Bulletin 363 Revised 2011

Total Crop Management for Greenhouse Production

with an emphasis on Integrated Pest Management and Nutrient Management

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This publication is a joint effort of the University of Maryland, Virginia Tech and North Carolinia State University and their specialists in various environmental fields

Integrated Pest Management for Commercial Horticulture
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Preface

This manual is designed for use by growers, greenhouse managers, and Extension educators involved with the floriculture industry. Our goal with this manual is to help greenhouse growers produce the highest-quality plants with minimal loss. This publication is based on the extensive experience of Maryland greenhouse growers, independent Total Plant Management and Integrated Pest Management (TPM/ IPM) scouts, and faculty and specialists of the University of Maryland Extension. It is our intent that this manual serve as a valuable tool for improved management of greenhouse crops. We have created charts for easy access to information and text for more in-depth information on key subjects.

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Integrated Pest Management (IPM) for Greenhouse Operations

Chapter 1
Integrated Pest Management: Scouting Overview

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Introduction

Greenhouse production of bedding plants and vegetable transplants is a profitable business; nevertheless plants will be attacked by pests at some point in time. No matter how vigilant the growers, all will still face dilemmas from nutrient problems, diseases, insects, and mites. The best approach to reduce the amount of pest damage in the greenhouse is through Integrated Pest Management (IPM) methods. IPM is a scientifically proven, yet practical system of pest control. It includes a combination of methods that reduces pest populations by merging good horticultural practices with research-based control tactics, keeping in mind environmental safety and realistic commercial standards. Control strategies include cultural, mechanical, physical, biological, and chemical methods. Biological control includes the use of live organisms that have been commercially proven to provide acceptable levels of pest control without the use of chemical pesticides.

The key to IPM is preventing problems, while being proactive once problems are found. The greenhouse should be clean prior to starting a new crop; i.e. free of old plant material, debris, and weeds. Vents and fans should be inspected and screened to prevent pests from entering. New crop plants, cuttings, or plugs coming in should be examined for pests and isolated if there is any suspicion of infection/infestation. Regular plant inspections (monitoring or scouting) are indispensable when conducted on a regular basis (weekly monitoring is suggested).

Once a pest is found, pest control strategies are chosen that effectively control the target pest with limited negative impact upon the surrounding environment. Using the appropriate application equipment and applying sprays properly will improve effectiveness. Repetitive pesticide applications can be circumvented by cultural, biological, and alternative tactics (e.g., sterilizing soil, screening vents, sanitizing greenhouse areas, eliminating weeds, releasing natural enemies, and treating with insecticidal soaps/horticultural oils). If pesticides are used, they should be applied in a rotation that alternates products with different modes of action against the target pest (e.g., rotating different chemical classes). The chemical class of each pesticide is listed in this publication in order to make this process easier.

Regular, systematic monitoring of the greenhouse is the backbone of a successful Integrated Pest Management (IPM) program. Insect and disease organisms can (and do) appear “suddenly”. Instead of reacting immediately to the pest (typically by spraying a pesticide), the IPM manager is proactive by regularly monitoring the pest population and treating only if and when necessary.

Monitoring is the key to predicting and managing pest populations. Monitoring (also called scouting) is the regular inspection of plant material, as well as the surrounding benches, floors, etc., for the presence and identification of any insect, disease, cultural, abiotic, weed and nutrient problems. By inspecting the greenhouse on a systematic basis (e.g. every 7-10 days during the crop season) pests that arise can be controlled before populations become economically intolerable. Small greenhouses (<4,000 sq.ft.) can be monitored as one unit. Larger greenhouses should be divided into 2,000 to 3,000 sq.ft.sections

for easier monitoring. IPM control decisions are all based on information gathered during monitoring. Smaller, immature pests are easier to control and can be managed with the least toxic methods. Monitoring information is used to locate and interpret all causes that directly and indirectly affect the problem (e.g. the pest, site, predators, environment and management practices).

Record Keeping

The monitoring process usually begins by creating a diagram of the greenhouse which can easily be done on a computer. A formal record keeping system that is consistently used while monitoring is essential to a successful IPM program. Many scouts create maps that chart the location of benches, fans, entry areas, and irrigation hoses. A new map is used for each crop cycle. Monitoring forms (or datasheets) are used to quickly record monitoring information, particularly on a large-scale basis. Monitoring forms used by professional IPM scouts in Maryland can be spreadsheets, check-off lists, or charts (Table 1.2). Forms can be very simple or quite detailed, and should be personally modified for ease of use and evaluation. The goal is to set up a clear, concise way of recording and communicating all plant and pest monitoring information so growers can make informed decisions. The datasheet ultimately needs to record what, where, and how many pests (as well as beneficial insects) are present.

Consistent and detailed record keeping is very important not only to improve overall control tactics, but to ultimately document the success of the program. Datasheets can be easily compared to one another over time. It is important that all records have the same standard format since they can only be compared if they uniformly and consistently report the same facts.

