plants and cuttings, or be maintained year-round on weeds. Aphids give birth to live young, so rapid population increase is possible. Appearances of the green peach aphid and the melon aphid are compared in table 11.

Table 12. Comparison of green peach aphid, melon/cotton aphid, and foxglove aphid

	Green Peach Aphid	Melon/Cotton Aphid	Foxglove Aphid
Color	light green; occasionally pink to orange	variable from light green, dark green to yellow	pale green
Cornicles (tailpipes) 	light green; slightly darker than the body, with black tips	black	green spot at base
Head (use hand lens to see profile of top of head)	 a indentation	 no indentation	 a indentation

Plant Signs and Symptoms

Infested plants have individuals or colonies, cast skins of molted aphids, honeydew, and sooty mold on plant leaves, and distorted or stunted new growth. Occasionally you may notice ants on aphid-infested plants.

Monitoring

Inspect incoming plant material, especially cuttings, for adults. Look at leaf undersides and buds of older, susceptible

23. Aphids and cast skins on chrysanthemum leaf, J. Sanderson

24. Aphids migrate from leaves to buds when flowers form, J. Sanderson

plants. Watch for cast skins, honeydew, sooty mold, and distorted or stunted growth. Green peach aphids tend to be spread throughout the crop, while melon/cotton aphids are often found in clumps of plants. Aphid adults have both winged and wingless forms. Only the winged aphids will come to yellow sticky cards, so do not rely on cards as an early indication of aphid infestations.

Management

Correct identification is important, as aphid species may differ in their susceptibility to insecticides. Green peach aphid and melon aphid, for example, are often poorly controlled with pyrethroid insecticides. Some biological controls work better against certain species of aphid as well.

There are a number of ways to avoid aphid infestations:

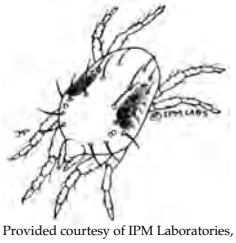
- eliminate weeds;
- do not move infested plants (such as perennials overwintered in a cold frame) to clean areas;
- remove infested growth;
- dispose of aphids by crushing them, vacuuming them, or blasting them off the plant with a jet of water;
- use spot treatments of insecticides;
- use biological controls;
- monitor fertilizers (high nitrogen often favors aphid population development).

Two-spotted Spider Mites *(Tetranychus urticae)*

Two-spotted spider mites (TSSM) attack many kinds of plants, including marigolds, impatiens, hydrangea, and ivy geranium. These mites can blow in from outside a greenhouse or move from older infested material to clean plants. They are easily spread by workers, so scout mite-infested areas *last*.

Plant Signs and Symptoms

Look for very fine stippling (chlorotic specks) on the upper surface of leaves, followed by yellowing or bronzing of the foliage (photo 25). Heavily damaged leaves can turn dry and defoliate. Stippling will not be seen on ivy geraniums, which may develop oedema in response to mite feeding. High populations of TSSM produce webbing, which will also reduce the attractiveness of the plant.



Provided courtesy of IPM Laboratories, Inc., Locke, NY

Actual size: .

Monitoring

When stippling is noted, inspect the undersides of older leaves for mites or webbing, or sharply tap the leaves over a sheet of white paper. The mites will appear as tiny moving specks that look like small spiders when viewed with a hand lens (photo 26). These mites prefer areas with low relative humidity and high temperatures, so check these areas first, as well as plants near doors and walkways. These mites turn slightly orange during the cool, short days of winter. Be sure not to confuse them with predatory mites, which run fast, are a darker orange, and are slightly larger.

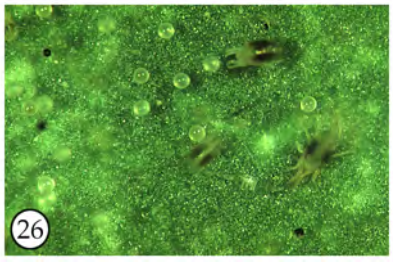
Management

- Control mites before applying fertilizers, as high nitrogen fertilization often favors development of TSSM populations.
- If you have a mite problem in an area of a greenhouse where air circulation is good and leaves will dry quickly, try washing the undersides of leaves to rid them of mites. (Washing leaves in areas of greenhouses where circulation is poor could promote diseases.)
- Use chemical or biological controls.

Tarsonemid Mites—Cyclamen Mite *(Phytonemus pallidus)* and Broad Mite *(Polyphagotarsonemus latus)*

These mites are visible only under high magnification, such as through a microscope. The cyclamen mite can cause severe damage to African violet, cyclamen, gloxinia, delphinium, vinca, New Guinea impatiens, and other plants (photo 28).

25. Spider mite damage to rose leaflet. Whitish specks are where mites inserted mouthparts and consumed chlorophyll, J. Sanderson



26. Tiny spider mites have eight legs; they are not insects, J. Sanderson

28. Damage to kalanchoe by cyclamen mites, M. Daughtrey

The broad mite occasionally attacks a number of greenhouse plants, including begonias and impatiens (photo 27).

Plant Signs and Symptoms

For evidence of the cyclamen mite, look for stunting or twisting of leaves and flowers, blackening and death of young growth, and leaves that are smaller and harder than normal. The cyclamen mite prefers higher relative humidity and lower temperatures than the TSSM, so check cool, moist areas first.

Broad mites will cause bronzing of undersides of lower leaves and curling and stunting of young growth.

Monitoring

These mites are so tiny that it is impractical to try to observe them. Keep careful watch for damage symptoms on common host plants. Confirm that the damage was caused by one of these mites by placing a leaf under a dissecting microscope, or by sending a sample to a diagnostic laboratory. Act immediately to minimize damage spread to nearby plants.

Management

- Remove infested plants as soon as they are detected.
- Some chemical and biological controls are available, but the effectiveness of available natural enemies has not been demonstrated.

Whiteflies—Silverleaf Whitefly, Greenhouse Whitefly, and Banded-winged Whitefly *(Bemisia argentifolii, Trialeurodes vaporariorum, Trialeurodes abutilonea)*

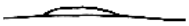
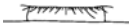
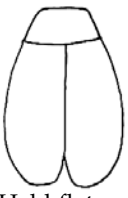
Three species of whitefly may infest bedding plants: the silverleaf whitefly (SLWF), the greenhouse whitefly (GHWF), and, less frequently, the banded-winged whitefly (BWWF). Whiteflies often remain in a greenhouse after the poinsettia season, living on weeds, hanging baskets, or stock plants.

27. Impatiens damaged by broad mite feeding on developing buds, D. Gilrein

Plant Signs and Symptoms

The presence of whiteflies can be objectionable, and heavy infestations can affect plant vigor. Sooty mold can grow on the honeydew they excrete. Bedding plant hosts include fuchsia, lantana, gerbera, geranium, ageratum, verbena, zinnia, cucumber, and tomato. The three whitefly species are readily distinguished by the appearance of the pupae and adults, as described in table 13.

Table 13. Comparison of silverleaf, greenhouse, and banded-winged whiteflies

	Silverleaf (SLWF)	Greenhouse (GHWF)	Banded-winged (BWWF)
Pupa	 Yellow; irregular sides without hairs	 White; regular sides with noticeable hairs	 Dark band along length of top
Pupa Side View			
Wing	 Held at a 45° angle; close to the body	 Held flat, parallel to leaf	 Two gray zigzag lines are visible

Monitoring

Use yellow sticky cards for adults (photo 7), and scout the foliage for immatures. Record the species and the life stages present on the plants; this information is needed to make whitefly management decisions.

7. Whiteflies on yellow sticky card, J. Sanderson

Management

- Eliminate weeds in and around greenhouses (photo 15); do not hold onto leftover poinsettias during bedding plant production.
- Whitefly eggs and pupae are tolerant to most insecticides. If eggs or pupae are the predominant life stage, withhold insecticide applications until the susceptible nymphal or adult stages are present. The adult whitefly is most susceptible to insecticides when it emerges from its pupal case (6 am–11 am). Determine stages by following whitefly development on sentinel plants; effectiveness of controls can be assessed this way as well.
- Several natural enemies are available for whiteflies, including parasitic wasps, predators, and insect pathogens. The parasitoids are species specific, so correct identification is important for this technique to be successful.

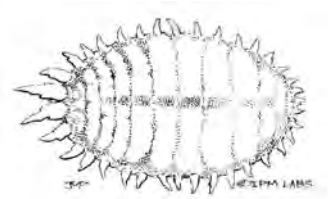
Longtailed Mealybug, Citrus Mealybug, Obscure Mealybug *(Pseudococcus longispinus, Planococcus citri, Pseudococcus affinis)*

The presence of fluffy, white masses on a plant is a sign of a mealybug infestation. The longtailed mealybug, the citrus mealybug, and the obscure mealybug attack dracaena, hoya, English ivy, calla lily, stephanotis, schefflera, poinsettia, and other greenhouse plants. Bedding plants are rarely affected; only plants produced from cuttings might encounter this pest. All immature stages and adult females are mobile, although slow moving; only adult males have wings and fly to mate.

Mealybugs are soft-bodied insects, 1/8 to 1/4 inch long. Their bodies are covered with a white waxy secretion; egg masses are covered with a fluffy white material. A long tail is usually visible on the longtailed mealybug.

15. Whiteflies on greenhouse weed, J. Sanderson

Plant Signs and Symptoms



Provided courtesy of IPM Laboratories, Inc., Locke, NY

Actual size: - to ——

Mealybugs infest all aboveground parts of a plant, although root mealybugs are occasionally seen on the roots of some plants. The white, cottony egg masses and bodies of the mealybugs are objectionable, and infested new growth is sometimes distorted. Mealybugs also leave deposits of honeydew, followed by the growth of sooty mold. Heavy infestations cause yellowing and leaf drop.

Monitoring

Check for early infestations—visible as scattered white flecks or cottony residue—on leaf axils, along leaf midribs, and on the undersides of leaves. Mealybugs tend to be more of a problem on older plants and vegetatively propagated material.

Management

- Young crawlers (nymphs) are more susceptible to chemical treatment than are other life stages.
- Apply spot treatments of registered insecticides.
- Use biological controls.
- Destroy infested plants.

Occasional Insects

Several other insects may occasionally be seen in the greenhouse. These include **drain flies** (also called moth flies), **tarnished plant bugs**, **caterpillars**, and **European corn borers**. The first is a nuisance pest, whereas the others can injure crops.