The base map/datasheet should include some background information, including the history of each crop, particularly that of past pest problems and exactly where the problems occurred. Mark greenhouse drainage patterns, as well as the sun/shade patterns and any applications of fertilizer and other materials. For each monitoring visit, the date, temperature, and humidity levels are recorded. The bulk of the datasheet is then used to record any pests or disorders found, where and when they were found, what was done, and any pertinent issues such as temperature inversions, residues, etc..

Specific information to include on the form/datasheet: (Use a scale of 1-10 for levels):

- Date(s) of monitoring;
- Minimum and maximum temperatures for each day
- Growing medium pH and soluble salts of plants in growing blocks
- Specific crop observation (height, leaf color, bud development, etc.)
- Visual health/appearance level of the plant
- Root health based on weekly check of random plants
- Specific pest/problem encountered and life stage
- Exact location of the pest
- Counts of pests on the plants, including stage of growth (egg, immature, adult)
- Insect or disease severity level (or counts of pest population levels)
- Presence/absence of beneficial organisms and competitors that are naturally occurring or released
- Results of control tactics.
- Insect counts from sticky cards (change cards weekly)

Notes on unusual weather patterns, any existing damage, or predisposing pest factors can be included or recorded in a “comments” column. Predictive information may also be included, such as an insect or disease appearance timetable and susceptibility of certain cultivars or plant species. Most charts rate the severity of the infestation using either a rating system of 1 to 10, or a rating ‘check-off’ system of “low-moderate-high” levels present. It is also helpful to estimate the percentage of bench area damaged. The area of pest

infestation on the map can then be either highlighted to document the location or color coded to indicate specific pests.

Carry the datasheet (or pocket PC) throughout each monitoring visit, recording monitoring notes directly. When a control tactic is initiated, note exactly when, where, and what was done. During the next monitoring visit, inspect and comment on the success of the control. Proper monitoring should identify specific areas within a crop where pests are absent or where pests are present at levels well below those necessary to cause damage, thus preventing unnecessary control applications and expenditures. By determining the focal point of an infestation early, a few plants can be either spot treated or rogued by placing them in a plastic bag before removal. The rest of the crop can be then be treated more effectively.

Weekly summaries of all monitoring observations should be recorded and the information should be itemized for each greenhouse, according to the pests detected, the counts, and any unusual circumstances found in the greenhouse. As the season progresses and pest trends develop, a direction for pest management decisions will become apparent.

Spray records are also important. State and federal regulations require growers to maintain detailed and up-to-date pesticide application records. Monitoring records should also include spray information, including the date and time of application, areas treated, name of the pest, pesticide used, rate and amount applied, method of application, time required to apply the pesticide, and effectiveness.

Recording the fertilizer analysis, rate applied (PPM) and frequency will also provide a valuable guide for future growing. It is important for the scout to have access to fertilization and irrigation application records in order to make more appropriate recommendations regarding the fertility of the crop. The best way to access this information is for the greenhouse grower or employee to post a chalkboard, clipboard, or data sheet to fill out with all the necessary pesticide application, irrigation, and fertilization information -- as well as minimum and maximum temperatures.

Scouting equipment

IPM scouts often use a backpack to carry monitoring equipment with them as they scout a greenhouse. A hand lens is the most useful tool used to detect live insect and disease symptoms. Scouts should wear clothing that is not attractive to insects to avoid inadvertently carrying insect pests into the greenhouse (e.g. shades of yellow and blue can attract thrips, whiteflies or other pests).

Some equipment suggestions include:

- Hand lens (preferably 16x)
- Pruners (for taking plant samples)
- Plastic bags (for taking plant samples)
- Pocket microscope
- Beating tray
- Flags/flagging tape to identify problem areas or for height control,
- Ruler (to measure plant height)
- Vials with rubbing alcohol (to collect small insect samples for identification)
- Apron (extra)
- Sticky cards (or other traps for monitoring flying insect populations)
- Gloves
- Waterproof permanent marker, pencil
- Plastic spoons and small paper cups/bags (for taking soil samples)
- Plastic bag for sample collection

- Small digital camera (that can take good close-up images)
- Conductivity and pH meters
- Resource information (small books with photographs of key pests, pesticide labels)
- Soil thermometer
- On-site diagnostic test kits

Monitoring Plan

Monitoring must be done in a thorough manner to be successful. The number of plants, their size, and the location of the benches will all influence the time and pattern needed to monitor. Start by following a route, or pattern, that will cover all areas of the greenhouse. Try to always begin from a major doorway, since this is typically where pest problems commence.

Scouts should aim to walk down every aisle and move from bench to bench in a zig-zag pattern. Individual plants should be chosen at random and inspection should include checking for insects, mites, or disease symptoms. At least 10 minutes should be spent inspecting 20 or more plants from every 1,000 square feet of production area. At least three plants on every bench should be inspected from the edge, the middle and as far into the bench as can be reached. Any plants that visibly appear discolored or dissimilar should be inspected more closely.