Drain flies, which are caught on yellow sticky cards, are aphid-sized, with light brown bodies and fuzzy wings. They may often be seen in high numbers. They are eliminated by cleaning out drains, where they breed.

Tarnished plant bugs enter the greenhouse through openings, primarily in the spring and late fall, when a warm

greenhouse is attractive. The adults are 1/4-inch long, bronze with light markings. Feeding injury appears as death of new terminals, distorted buds that die before opening, or small (1/8-inch) dark circles that may be mistaken for leaf spots. These insects overwinter under rubbish, weeds, or plant material outside the greenhouse. Remove this material and use chemical control to manage this pest.

Many species of **caterpillars** may also occur as occasional pests in the greenhouse. These include loopers, armyworms, cutworms, leaftiers, and leafrollers. These insects enter on infested plant material or as adult butterflies or moths. Adults of some species are attracted to the lights in the greenhouse. These insects are often very small (1/8-inch) when they first hatch, so plants need to be inspected carefully for their presence. Damage may render plants unmarketable if not detected early. Types of injury include leaf eating; feeding on growing points, causing excessive branching; webbing, tieing, or rolling together of leaves; and plants cut off at the base. Management includes biological control with the biopesticide *Bacillus thuringiensis kurstaki* (Dipel, MVP, or MVP II) and chemical control.

European corn borer in its larval stage bores into stems of succulent new growth, causing plants to collapse. Pheromone traps can be used to monitor the adults. Do not use blacklight traps inside a greenhouse to monitor these insects, as they can attract adults into the greenhouse, where they can lay eggs.

VIII. CONTAGIOUS DISEASES

Unlike growers of outdoor crops, greenhouse growers are able to control many aspects of a plant's environment to favor production, including the growing media, temperature, light, humidity, and pest access. An upset in one or more elements of this balancing act can favor the pathogens, encouraging contagious diseases. An imbalance might also lead to noncontagious, stress-related disease.

Managing bedding plant diseases in greenhouses requires some knowledge of four interacting elements that allow a problem to develop:

- a pathogen
- a susceptible host plant
- environmental conditions conducive to disease
- time for the problem to develop

To illustrate, some organisms—such as *Botrytis cinerea*—are probably present in every greenhouse, but infections occur only when plant surfaces are wet for extended periods of time. Therefore, growers need to be attentive to moisture and relative humidity levels, use clean plant material, sterilize the soil, use clean pots and tools, and monitor regularly. When handling diseased seedlings, wash your hands before touching healthy plants. If a disease cannot be easily identified, contact the nearest Cooperative Extension office, or send the sample to the Cornell Diagnostic Laboratory (see the bibliography).

Pathogenic fungi, bacteria, and viruses cause the most common contagious bedding plant diseases.

Damping-Off Fungi(*Pythium* spp., *Rhizoctonia solani, Botrytis cinerea*)

Damping off, a seedling problem, is familiar to most growers. Although this disease may be caused by thirty or more species of fungi, the most common agents are *Pythium* spp. and *Rhizoctonia solani*. Seedlings may be killed before emergence, usually by *Pythium*, or attacked at the soil line, usually by *Rhizoctonia* (photo 29). *Botrytis* attacks foliage or stems.

Plant Signs and Symptoms

Look for seedlings that fail to emerge *(Pythium* activity) or that fall over and are accompanied by fine, web-like strands of fungus *(Rhizoctonia*). Watch for greyish powdery sporulation where the stem is cankered *(Botrytis cinerea*). Single plants, circular areas, or entire flats can be affected as the pathogen spreads from a central point.

Monitoring

Each week, while walking along benches or aisles, scan flats of young plants (to about the 8-leaf stage). Note areas affected and severity, and flag flats with damping off.

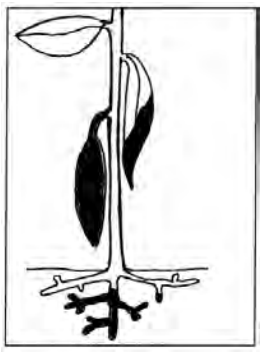
Management

- Sanitize equipment, flats, and benches.
- Use treated seed to avoid problems prior to seedling emergence (fungicide drench treatments at seeding may reduce germination).
- Improve air circulation to reduce problems with Botrytis blight and Rhizoctonia web blight.
- Spot treat known problem species.
- Discard heavily infested flats to avoid problems with root rot disease on transplants.

29. Rhizoctonia damping off of vinca, M. Daughtrey

Root Rots Caused by Various Fungi

Many of the same fungi that cause damping-off can also affect more mature plants. Pythium root rot attacks root tips, major roots, and stem bases, causing a black or dark brown canker or rot (photo 30). *Rhizoctonia solani* can grow upwards from the soil surface during very humid conditions (such as in a dense impatiens canopy), attacking plant stems and leaves and causing a web blight. *Fusarium* spp. can cause root rot when drainage is poor, calcium levels are low, and ammonium nitrogen levels and temperatures are high. *Phytophthora* spp. and *Thielaviopsis basicola* may also cause root rots.



Plant Signs and Symptoms

Infected plants are weak, off-color, wilting, stunted, or falling over. Look for the web-like strands of the fungus *Rhizoctonia solani* within the plant canopy. Affected roots will have black or brown rotten areas or a cortex that is sloughing off. Roots attacked by *Thielaviopsis* are stunted and blackened.

Monitoring

Scan plants and flats weekly. Watch for continually soggy media. Randomly select plants and gently dislodge them from the flat or pots, looking carefully at the roots for symptoms of disease. Monitor fungus gnats and shore flies, which can carry spores between plants. This is especially important in propagation houses. Test soluble salts levels weekly to ensure that conductivity levels are below 1.5 µS (microsiemens).

Management

Infection is favored by poor drainage or other cultural stresses to the root system, particularly high levels of soluble salts and high fertility. To manage root disease problems caused by fungi

- rogue diseased seedlings;
- use pasteurized, well-drained potting media;
- avoid high-ammonium nitrogen fertilizers;

30. Geranium root system with Pythium root rot, M. Daughtrey

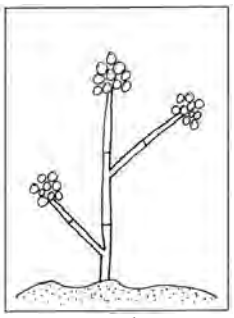
- keep watering nozzles off the ground;
- manage fungus gnats and shore flies, since they can carry disease spores;
- use a fungicide drench at transplanting that is specific to the pathogen.

Foliar Diseases Caused by Fungi

Only a few foliar diseases are common problems to bedding plant producers.

Botrytis Blight

Botrytis blight *(Botrytis cinerea)* can attack the tissues of bedding plants that are wet for longer than four hours. Although dead tissue is most susceptible, even healthy foliage, flowers, stems, or seedlings can be affected.



Botrytis sporulation

Monitoring. Scan the crop, especially where canopies are dense. Inspect stems for dieback, stem cankers, and the characteristic powdery gray spores near affected areas (photo 31). Dieback and gray mold may also be apparent on leaves.

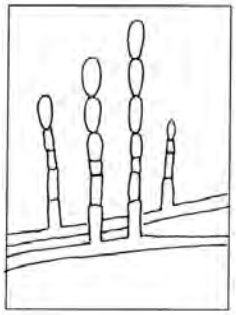
Management. Botrytis blight is managed by sanitation and environmental control. Water plants in the morning so leaves will be dry by night. Improve air circulation, and heat and ventilate at dusk to avoid overnight condensation. Remove infected leaves, petals, or plants in plastic bags. Pay attention to dead leaves and petals falling from hanging baskets. If possible, avoid problem-prone cultivars.

Powdery Mildew

Early monitoring for powdery mildew could help a grower prevent an epidemic. Powdery mildew is spread by spores that blow from nearby plants. There are many species of powdery mildew in the greenhouse, and these affect different

plant hosts. Because this disease is fairly host specific, it will not spread to adjoining crops of different species.

Fluctuating temperatures and high humidity (but not wet foliage) seem to favor disease development. Symptoms in vegetatively-propagated petunias mimic nutrient deficiency.



Powdery mildew sporulation.

Monitoring. In your routine scouting, look for white, powdery coating on foliage (use a hand lens to help you distinguish the fungus from spray residue). On highly susceptible plants, such as begonia and gerbera, examine leaf spots with a hand lens for powdery mildew mycelia. Pay attention to areas with fluctuating temperatures and poor air circulation.

Management. Encourage the grower to
- keep temperatures as consistent as possible;
- maintain good air circulation.
- keep greenhouse humidity below 85% RH

Alternaria Leaf Spot (Alternaria spp.)

This disease on common impatiens may be confused with impatiens necrotic spot virus or a bacterial leaf spot caused by *Pseudomonas syringae*. Marigolds and zinnias are also subject to Alternaria leaf spots (photo 32). Alternaria fungi are sometimes seed-borne.

Plant Signs and Symptoms. On impatiens, lesions are uniformly round, 1/8" in diameter, and scattered across the leaf. They have dark rims with a tan center; affected leaf areas often turn yellow (photo 33).

Monitoring. Inspect common impatiens as part of your regular scouting routine. This disease can show up early in production.

Management. Certain practices are effective.
- Rogue infected plants.
- Avoid prolonged wetness.

31. Botrytis leaf spot on geranium initiated by petal tissue, M. Daughtrey

32. Alternaria leaf spot of zinnia, T. Zitter

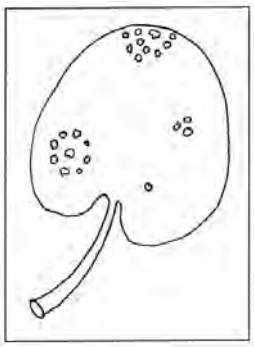
33. Alternaria leaf spot on impatiens, M. Daughtrey

- Avoid thiophanate-methyl fungicides, which can worsen an existing problem.

Geranium Rust (Puccinia pelargonii-zonalis)

This disease occurs infrequently, but the fungus is easily spread by splashing spores when it is present (photo 34).

Plant Signs and Symptoms. Yellow spots appear on upper leaf surfaces, followed by concentric rings of reddish brown spores on leaf undersides.



Monitoring. This is a serious disease, so incoming shipments should be inspected before they enter the greenhouse. Ivy and Martha Washington geraniums are not affected.

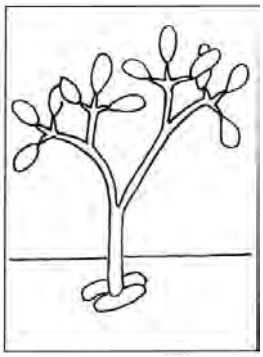
Management. To prevent geranium rust

- avoid extended foliar wetness;
- follow the other practices noted above for Botrytis blight;
- use systemic and contact fungicides labeled for this disease.

Downy Mildew (Peronospora and Pseudoperonospora spp.)

Plants become systemically infected with this fungus.

Signs and Symptoms. Under humid conditions, look for beige to violet spores on the undersides of leaves. Foliage may be distorted. Snapdragon seedlings infected by downy mildew are quite stunted, and the growing tips may be chlorotic (yellowed or blanched). Infected pansies show yellowing or purpling of leaves that makes them appear to have a nutrient deficiency. Salvia, lisianthus, and roses are also susceptible to downy mildew diseases.



Sporangia of downy mildew on leaf surface.

Monitoring. Look for this disease on snapdragons and pansies when scouting. The downy mildew species that infects snapdragons is different from the species that affects pansies, so snapdragons would not be at risk from adjacent infected pansies.

Management. The best practice is to destroy infected plants. Preventive sprays require weekly treatment with excellent coverage.

Foliar Diseases Caused by Bacteria

Bacterial Blight of Geranium (Xanthomonas campestris pv. *pelargonii)*

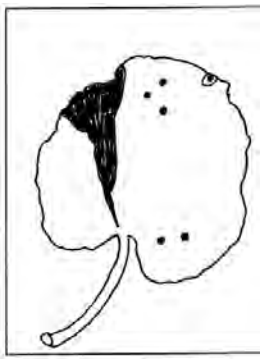
Because geraniums are an important crop, bacterial blight can be an extensive, serious problem. Symptoms are difficult to detect during winter months, but as temperatures rise in the spring and overhead watering begins, they become more obvious. Bacteria, spread from plant to plant by splashing water or handling, enter the plant through wounds or stomata. Cuttings from infected plants can carry the pathogen as well.

Plant Signs and Symptoms. Small brown spots appear on foliage (1/16–1/8 inch diameter), often with yellow halos. Sometimes the spots appear in a V-shaped brown wedge (photo 36). Entire plants or perhaps only a leaf or stem may show wilting. Wilting without leaf spotting may indicate another bacterial disease, Southern wilt *(Ralstonia solanacearum)*.

34. Rust pustules on the underside of a geranium leaf, M. Daughtrey

35. Fuchsia rust, M. Daughtrey

36. Bacterial blight on geranium, M. Daughtrey

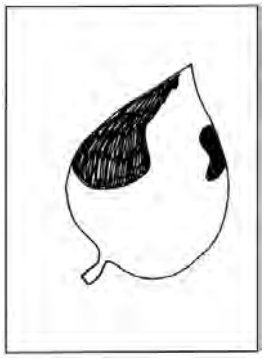


Monitoring. Look for the symptoms among the foliage. Since seed-grown plants are less likely to have the disease, watch cutting-grown crops most carefully. Check roots to rule out Pythium root rot. Roots are generally not discolored when plants are wilting from bacterial blight or Southern wilt.

Management. To manage this disease
- use culture-indexed cuttings;
- grow cuttings separately from seed crops;
- do not grow ivy geraniums over zonals;
- separate plants from different suppliers;
- after obtaining a positive laboratory diagnosis, discard infected plants (they do not recover).

Pseudomonas Leaf Spot (Pseudomonas syringae)

This leaf spot disease, seen most often on common impatiens and New Guinea impatiens, is of minor importance unless conditions are wet. Pseudomonas leaf spot may be confused with Alternaria leaf spot on common impatiens or with INSV on either common or New Guinea impatiens. Geraniums (particularly seed geraniums) also may develop Pseudomonas leaf spot or another bacterial leaf spot caused by *Acidovorax* sp.



Plant Signs and Symptoms. Impatiens leaves will develop brown spots that are 1/8 inch (or more) across, with tan centers, sometimes encompassing an entire leaf (photo 37). They are often associated with a leaf hydathode (water pore) on the edge of a leaf. The infected area may have a greasy, water-soaked appearance that is often associated with bacterial disease.

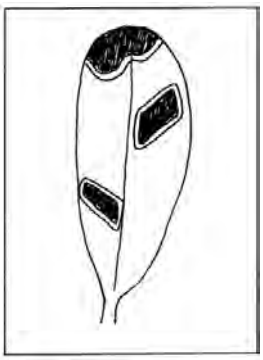
37. Pseudomonas leaf spot on impatiens, M. Daughtrey

Monitoring. Inspect all impatiens as part of your regular monitoring.

Management. To help prevent this disease
- avoid splashing water on the crop;
- water early in the day so foliage dries before nightfall.

Bacterial Leaf Spot of Zinnia (Xanthomonas campestris pv. zinniae)

The pathogen causing this disease is spread in seed and then moved from plant to plant by splashing water and handling. A leaf spot on zinnia caused by *Alternaria zinniae* has similar symptoms and is often confused with bacterial leaf spot. Its effects are also lessened by minimizing foliar wetness.



Plant Signs and Symptoms. Diseased seedlings show small, angular brown spots with yellow halos.

Management. If this problem is observed
- water zinnias early in the day;
- avoid splashing (try subirrigating);
- destroy infected material;
- use treated or surface-sterilized seed.

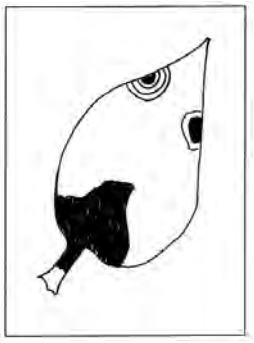
Bacterial Leaf Spot of Begonia (Xanthomonas campestris pv. begoniae)

This leaf spot disease is rarely a problem in begonias grown from seed, but is sometimes quite damaging in vegetatively produced begonias.

Viral Diseases

Tospoviruses

Impatiens necrotic spot tospovirus (INSV) and tomato spotted wilt tospovirus (TSWV) are two important plant viruses that are transmitted by thrips. These viruses can also be carried in infected cuttings or tubers, such as dahlia or ranunculus. INSV is the predominant virus affecting bedding plants. More than 550 species of plants are recognized as hosts of TSWV, and the number of INSV host species appears to be as large. Of all bedding plants tested, only geraniums appear to be resistant. Symptoms reported for zonal geranium are relatively mild, and infection has not led to geranium crop losses. Ivy geraniums, which are favored by thrips, have on rare occasions shown yellow ring spots when infected by TSWV. Infected, symptomless weeds can serve as reservoirs of the virus in and around greenhouses.



Plant Signs and Symptoms. The two viruses show similar symptoms, but these can be quite varied. They include brown or black spots on leaves; yellow, black, or necrotic rings or oakleaf patterns on the leaves, stems, or flowers; wilting or stunting; tip dieback; and a chlorotic mottle or mosaic on foliage (photos 38-40). Symptoms of INSV or TSWV may not be apparent in infected plants, but these symptomless plants may still be a source of the virus for thrips.

A few species and cultivars will show symptoms within two or three days if infected, whereas others, such as cyclamen, may not show symptoms for as long as two months.

Monitoring. Keep track of thrips. Scan the crop regularly, and randomly select plants known to be highly susceptible, looking closely at stems and leaf petioles. Inspect new plants for thrips or virus infection as they are brought into a greenhouse.

Indicator plants can also be used to detect the presence of thrips carrying the tospoviruses INSV or TSWV. These plants will develop viral symptoms within one week if fed on

by infected thrips. The petunia cultivars 'Red Cloud,' 'Summer Madness,' and 'Super Magic Coral' have all been shown to work as indicators for tospoviruses, while any variety of fava bean may be used. Viral symptoms on these plants are described in table 14.

Table 14. Symptoms of tospoviruses on indicator plants

PETUNIA	FAVA BEAN
Circular tan to brown lesions, 1/8" to 1/4" across, on leaves around thrips feeding scars. Lesions usually have a dark brown to black border.	On leaves, yellow to light green ring spots surrounding thrips feeding scars. Angular brown lesions on leaves. (Do not confuse these with black spots on stipules, which are normal.) Dark necrotic areas on stems.

Place indicator plants every 20 to 30 feet along a greenhouse bench in areas of air movement. Attach a non-sticky blue card or blue plastic plate to each plant to increase its attractiveness to thrips. Discard and replace indicator plants if viral symptoms are seen.

In addition to using these plants during the bedding plant season, when susceptible crops such as impatiens or tomatoes are being grown, you should place indicator plants in a greenhouse before the spring crop arrives. Petunias or fava beans placed in a fall poinsettia crop that is to be followed by a susceptible crop can signal a problem before the crop is exposed. Strategies for using indicator plants to detect tospoviruses are summarized in table 15.

38. Impatiens necrotic spot virus (INSV) on impatiens, M. Daughtrey

39. Black rings around thrips scars on petunia due to INSV, M. Daughtrey

40. Dahlia with tomato spotted wilt virus (TSWV), M. Daughtrey

Table 15. Strategies for using indicator plants to detect tospoviruses

How to Use the Indicator Plant	Action if Virus is Detected
Place in a nonsusceptible crop, such as poinsettias, that is to be followed by a susceptible crop.	Control thrips during a fallow period or consider not using this greenhouse in the spring if the virus is detected in the fall. Eliminate weed hosts of the virus.
Place in a susceptible crop.	Control thrips and do not move plant material in or out of a greenhouse where the virus has been detected.
Confirm the presence of the virus even when thrips populations are so low that sticky cards are not detecting them. Only one infected thrips is needed to transmit the virus.	Control thrips and do not move plant material in or out of a greenhouse where the virus has been detected.
Place in a greenhouse after infected plants are removed.	If indicator plants show symptoms, continue thrips control and do not move plants into that greenhouse until it is "clean."

Management. Management practices for the two viruses are identical. Plants infected with the virus cannot be cured.

- Do not keep virus-infected material in a greenhouse from year to year.
- Keep plants suspected of carrying thrips or the virus away from other susceptible plants until they can be tested.
- Continually eliminate weeds from greenhouses.
- Control thrips.

Other Viruses

Viruses other than tospoviruses are rarely encountered on bedding plants. To monitor for other viruses while scouting, watch for virus-like symptoms such as ring spots, chlorotic mottle, line patterns, mosaic, distortion, or stunting. Problems are more likely in vegetatively propagated crops, but there are some viruses —cucumber mosaic virus (CMV), tobacco ringspot virus (TRSV), and alfalfa mosaic virus (AMV), for example—which may be seedborne.

Chlorotic spotting and ringspots, seen occasionally in zonal geraniums, are due to pelargonium flower break and possibly other viruses that are not excluded by virus-indexing programs. Symptoms of these viruses on geraniums are generally minor and become less pronounced in the spring, as the greenhouse becomes warmer and plants are growing more vigorously.

Vegetatively propagated petunias have shown stunted foliage and chlorotic mottling when infected by a complex of viruses including alfalfa mosaic (AMV), potato virus Y (PVY), and tobacco mosaic (TMV). AMV and PVY are spread by aphids. The tobacco mosaic virus may be spread by handling plants.

To manage viruses, rogue individual symptomatic plants and always keep potential insect vectors (especially green peach aphid and melon/cotton aphid) under control. Utilize virus-indexed stock whenever it is available. Before discarding large numbers of plants that you suspect are being damaged by a virus, send a sample to a diagnostic lab for testing.

IX. WEEDS AND ALGAE

Weeds in and around the greenhouse serve as hosts for whiteflies, mites, aphids, and thrips, and as reservoirs for tospoviruses. Algae serves as food for shoreflies. Weeds or weed seeds can be introduced into greenhouses in plant material or on tools, equipment, or people. Seeds can blow in through vents or other openings, and some perennial weeds can grow under a greenhouse foundation from the exterior. Even crop seeds or plugs that are dropped on a greenhouse floor can become weeds.

Monitoring

With each scouting visit, inspect greenhouse interiors for weeds and algae. Checking both of these sources for insects at the same time will help you locate insect reservoirs. Be sure to record these observations on a scouting form (see appendix). Small numbers of weeds should be pulled by hand as you scout. Inspect the exterior several times during the growing season to catch developing weed problems while they are minor. A winter inspection of greenhouse exteriors when there is no snow cover can give you an idea of the size of the previous summer's weed population (based on the number of dead weeds).

Weed Management

Greenhouse interior

- Use concrete floors or weed barrier fabric to prevent weed growth on floors.
- Use sterilized soil.

- To remove weed seeds, clean tools or equipment that have been outside.
- Pull new weeds by hand as soon as they are observed.
- Use herbicides labeled for greenhouse interiors.

Greenhouse exterior

- Control weeds with herbicides or by mowing. Close greenhouses vents during application to prevent drift into a greenhouse.
- Maintain a weed-free barrier around a greenhouse by removing all weeds and installing a weed barrier fabric covered by gravel.

Algae Management

- Eliminate excess moisture and plant debris, which favor algal growth.
- Thoroughly remove algae between crops. Clean floors, walls, and benches. A power washer (high-pressure nozzle) can be helpful.
- Use registered algicides.

X. NONCONTAGIOUS DISORDERS

Adverse growing conditions can cause symptoms that mimic contagious diseases but are not caused by a pathogen. For example, leaf spotting from a misapplied spray or root damage resulting from high levels of soluble salts are common symptoms mistaken for diseases caused by a pathogen. A cultural history is often the key to interpreting symptoms of plant damage. In a few cases, it will be difficult to make an accurate determination without a formal laboratory diagnosis that includes an analysis of the soil or the foliage.

Spray Injury

Spray applications of pesticides, growth regulators, and fertilizers can cause plant injury if applied to sensitive plants, at excessive rates, or under the wrong conditions. Some plant responses to common treatments are actually *not* problematic, such as the yellowing of geranium leaves following Cycocel (a growth regulator) application. In this case, the injury is temporary and not harmful to the crop. Certain cultivars may exhibit this response, while others will be unaffected.

Plant Signs and Symptoms

Plants will show brown spotting, a faint yellowish mottling, leaf edge burn or yellowing, or bronzing of leaf undersides. Spray damage can appear within hours of treatment or a few days later. Petals, buds, and young growth are usually most susceptible to injury and may become twisted or distorted when they fully expand.

Monitoring

Inspect crops visually, noting locations of symptoms on plants and distribution of injury throughout each crop. Spray injury

will usually appear quickly, with all plants showing symptoms simultaneously. It differs from contagious disease development, where symptoms develop over time and only a limited number of plants are infected initially.

Management

If you suspect spray injury,

- review the materials and application methods, rates, timing, and frequency with the applicator;
- monitor environmental conditions such as high humidity, wet foliage, or temperatures above 85°F—all of which can lead to the development of spray injury;
- be sure that plants are not stressed. Plants under stress are generally more prone to injury than healthy plants.

Excess Soluble Salts

Soluble salts can build up in the growing media. You will find this particularly in crops receiving regular fertilization, where the mineral content of the water is high and there is little or no leaching. High levels of soluble salts reduce water uptake and are toxic to root tissue.

Plant Signs and Symptoms

Root tips desiccate, collapse, and turn brown, reducing plant water uptake. Results can be wilting, marginal chlorosis (yellowing) or necrosis (tissue death), stunting, and invasion by pathogens.

Monitoring

Look for this injury first in areas where pots or flats dry out, such as at the ends or sides of benches. Knock several plants out of their pots or flats to see whether plant roots are healthy and white. Discolored and collapsed root tips may be the result of root rot caused by a pathogen such as *Pythium* or root desiccation caused by high levels of soluble salts. Monitor soluble salts regularly.

Management

If high soluble salts are detected in the growing medium

- leach with dilute fertilizer solution or clear water;

- adjust the crop's fertilization program and watering practices.

Problems with pH

The three most frequently encountered problems related to pH in bedding plants are iron/manganese toxicity (which occurs when the pH value is lower than 5.8); iron, manganese, copper or zinc toxicity (which occur when the pH value is higher than 6.2); and boron deficiency, caused by low levels of micronutrient amendments in the substrate or soluble fertilizer.

Plant Signs and Symptoms

Low pH. When grown at an excessively low pH, French dwarf double or Signet-type marigolds exhibit stunting and purplish flecking on leaves. This is caused by iron-manganese toxicity. Zonal geraniums are also sensitive to very low pH. For example, 'Aurora' is a cultivar that shows brown flecking, necrotic margins, and chlorosis (yellowing) on the lower leaves, which is again a response to excessive uptake of iron or manganese. Many other zonal geranium cultivars may show this same response to excess iron or manganese.

High pH. Symptoms caused by lack of micronutrients or high pH (which makes micronutrients unavailable) are listed in table 16.

Monitoring

Check pH levels regularly, especially in sensitive crops, to make sure they are within the acceptable range. Micronutrient levels are monitored by plant leaf analysis.

Management

- Raise the pH to 5.8–6.2.
- Change the fertilizer program to products that raise pH, or treat with lime (1 teaspoon dolomitic lime per 6-inch pot) to improve crop health.
- Apply 1 to 2 pounds potassium carbonate or potassium bicarbonate to 100 gallons of water; mix, and let sit overnight. Water with the supernatant the next day for a

rapid, short-term increase in pH. Or add 1 pound hydrated lime to 100 gallons of water, mix, and let sit overnight. Water with the supernatant the next day for a rapid, short-term increase in pH.

Nutrient Toxicities and Deficiencies

Inadequate or excessive levels of plant nutrients can cause a variety of symptoms that affect bedding plant growth and appearance. These problems are caused by improper fertilization, irrigation water with incorrect pH or alkalinity, or incorrect soil pH and soluble salts.

Plant Signs and Symptoms

The following three tables list symptoms associated with inadequate or excessive levels of nutrients. The first lists macronutrient deficiencies in bedding plants; the second lists micronutrient deficiencies in bedding plants; and the third lists toxicity symptoms caused by excessive levels of nutrients.

Monitoring

Look for these problems during routine scouting. Regular measurements of pH and salts will signal the onset of soil conditions that could favor development of these toxicities and deficiencies.

Table 16. Macronutrient deficiency symptoms for several crops

	Nutrient[1]					
	N	**P**	**K**	**Ca**	**Mg**	**S**
SYMPTOM						
Whole Plant						
Stunted	BMP G[2]	BM PG	BM PG			
Defoliated	G		G			
Off color		P				
Deep green						
Dull green		G				
Pale green						G
Branching, compact growth, short internodes			M			
Leaves						
Young (upper) leaves						
Chlorosis						
Whole leaf	BG					
Interveinal						
Tips				G		
Necrosis (dead areas)				G		
Tips						
Margins						
Vein tops						
Reddeing/ bronzing						
Whole leaf		BG				
Cupping/curling						
Downcupping						
Upcupping				G		
Older (lower) leaves						
Chlorosis						
Whole leaf	BMP	PG	BG			
Margins						G
Interveinal					PG	
Necrosis (dead areas)	P	P				
Whole leaf						
Margins			PB			
Tips			G	BM		
			G			
Reddening/ bronzing	G	G				
Whole leaf	BMG	BMG				
Margins						
Cupping/curling						
Downcupping			M			

[1]N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur [2]B = begonia; M = marigold; P = petunia; G = general crops. Used with permission from *Water and Nutrient Management for Greenhouses,* published by NRAES-56, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701; 607-255-7654.

Table 17. Micronutrient deficiency symptoms for several crops

	Nutrient[1]					
	B	**Mn**	**Cu**	**Fe**	**Zn**	**Mo**
SYMPTOM						
Whole Plant						
Stunted						
Defoliated						
Off color						
Deep green	G[2]					
Dull green						
Pale green						
Branching, compact growth, short internodes	P				G	
Leaves						
Young (upper) leaves						
Chlorosis						
Whole leaf	PG			G		
Interveinal		PG	G	PG	G	
Tips				G		
Necrosis (dead areas)						
Tips						
Margins	PG					
Vein tops						
Cupping/curling						
Downcupping	G					
Upcupping						
Older (lower) leaves						
Chlorosis						
Whole leaf	P					
Margins						
Interveinal						
Necrosis (dead areas)						
Whole leaf						
Margins/Tips						
Reddening/ bronzing						
Cupping/ curling						

[1]B = boron; Mn = manganese; Cu = copper; Fe = iron; Zn = zinc; Mo = molybdenum; [2]G = general crops; P = petunia**;** Used with permission from *Water and Nutrient Management for Greenhouses,* published by NRAES-56, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701; 607-255-7654.

Table 18. Nutrient toxicity symptoms

Excess Nutrient	Salt Injury[1]	Nutrient Deficiency[2]	Chlorosis	Necrosis	Other
N[3]	yes				
NH_4			Lower leaf margins		Orange-brown root tips
P		Fe, Zn, Cu, Mn			
K		N, Ca, Mg			
Ca		K, Mg, B			
Mg		Ca			
S					
B				Lower leaf margins	
Mn		Fe		Tips or across leaf	
Fe		Mn	Upper leaves	Small spots	
Cu		Mn			
Zn					
Mo					
Other				Leaf margins	

[1]Injury to root system resulting in wilting and leaf curl

[2]Caused by interaction with excess nutrient

[3]N = nitrogen; NH_4 = ammonia; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Mn = manganese; Fe = iron; Cu = copper; Zn = zinc; Mo = molybdenum

Used with permission from *Water and Nutrient Management for Greenhouses,* published by NRAES-56, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701; 607-255-7654.

Injury from Air Pollutants

In the cool temperatures at the beginning of the bedding plant season, unvented space heaters frequently injure plants. Smokestacks that are not tall enough may also cause phytotoxic fumes to be pulled back into a greenhouse through the vents. The resulting sulfur dioxide (if the fuel contains sulfur) may cause bleached or dead areas between the leaf veins of sensitive bedding plants.

Ethylene, a gas that can result from incomplete combustion of fossil fuels, is sometimes formed in greenhouses when burners have insufficient oxygen. Ethylene can cause various plant symptoms, including distortion of terminal growth, inhibition of the apical meristem, flower drop, and leaf chlorosis. Tomatoes are particularly sensitive and have been used as indicator plants. Ivy geraniums will show leaf chlorosis (yellowing).

XI. BIOLOGICAL CONTROL

Biological control is an option that some growers are now incorporating into their pest management programs. This chapter describes insect and mite natural enemies, biopesticides (insect toxins or pathogens packaged and sold as pesticides), and fungal antagonists. Table 19 lists biological control agents that are available for bedding plant pests. The order of pests in the table is the same order followed in the pest descriptions in this chapter.

A list of natural enemy suppliers can be obtained from the California Environmental Protection Agency, Division of Pesticide Regulation (916-324-4100). Biological control is a rapidly changing field, so check with a supplier or a university specialist for new developments before starting.

Many biological control products such as these are available. They are pesticides and users must follow the label directions. Photo: R. Way

Table 19. Biological control agents available for bedding plants

Pest Problem	Biological Control Agents	Common Name or Trade Name
Western flower thrips	*Neoseiulus cucumeris* *Orius insidiosus* *Iphiseius (=Amblyseius) degenerans* *Hypoaspis miles* *Beauveria bassiana*	Cucumeris Insidious flower bug Naturalis-O, BotaniGard®
Fungus gnat	*Hypoaspis miles* *Bacillus thuringiensis israelensis* *Steinernema feltiae*	 Gnatrol Nemasys, Scanmask
Green peach aphid	*Aphidius matricariae*	
Green peach aphid and Melon/cotton aphid	*Hippodamia convergens* *Aphidoletes aphidimyza* *Chrysoperla rufilabris* *Aphidius colemani* *Beauveria bassiana*	Convergent lady beetle Aphid midge Green lacewing Naturalis-O, BotaniGard®
Two-spotted spider mite	*Phytoseiulus persimilis* *Mesoseiulus (=Phytoseiulus) longipes* *Neoseiulus (= Amblyseius) fallacis* *Neoseiulus californicus*	Persimilis

Table 19—*Continued*

Pest Problem	Biological Control Agents	Common Name or Trade Name
Broad mite	*Neoseiulus barkeri*	
Citrus mealybug	*Cryptolaemus montrouzieri* *Leptomastix dactylopii*	Crypts, mealybug destroyer
Long-tailed mealybug	*Chrysoperla rufilabris*	Green lacewing
Greenhouse whitefly	*Encarsia formosa* *Delphastus pusillus* *Beauveria bassiana*	Naturalis-O, BotaniGard®
Silverleaf whitefly	*Eretmocerus eremicus* (=*californicus*) *Delphastus pusillus* *Beauveria bassiana*	Naturalis-O, BotaniGard®
Caterpillars	*Bacillus thuringiensis kurstaki*	Dipel, MVP, MVP II
Damping off (*Pythium* spp., *Rhizoctonia solani*)	*Gliocladium virens* GL-21 *Trichoderma harzianum* Rifai strain T-22 (KRL-AG2)	SoilGard™ 12G RootShield™ 1.15G
Leafminers	*isa sibirica* *Diglyphus isaea*	
Pythium and Rhizoctonia root rot	*Gliocladium virens* GL-21 *Trichoderma harzianum* Rifai strain T-22 (KRL-AG2)	SoilGard™ 12G RootShield™ 1.15G

You *must plan* before undertaking any biological control project because natural enemies are living organisms that function differently from more familiar pest control tactics. Since these organisms do not act as quickly as pesticides and sometimes must be shipped in a stage that does not attack pests, they generally cannot be used as rescue treatments. Pest populations should be at low levels when natural enemies are released. Effective natural enemies should keep a low population from building. The use of natural enemies must be carefully monitored and evaluated, so it's best not to undertake it unless a scouting program is already in place.

Start by using biological control for one pest problem in a limited area of the greenhouse. Practice by ordering a small quantity of natural enemies before you make your first release, so you are familiar with the process of receiving the shipment and assessing its viability. As you gain experience and confidence, expand to larger areas and to several pests.

Important issues that must be considered before any biological control program is initiated are cost, compatibility with pesticides, the need for appropriate environmental conditions, mode of action, and efficacy. These topics are discussed below. In addition, you should keep in mind the location of a reputable supplier and release rates and timing. Communicate with your supplier about release rates and other specifics.

Cost

Biological controls tend to cost more than pesticides, although this is changing as the demand for natural enemies increases and newer, more expensive pesticides are developed. Cost of natural enemies might be offset by their advantages, such as limited or nonexistent reentry intervals and reduced health, environmental, and phytotoxicity risks.

Compatibility with Pesticides and Other Natural Enemies

Many pesticides are capable of affecting harmful *and* beneficial insects, mites, fungi, nematodes, or bacteria. Although some natural enemies and pesticides can be used together, many cannot. If you will be releasing biological controls, the entire pest management program will usually need to shift toward methods compatible with natural enemies. In some cases, there is no information about compatibility between specific natural enemies and specific pesticides. Fortunately, this situation is slowly changing. We are gaining practical knowledge as more growers use natural enemies. Consult your supplier or the Koppert side effects list (see bibliography) for specific compatibilities.

Pesticide residues in the greenhouse can affect natural enemies. Wood and soil absorb pesticides as they are applied and the chemical residue can be picked up by natural enemies as they walk across greenhouse surfaces. Volatilization of pesticide residues over time can harm beneficials. A greenhouse with many wooden structures and a history of pesticides with long residuals may not be the best location in which to use natural enemies.

In general, an insecticidal soap or horticultural oil is safe once it has dried, although it can kill beneficials if it contacts them as a spray. Fungicides are often compatible with insect natural enemies, and insect growth regulators are fairly compatible as well. Fungicides usually aren't compatible with insect fungal pathogens, and should be applied 48 hours before or after the insect pathogen is applied. There are some exceptions to these guidelines, so consult your supplier for more information.

Synthetic pyrethroids are particularly harmful to most natural enemies, whereas natural pyrethrum has a shorter residual time and is not as detrimental. Organophosphates and carbamates are also generally harmful to natural enemies and have a long residual. Many of the newer reduced-risk pesticides have better compatibility with natural enemies. Some are compatible immediately, whereas others are safe once the spray has dried. Again, consult the Koppert

Side Effects List for information on compatibilities of specific pesticides and natural enemies.

Pesticide residues remain in sprayers and pose a risk to natural enemies that are applied with a sprayer, such as insect pathogens and nematodes. It is a good idea to dedicate a sprayer to application of biopesticides and natural enemies. It is also important to consider compatibility of natural enemies with each other. For example, some insect pathogens may not be compatible with certain arthropod predators and parasitoids. Generalist predators, such as *Orius,* may eat certain natural enemies.

Viability of Natural Enemies

Reputable natural enemy suppliers work hard to ensure that the agents they sell are healthy. Despite this, problems occasionally develop in production or shipping. It is a good practice to examine natural enemies when they arrive at the greenhouse to make certain they are alive. Part of the shipment should be held for a day in containers that will prevent escape of the natural enemy. Live material should be shipped to arrive within one to two days; it should arrive at the greenhouse at a time of day when someone will be there to receive it. Keep the package out of extremes of sun, heat, or cold, and refrigerate it if specified by the supplier.

Predators and parasitoids that are shipped as mobile stages (e.g., predaceous mites and some wasps, such as aphid parasitoids) should be inspected upon arrival to determine if they are actively moving. A microscope or hand lens may be needed to see them. Natural enemies that are shipped as eggs or pupae should be checked for viability by placing a small sample in a clear, airtight, dry container, keeping the container in a shaded, unsprayed area for two to three days, and carefully looking for active larvae or adults.

Environmental Conditions

As living organisms, natural enemies require specific environmental conditions to be effective. For example, *Orius* and *Aphidoletes* enter a type of dormancy called diapause when

day lengths shorten in the fall and winter; low relative humidity and high temperature is unfavorable to *Persimilis*. Discuss the environmental requirements of each biological control agent with the supplier. In addition, keep in mind that environmental conditions during shipping, storage, and release are important. For example, winged natural enemies should be released away from yellow sticky cards and at dusk, after the vents are closed.

Mode of Action

Insect and mite natural enemies work by eating, parasitizing, or poisoning their prey, while fungal antagonists compete with and displace plant-pathogenic fungi. These activities are dependent on the environmental conditions in the crop, the life stage of the insect or mite pest, and crop stage.

Natural enemies usually do not kill as quickly as pesticides, and some insects continue to feed while they are being killed, so *biological control must be started when pest populations are low.* They are often most effective at keeping a low pest population low, rather than reducing a large pest population. Some natural enemies will starve once they have eliminated their prey, so additional releases will be required if pests return. Others can switch to alternative food sources until the preferred prey returns. Biological control often seeks to maintain a balance between pest and natural enemy populations. However, in short-term crops with little tolerance for pest damage (such as bedding plants) it is desirable to make repeated releases to reduce pest population to negligible levels, rather than trying to establish a balance.

Evaluation of Efficacy

Begin your evaluation of efficacy by checking the survival of natural enemies when you receive them. Suppliers usually send a description of what to look for with the shipment. Open the container and assess the health of the natural enemies (see above section). Notify the supplier immediately if the shipment is of poor quality.

You should evaluate the effectiveness of biological control agents as part of routine scouting. Although optimum release rates and timing for many natural enemies are not known, careful evaluation will suggest where recommended release rates can be adjusted to fit a particular situation. Suppliers and university biological control specialists can help.

Performance evaluation depends on the mode of action of the natural enemy—how it kills, as well as how quickly it does so. Predators often begin feeding soon after release, whereas it may take two to four weeks for parasitism to become apparent. If insect or mite numbers have not dropped by two to three weeks after the release, or if populations rise quickly a few days after the release, consider other measures.

In many cases involving predators, the dead insects or mites are not visible, so evaluation is based on a drop in the pest population or observation of active natural enemies. Signs of parasitism often are visible, however, and an estimation of percent parasitism can be an important evaluation tool. The papery skins of aphid mummies caused by *Aphidius colemani* and *Aphidius matricariae*, the amber SLWF pupae parasitized by *Eretmocerus eremicus* (= *californicus)* or the black GHWF pupae parasitized by *Encarsia formosa* are all visible. Sometimes you can observe insects infected by pathogens. Infected whitefly nymphs may turn reddish orange when infected by *Beauveria bassiana.* Under humid conditions, life stages infected by fungal pathogens may be covered with white, powdery mycelia.

Predation or infection of soil-inhabiting insect life stages will be difficult to determine. If they can be located for observation, nematode-infected fungus gnat larvae will appear a cloudy white to yellow. *Hypoaspis miles*, the fungus gnat and thrips predator, is occasionally seen on potato disks. Look for a drop in the number of adult fungus gnats on yellow sticky cards or a drop in the number of larvae on potato disks to evaluate fungus gnat biological control.

Fungal antagonists can be evaluated accurately only in the laboratory. Regular root system inspection will show whether the roots are remaining free of disease. Leave some flats or pots untreated so the effect of the treatment on crop growth can be assessed.

Biological Control of Specific Bedding Plant Pests

Western Flower Thrips

Several options are available for thrips biological control.

Neoseiulus cucumeris (Cucumeris) is a predatory mite that feeds on first instar thrips larvae. The mite is distributed in the greenhouse in one of two ways: sprinkled onto the crop from a container that holds a mixture of Cucumeris mixed in a bran carrier, or in paper bags that are placed every 25 to 30 square feet on the bench so that the bags touch the plant canopy. The bag contains bran and a bran mite that serves as a food supply for Cucumeris, which reproduces in the bag and emerges over a six-week period to feed primarily on first instar western flower thrips (WFT). They are most effective when the temperature is higher than 70ºF and the greenhouse humidity is high. Use these preventatively.

Place bags in the greenhouse even if thrips are not present so predators are in place before thrips arrive, and so predator populations can increase before thrips populations. Replace one-quarter to one-half of the bags every three weeks to maintain a viable supply of predators. Cucumeris will feed on pollen and can increase to large numbers on pollen-producing crops such as peppers. Avoid wetting the bags since high moisture can cause the bran to rot. Slugs and mice occasionally feed on the bags. Cucumeris is adversely affected by most insecticides but is compatible with insect growth regulators (IGRs).

Iphiseius* (= *Amblyseius) degenerans is another predatory mite used for thrips biological control. It has been demonstrated to effectively manage WFT on sweet peppers, an excellent source of pollen. It is also reported to be drought resistant. Limited studies have shown this mite to be more effective than Cucumeris against WFT in greenhouse vegetables. It is adversely affected by most insecticides other than IGRs.

One species of ***Orius*** is sold for thrips biological control. Members of this species attack all stages of thrips by sucking out their body fluids. They enter a type of dormancy called diapause during short days (eight hours or less of daylight), so they are effective only in spring and summer. They sometimes bite people who are handling plants. *Orius* biological

control agents are distributed over the leaves directly from the shipping container. They will feed on pollen (especially gerbera, chrysanthemum, and pepper) in the absence of thrips, spider mites, or aphids, and can also be cannibalistic. They are adversely affected by most insecticides.

Beauveria bassiana is an insect pathogen sold as the biopesticides Naturalis-O and BotaniGard®. The fungal spores land on the insect's cuticle (skin), germinate, and develop into hyphae, which penetrate the cuticle of the insect to create an infection. Uninfected thrips may pick up spores as they walk across an infected insect and spread the infection. Unlike most insect pathogens, *Beauveria* functions at relative humidities as low as 45 percent. It is adversely affected by many fungicides.

Fungus Gnat

Several options are available for fungus gnat biological control, all directed against the larvae.

Hypoaspis miles is a soil-dwelling predatory mite that feeds on fungus gnat larvae. It is packaged in sawdust that is distributed over the soil surface or incorporated into the media before planting. These mites will reproduce in the greenhouse, so one application is often sufficient. They are active when soil temperatures are above 50ºF, and are most effective in pot-to-pot spacing or flats, both of which permit easy mite dispersal. If fungus gnats are already numerous, these predatory mites should probably be used in conjunction with either Gnatrol or nematodes when they are released, as it may take several weeks for *Hypoaspis miles* populations to reach an effective level. They will feed on alternative prey (such as thrips pupae) in the absence of fungus gnat larvae. Pesticides running onto the soil surface may have an adverse effect on *Hypoaspis*.

Bacillus thuringiensis israelensis is an insect pathogen that is sold under the trade name Gnatrol. This subspecies of the bacterium is specific to certain larvae in the order Diptera, the flies. The bacteria must be ingested by the fungus gnat larva, after which a lethal protein crystal is released into the insect gut. Feeding stops within a few hours, but death can take several days, The bacteria do not leave the larva to infect other fungus gnats.

This material is most effective when young fungus gnat larvae are actively feeding; older larvae must feed longer to

ingest a lethal dose. One to three applications may be needed, depending on fungus gnat levels. This material should not be tank-mixed with fertilizer concentrates (but dilute solutions may be applied at the same time) or with any compound containing more than 100 ppm copper or chlorine. It has a shelf life of one year when stored under refrigeration, and is compatible with most pesticides.

Steinernema feltiae is a nematode—a microscopic worm-like organism. Nematodes are mixed with water and applied through an injector or a sprayer under low pressure with the filters removed. Nematodes move through the media on a film of moisture and enter the fungus gnat larva through body openings, where they release bacteria whose toxin kills the larvae within one to two days. The nematodes reproduce within the larva and can go on to infect other fungus gnats. Adequate soil moisture is required for the nematodes to move through the soil and find their hosts. One application is sometimes sufficient, especially if used in conjunction with Gnatrol. They are not compatible with nematicides.

Green Peach Aphid and Melon/Cotton Aphid

There are several biological controls for both of these aphids. They must be used when aphid populations are low, since aphids can multiply rapidly and will develop faster than they can be killed.

Hippodamia convergens (convergent lady beetle) is a predatory beetle that is often released for aphid biological control. Both adults and larvae prey on aphids, but may switch to other insects, honeydew, or nectar when aphids are not present. They sometimes reproduce if food supply and day length are suitable. If eggs or larvae are not observed, additional releases may be necessary. Adults should be preconditioned by your supplier to minimize migration when they are released. Adults may be able to tolerate some pesticides.

The green lacewing ***Chrysoperla rufilabris*** is more adapted to humid areas than ***Chrysoperla carnea***, so it is used in greenhouses. The adults feed on nectar, pollen, and honeydew. The larvae feed on aphids as well as other greenhouse pests, including mites and whiteflies. They are very cannibalistic and must be released in ways that minimize encounters with other lacewing larvae, which means dispersing them as widely as possible. All lacewing life stages can be purchased from insectaries, but eggs or larvae are preferable

because adults will leave to search for food before laying eggs. Releasing larvae rather than eggs may reduce cannibalism. These insects do not tolerate most pesticides, although insecticide-resistant lacewings have been developed in the laboratory.

The aphid midge, ***Aphidoletes aphidimyza*** is another aphid predator used in greenhouses. The midge larvae bite aphids on their legs, inject a toxin, and extract body fluids. The adults feed on honeydew, and are rarely seen because they are short-lived and active at night. They are effective summer predators but will enter diapause under short days unless supplemental lighting is provided. They are shipped as pupae, so they must pass through the adult and egg stages before they begin aphid predation. They are not compatible with some pesticides.

Aphidius colemani is a parasitic wasp that attacks green peach and melon/cotton aphids in the greenhouse. The wasp lays an egg in the aphid nymph or adult, and the developing larva feeds within the aphid, causing its skin to turn brown and papery. These are called aphid mummies, and an adult parasite emerges from them. Mummies can be seen among a population of aphids, so parasitism can be estimated. Count only mummies without an exit hole to avoid re-counting old mummies.

Aphidius matricariae is a parasitic wasp similar to *A. colemani* and favors the green peach aphid. It kills aphids in the same way as *A. colemani*, and percent parasitism can be counted the same way as well. Adults of this species feed on nectar or honeydew.

The insect pathogen ***Beauveria bassiana,*** sold as Naturalis-O or BotaniGard™ is also used against aphids. It is most effective against adults because the rapidly developing nymphs shed their skins before the fungus can penetrate, necessitating several applications for adequate control.

Two-spotted Spider Mite

The predatory mite ***Phytoseiulus persimilis*** is used for biological control of two-spotted spider mite (TSSM). It works best at moderate temperatures (70–85˚F) and high humidity (70–90 percent). Plants that are close enough to touch will facilitate predator movement among plants and will promote high humidity within the canopy. It is important to release Persimilis when TSSM levels are low; the recommended rate

is one predator per ten TSSM. The onset of cool, short days in late fall and winter can cause TSSM to turn orange. They should not be confused with the rapidly moving predatory mites, which are slightly larger than TSSM, bright orange, and pear-shaped. Most pesticides are toxic to Persimilis, although it can tolerate some fungicides, IGR insecticides, avermectin, and residues of insecticidal soap and horticultural oil.

Mesoseiulus* (= *Phytoseiulus*) *longipes is another predatory mite used for biological control of TSSM that is more tolerant of low humidity (40–50 percent). Release the predators when TSSM populations are low.

Broad Mite

The predatory mite ***Neoseiulus barkeri*** is available for broad mite. Not much is known about the use of this mite as a biological control agent, although limited research has demonstrated that it will attack the broad mite. It will also feed on WFT.

Mealybug

Three natural enemies of mealybugs can be purchased commercially. The mealybug's waxy coating and cryptic feeding habits can hinder chemical control; therefore, biological control can be an important part of a mealybug management program.

Cryptolaemus montrouzieri is a beetle that consumes all stages of the citrus mealybug. It is released as an adult and is most effective around 80˚F. Under favorable conditions (temperature above 68˚F and an ample food supply), *Cryptolaemus* will reproduce in the greenhouse. It will feed on scale insects or immature whiteflies if mealybugs are not present. It is effective when mealybugs are plentiful, but usually will not eliminate a population. Using it in combination with *Leptomastix dactylopii* for citrus mealybug will ensure better control. Place cotton balls in the crop to provide additional egg-laying sites.

Leptomastix dactylopii is a parasitic wasp that attacks citrus mealybugs and has limited effectiveness against other mealybug species. It prefers to lay its eggs in larger mealybugs, i.e., third and fourth instars and female adults. *Cryptolaemus* will feed on newly parasitized mealybugs but will

leave them untouched as the parasite reaches maturity. Both of these natural enemies are adversely affected by pesticides.

The green lacewing, ***Chrysoperla rufilabris***, has been used against mealybugs in interiorscapes, where repeated releases are required. Its effectiveness in the greenhouse has not yet been demonstrated.

Leafminer

Two commercially available parasitoids attack leafminer larvae and are generally released on a preventative basis, before leafminers become problematic. In chrysanthemum, time releases to control leafminers within 40 days of crop initiation, before marketable foliage is present.

Some people believe *Dacnusa* works best under the cooler conditions of winter and spring and is most effective at finding leafminers when populations are low. *Diglyphus* is may be most effective at warmer temperatures, establishing only when leafminer populations have reached a critical threshold. Combinations of chemical control early, followed by biological control at the end of the crop, may be the best approach in ornamental crops.

Whitefly

Development of biological control methods for greenhouse whitefly (GHWF) and silverleaf whitefly (SLWF) has been the subject of a great deal of research; the result has been the commercialization of several predators, parasitoids, and pathogens. All whitefly parasitoids attack nymphs (also known as whitefly scales), while predators and pathogens affect all stages. Parasitoids kill by parasitism and host feeding, which occurs when a female wasp punctures the body of a whitefly and feeds on the body fluid that seeps out. She may also lay an egg in the same nymph. Regular releases are often made on short-term crops, and much mortality occurs through host feeding rather than parasitism. Measures of parasitism should not be used exclusively to measure effectiveness of whitefly parasitoids.

Encarsia formosa is a parasitic wasp that attacks GHWF and SLWF. It is most effective against GHWF, but has been used with limited success on SLWF. These wasps parasitize immature whiteflies; third and fourth instars are preferred,

but they will host feed on smaller instars. Whiteflies of all life stages are often present in a crop at the same time, so regular, weekly releases are usually made until all whiteflies have been controlled.

Encarsia is shipped as parasitized whitefly pupae glued to cards that are placed in the greenhouse, usually once per week. Place the cards face down, as close to the center bottom of the plant as is possible. Because whitefly nymphs are located on leaf undersides, inverting the cards mimics the orientation from which the wasps normally emerge. In addition, the wasps fly in an upward spiral as they emerge, so placing the cards near the center bottom ensures that they will encounter nymphs as they fly upwards. Your supplier can suggest a release rate based on plant size and density. These wasps are most effective at about 80˚F and 50–80 percent relative humidity. They cannot tolerate most pesticide applications or residues, but soap, oil, most insect growth regulators, and Avid are compatible, as are fungicides.

Eretmocerus eremicus* (= *californicus) is a parasitic wasp used for SLWF control, although it will also attack GHWF. These wasps parasitize immature whiteflies; all immature stages may be killed by host feeding, while second and third instars are preferred for parasitism. Because all life stages of whitefly are typically present in a crop, regular releases are usually made until all whiteflies have been controlled.

Pupae of this parasite are either glued to cards (as with *Encarsia formosa)* or are mixed with a sawdust carrier. Batches of the pupae can be divided and placed in release cups from which *Eretmocerus eremicus* adults emerge. The cups are distributed uniformly throughout the greenhouse. Place these cups as close to the center of the plant as possible to increase the encounter rate between wasps and immature whiteflies. The suggested release rate is one to three wasps per plant per week, but your supplier may suggest a different rate based on plant size and density.

These wasps are very attracted to yellow sticky cards, so use fewer cards than normal when they are being released. The wasps cannot tolerate most pesticide applications or residues, but soap, oil, most insect growth regulators, and fungicides are compatible.

Delphastus pusillus is a predatory beetle that feeds on all stages of whitefly. Both larval and adult beetles are predaceous. They are most successful against high populations

and are typically released in whitefly "hot spots" and in conjunction with other whitefly biological controls. They will reproduce in the greenhouse if they are able to consume large numbers of whiteflies. They should not be released near yellow sticky cards, as they are attracted to them.

Beauveria bassiana is an insect pathogen sold as the biopesticides Naturalis-O and BotaniGard®. The fungal spores germinate and develop into hyphae, which penetrate the cuticles of the whiteflies to create infections. Uninfected whiteflies may pick up spores as they walk across an infected insect, thus spreading the pathogen. Infected whiteflies may turn an orange brown color. Unlike most insect pathogens, *Beauveria* can infect at relative humidities as low as 45 percent. It is not compatible with fungicides.

Caterpillars

Bacillus thuringiensis kurstaki is an insect pathogen that is sold as the biopesticides Dipel, MVP, and MVP II. This subspecies of the bacterium is specific to insects in the order Lepidoptera, the butterflies and moths. The bacteria must be ingested by the caterpillar, after which a lethal protein crystal is released into the insect gut. Death can take several days, and the bacteria do not leave the larva to infect other caterpillars. This material is most effective when small larvae are actively feeding; older larvae must feed longer to ingest a lethal dose. One to three applications may be needed, depending on caterpillar population and development. It has a shelf life of one year when stored under refrigeration, and is compatible with most pesticides.

Plant Pathogens

***Gliocladium virens* GL-21** is a naturally occurring soil fungus sold as SoilGard™ 12G. It is antagonistic to plant pathogenic fungi such as *Pythium* and *Rhizoctonia*, and helps to prevent the damping off diseases they cause. The SoilGard™ 12G fungus colonizes the root zone as new roots grow, making it difficult for other fungi to become established. Once pathogens are present, it has little effect, so it cannot cure diseased plants. The material is mixed with the growing medium and left to sit for a day before planting. Fungicides should not be used at planting, but may be used later on.

***Trichoderma harzianum* strain T-22 (KRL-AG2),** sold as RootShield 1.15G, is based on another naturally occurring soil

fungus that is an antagonist of *Pythium* and *Rhizoctonia*. It is only active when soil temperatures are above 50˚F. It can be incorporated into the soil prior to planting or applied as a drench after planting. Fungicides may be used with this product.

When using biological control against plant pathogens, always leave some flats or pots untreated and label them "untreated" so the effect of the treatment on crop growth can be assessed. Accurate evaluation of fungal antagonists can be accomplished only in the laboratory, but regular root system inspection will show whether the roots are remaining free of disease. BioWorks, the manufacturer of RootShield, will help you with the evaluation of this product (315-781-1703).

XII. BIBLIOGRAPHY

Basic Scouting References

The following books provide pictures and descriptions of the arthropod, disease, and cultural problems you are likely to encounter while scouting bedding plants; they will be useful companions to this guide.

Ball Field Guide to Diseases of Greenhouse Ornamentals. M. L. Daughtrey and A. R. Chase. 1992.*

Ball Pest and Disease Manual. C. C. Powell and R. K. Lindquist.*

Diseases of Annuals and Perennials. A. R. Chase, M. Daughtrey and G. W. Simone. 1995.*

*Available from Ball Publishing, P.O. Box 9, 335 River Street, Batavia, IL, 60510. 1-888-888-0013 or 630-208-9080. Fax: 888-888-0014 or 630-208-9350. <www.ballpublishing.com>

Identification of Insects and Related Pests of Horticultural Plants: A Pictorial Guide. R. K. Lindquist. 1991. Columbus, OH 43 pp. Available from: Ohio Florists Assn., 2130 Stella Court, Suite 200, Columbus, OH 43215. 614-487-1117. Fax: 614-487-1216. <ofa@ofa.org> or <www.ofa.org>

Biological Control Information

The following sources include lists of biological control suppliers and information on how to recognize and use natural enemies.

Association of Natural Bio-Control Producers, 10202 Cowan Heights Dr., Santa Ana, CA 92705. 714-544-8295. <www.anbp.org>

Biological Pest Management for Interior Plantscapes, 2nd edition. M. Y. Steiner and D. Elliott. 1987. Alberta Public Affairs Bureau, Queen's Printer Bookstore, 11510 Kingsway Avenue, Edmonton AB, Canada T5G 2Y5. 780-427-4952. Fax: 780-452-0668. <www.gov.ab.ca/pab> See "on-line shopping" section.

Knowing and Recognizing —The Biology of Glasshouse Pests and Their Natural Enemies. M. Malais and W. J. Ravensberg. Koppert Biological System, PO Box 155, 2650 AD Berkel In Rodenrijs, The Netherlands, <www.Koppert.nl>. Also available from Ball Publishing.

Koppert Side Effects List. Koppert Biological Systems, Inc., 28465 Beveryl Road, Romulus, MI 48103. 734-998-5589.

Suppliers of Beneficial Organisms in North America. One free copy available from California Environmental Protection Agency, Division of Pesticide Regulation, Environmental Monitoring and Management Branch, Attn: Charles Hunter, 830 K Street, Sacramento, CA 95814. 916-324-4100. This list is also available at <www.cdpr.ca.gov/docs/ipminov/bensuppl.htm>.

Books

These books provide additional information about bedding plant pest problems as well as information about proper plant culture.

Baker, J. R., ed. 1978. Insect and Related Pests of Flowers and Foliage Plants. The North Carolina Agricultural Extension Service, Dept. of Agricultural Communication, Box 7603, North Carolina State University, Raleigh, NC 27695-7603. 75 pp. <http://ipmwww.ncsu.edu/INSECT_ID/AG136/nccredit.html>

Ball Culture Guide. J. Nau. 1993. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublising.com>

Ball Redbook, 16th Edition. 1997. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublising.com>

Bedding Plants IV: A Manual on the Culture of Bedding Plants as a Greenhouse Crop. E. J. Holcomb. 1994. Pennsylvania Flower Growers, Grower Talks Bookshelf, P.O. Box 9, Batavia, IL 60510. 1-888-888-0013. <www.ballpublising.com>

Compendium of Ornamental Foliage Plant Diseases. A. R. Chase. APS Press, 3340 Pilot Knob Road, St. Paul, MN 55121. 800-328-7560. <www.scisoc.org/apspress/>

Compendium of Chrysanthemum Diseases. R. K. Horst. APS Press, 3340 Pilot Knob Road, St. Paul, MN 55121. 800-328-7560. <www.scisoc.org/apspress/>

Compendium of Flowering Potted Plant Diseases. M. L. Daughtrey, R. L. Wick and J. L. Peterson. APS Press, 3340 Pilot Knob Road, St. Paul, MN 55121. 800-328-7560. <www.scisoc.org/apspress/>

Diseases and Pests of Ornamental Plants, 5th Ed. P. P. Pirone. 1978. John Wiley and Sons, NY. 566 pp. <www.wiley.com>

Fundamentals of Pesticides, A Self-Instruction Guide, 3rd edition. G. W. Ware. Thomson Publications, PO Box 9335, Fresno, CA 93791. 209-435-2163. Fax: 209-435-8319. <www.agbook.com>

Geraniums IV. J. W. White. 1993. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublishing.com>

Gerbera Production. D. A. Bailey. Timber Press, Inc., 133 SW 2nd Avenue, Suite 450, Portland, OR 97204. 800-327-5680 or 503-227-2878. Fax: 503-227-3070. <www.timberpress.com>

The Greenhouse Environment: The Effect of Environmental Factors on Flower Crops. W. J. Mastalerz. John Wiley and Sons, Inc., New York, NY 10016. <www.amazon.com>

Greenhouse Pests and Beneficials. S. Gill and J. Sanderson. 1998. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublishing.com>

Grower Talks on Plugs II. Debbie Hamnick, ed. 1996. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublishing.com>

Identification of Insects and Related Pests of Horticultural Plants—A Pictorial Guide. R. Lindquist. 1998. O.F.A. (Ohio Florists' Association) Services, Inc., 2130 Stella Court, Suite 200, Columbus, OH 43215-1033. 614-487-1117; <ofa@ofa.org>; http://www.ofa.org

New Guinea Impatiens. W. Banner and M. Klopmeyer. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublishing.com>

Scale Insects of Northestern North America: Identification, Biology, and Distribution. M. Kostarab. 1996. Museum of Natural History, Special Publication No. 3, Martinsville.

Diagnostic Laboratories

First seek assistance from your local Extension office.

For diagnosis of plant diseases:
Cornell University
Plant Disease Diagnostic Laboratory
321 Plant Science Building
Ithaca, NY 14853
607-255-7850

Cornell University
Long Island Horticultural Research Lab
3059 Sound Avenue
Riverhead, NY 11901
516-727-3595

For testing of plant viruses:
Agdia
30380 County Road 6
Elkhart, IN 46514
1-800-622-4342

For diagnosis of insects:
Cornell University
Insect Diagnostic Laboratory
Department of Entomology
4140 Comstock Hall
Ithaca, NY 14853
607-255-3144

Newsletters

These newsletters are good sources of new information about integrated pest management in the greenhouse.

Cox, D., ed. Floral Notes. Dept. of Plant and Soil Sciences, Stockbridge Hall, University of Massachusetts, Amherst, MA 01003. 413-545-5214. <www.umass.edu/umext/programs/agro/floriculture/newsletter.html> or <dcox@pssci.umass.edu>

Willmott, J., ed. Northeast Greenhouse IPM Notes. Rutgers Cooperative Extension, 152 Ohio Avenue, Clementon, N.J. 08021. <http://aesop.rutgers.edu:80/-floriculture/grower/IPMintro.htm> or <willmott@aesop.rutgers.edu>

McAvoy, R. S. and L. S. Pundt, eds. Yankee Grower. Plant Science Dept., U-67, University of Connecticut, Storrs, CT 06269-4067. 860-345-4511. <lpundt@canr.cag.uconn.edu> or <http://www.canr.uconn.edu/ces/ipm/general/htms/yankgrwr.htm>

Pesticide Emergency Numbers

Pesticide spills and accidents:
CHEMTREC, 1-800-424-9300

Pesticide and information emergencies:
National Pesticide Telecommunications Network
1-800-858-7378

To report oil and hazardous material spills:
NYS DEC (within NYS) 1-800-457-7362; (from outside NYS) 1-518-457-7362.

Information on symptoms and treatment:
Poison Control Centers. Western NY (1-800-888-7655); Eastern NY (1-800-336-6997); Finger Lakes Region (1-800-333-0542); New York City (1-212-340-4494); Central NY (1-800-252-5655); Long Island (1-516-542-2323).

Agricultural Nurse Program:
Western NY (1-800-388-6536); Central NY (1-800-343-7527); Eastern NY (1-518-436-5511).

Pesticide Recommendations

These references contain current information about pesticide use and labeling. These books are guides; they are not a substitution for pesticide labels.

Guidelines for the Integrated Management of Greenhouse Florist Crops: Management of Pests and Crop Growth. Revised annually; covers NY state. Media Services Resource Center, Cornell University, 7 Business and Technology Park, Ithaca, NY, 14853. 607-255-2080. E-mail: dist_cent@cce.cornell.edu

New England Greenhouse Floricultural Recommendations: A Management Guide for Insects, Diseases, Weeds and Growth Regulators. University of Massachusetts Cooperative Extension Bulletin Distribution Center, Cottage A, Thatcher Way, Amherst, MA 01003-0051. 413-545-2717. Covers CT, ME, MA, NH, RI, and VT.

Sources of Pest Monitoring Supplies

BioQuip Products
17803 LaSalle Avenue
Gardena, CA 90248-3602
310-324-0620
Fax: 310-324-7931
<www.rth.org/entomol/bioquip.htm>
E-mail: bioquip@aol.com

E.C. Geiger
Box 285
Harleysville, PA 19438
800-443-4437 or 215-2566-6511
<www.hortnet.com/ecgeiger/

Gempler's
211 Blue Mounds Road
PO Box 270
Mt. Horeb, WI 53572
800-382-8473
Fax: 800-551-1128
<http://www.gemplers.com>

Great Lakes IPM
10220 Church Road NE

Vestaburg, MI 48891
800-235-0285 or 517-268-5693
Fax: 517-268-5820

Griffin Greenhouse & Nursery Supplies
4 Airport Park Blvd.
Latham, NY 12110
518-786-3500
<www.griffins.com>

Griffin Greenhouse & Nursery Supplies
1 Ellis Drive
Auburn, NY 13021
315-255-1450

Trade Magazines

These magazines are good sources of new information about pest problems, IPM, and biological control.

Greenhouse Grower. Meister Publishing Co., 37733 Euclid Ave., Willoughby, OH 44094. 800-572-7740. Fax: 440-942-0662. <www.meisterpro.com>

GM Pro. Branch-Smith Publishing, 120 St. Louis Ave., Fort Worth, TX 76104. The Green Beam—Hort on the Web: <www.greenbeam.com/adlinks/gmpro.stm>

GrowerTalks. Ball Publishing, P.O. Box 9, Batavia, IL, 60510. 1-888-888-0013. <www.ballpublishing.com>

Interiorscape. Brantwood Publications, Inc., 2410 Northside Drive, Clearwater, FL 33761-2236. <www.interiorscape.com>

XIII. APPENDIX

Forms Used in Bedding Plant Scouting

Three types of forms are used in bedding plant scouting. The first is used to record sticky trap information, the second is used to make notes while scouting, and the third is a summary to leave with the grower in the IPM Notebook when the monitoring session is completed. The forms appended here and explained below can be modified to fit your needs.

Each form has been reduced by about a third to fit this guide, so you could enlarge each form by approximately 150 percent to restore it to its original size. Print these forms on carbonless duplicates so you will have records for your files.

Each box on the Sticky Card Counts form is used to record information from one sticky card at four monitoring visits. Record the house, card number, card location (bench, floor, or ceiling), and make a note if the card is changed. If it is not, circle the counted insects so they will not be included at the next monitoring visit. Record the number of insects on the card in the appropriate column; WF = whitefly; FG = fungus gnat; SF = shorefly. To avoid confusion, write "0" rather than leaving a blank when no insects are present.

The Greenhouse Total Plant Management form is used to record plant observations while scouting. Be sure to note the date, location, and time scouting starts and finishes. There are columns to note the plant and variety, problems observed, and root health information, including salts, pH, and the average root color rating. Use the blank lines at the bottom to note the presence of weeds and any insects they may be harboring.

The Scouting Summary Report form is used to summarize card counts and plant inspections. Be sure to include the date and time scouting started and stopped. On the left, record the average number of each type of insect trapped on sticky cards

in each house. Again, write "0" rather than leaving a blank. Estimate the level (high, medium, low) of the different pests found on plants and record this on the right. The percentage of plants infested with whiteflies is generally recorded only when scouting poinsettias. Use the blank lines at the bottom to note the presence of weeds and any insects they may be harboring.

Cornell University IPM

GREENHOUSE IPM PROGRAM

Sticky Card Counts

GROWER ______________________

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

House _____ Card # _____ (Bench Floor Ceiling)

DATE	Chngd?	WF	Thrips	Aphids	FG	SF	Misc.
	Y/N						
	Y/N						
	Y/N						
	Y/N						

Notes: ____

GREENHOUSE TOTAL PLANT MANAGEMENT

CORNELL UNIVERSITY IPM PROGRAM

GREENHOUSE: _____ LOCATION: _____ DATE: _____

SCOUT: _____ TIME IN: _____ OUT: _____

PLANT/VARIETY	PROBLEMS OBSERVED	FULL ROOT BALL (Y/N)	ROOT COLOR (1-3 = GOOD TO DEAD)

SALTS: _____ pH: _____ AVERAGE: _____

NOTES: _____

GREENHOUSE IPM
SCOUTING SUMMARY REPORT

GROWER: _____ DATE: _____

SCOUT: _____ TIME: IN _____ OUT _____

	STICKY CARD COUNTS							PLANT INSPECTIONS							
	No. of	AVERAGE # PER CARD							Pests Found on Plants						PLEASE
House	cards	WF	Thrips	Aphids	FG	SF	Other	Plant Variety	WF	Thrips	Aphids	FG	SF	Other	NOTE

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

R

S

T

V

W

X

Y

Z