Inspection starts by looking for deviations from normal crop height and color. Pick up each plant and visually examine it beginning at the soil line. Scan the whole plant, inspecting the stem and undersides of the lower leaves for discoloration, signs or symptoms of pests, and indications of nutrient disorders. Look first at lower, older leaves, then the upper, younger leaves and finally, the new tip growth. Pay special attention to tip growth, buds and blooms. Because insects and some diseases are found on the underside of a leaf, it is important to turn the leaves over to check for pests. Invert and remove the pot to examine the roots. Pay special attention to plants on the outside rows of benches. Remember to also inspect hanging baskets.

Keep in mind that most pests are not distributed evenly throughout the crop. It is therefore very important to check all the leaves on the plant, especially when the crop is young. Never assume to know exactly where the pests are located (Table 1.3).

Once an infestation is detected, monitoring should occur more frequently. The customary monitoring route should also change at this point. Using scouting records, monitor the least infested areas first and the most heavily infested areas last. This will prevent you, the scout, from spreading any pests from an infected area to a new area unknowingly. Likewise, examine stock plants before inspecting cuttings in order to reduce the possibility of infesting the stock plants.

Indicator plants

Indicator plants are highly susceptible host plants (Table 1.1). They are often grown purposely, either among the commercial crop or at the edge of the crop/benches. Since these indicator plants are the first plants to become infested/infected, the scout knows that the adjacent main crop may be attacked soon. Indicator plants therefore aid in predicting pest problems.

Indicator plants are marked with a stake or flagging tape so they can be easily located and examined repeatedly to study pest establishment. Rechecking the same plant gives the scout an opportunity to closely examine an ongoing pest population -- or symptoms – before they spread to surrounding plants. Tracking pest establishment rates provides information regarding the rate at which the pest's life cycle is developing, as well as the best time to apply pest control measures. Indicator plants can also be used to check if control treatments were effective.

Table 1.1 Pest Problems and Indicator Plants

Pest Problem	Indicator Plants
Aphids	Sweet peppers and fuschias
Impatiens Nectoric Spot Virus	Fava beans, petunias, impatiens
Spider Mites	Marigolds and roses
Thrips	Marigolds, dracaena spikes, verbena, petunias and impatiens
Whiteflies	Tomato, lantana, gerbera daisy, poinsettia, and eggplant

For example, peppers and eggplants are prone to aphid and thrips infestations. Therefore, if peppers are purposely grown near susceptible bedding plants, they will be the first to be attacked by these pests. In this way, they will also indicate that an early thrips population is present in the greenhouse.

The best indicator plants to detect the presence of thrips carrying both Impatiens Necrotic Spot Virus and Tomato Spotted Wilt Virus are fava beans and certain cultivars of petunia. These plants will develop viral symptoms within one week if fed on by the infected thrips.

The following steps are recommended when using petunias and fava beans as indicator plants:

- Remove flowers from indicator plants to encourage feeding on foliage where symptoms can be observed.
- Place a blue non-sticky card in each pot at plant height. The blue card will attract thrips to the indicator plant. Blue plastic picnic plates also work well.
- Plant 1-2 fava bean seeds per 4 inch pot and place them at 12 pots per 1,000 ft^2.
- Remove fava beans plants if symptoms are observed because the virus is systemic in these plants. Viral symptoms appear as dark brown angular lesions on leaves or yellow to light green ring spots. Dark necrotic areas can also be seen on the stem. Fava beans have dark black spots on their stipules that should not be confused with viral symptoms.

Traps

A monitoring program includes utilizing sticky trap cards to determine initial pest levels as well as pest population trends. Sticky cards attract insect pests which become stuck on the sticky coating of the trap. The traps come in two colors, either a bright yellow or an medium blue. The yellow traps attract flying aphids, fungus gnats, whiteflies, leafminers, thrips, and others. Blue sticky traps are used primarily to attract thrips.

Sticky cards are placed in a grid pattern approximately every 1,000 square feet. They are positioned just above the plant canopy, from 4 inches to 16 inches above the top foliage. One way to easily position sticky cards is to attach each card vertically to a bamboo stake with a clothespin. As the crop grows, cards can be moved up. Place additional sticky cards near all entryways and vents.

Designate the location of each sticky card on the greenhouse datasheet. Check the sticky cards every scouting visit (twice a week if possible). Record the total number of whiteflies, thrips, fungus gnats, winged aphids, and shore flies from each card on the field data sheet. (Use a hand lens to identify insects found on the sticky traps). When handling the sticky traps, it helps to wear gloves or have some waterless hand cleaner nearby.

The time spent counting insects on sticky traps can be reduced by counting the insects within a one inch wide vertical column on the trap. Since insects are not distributed evenly horizontally across the trap, columns counted should be vertical towards the middle of the trap. For example, aphids and thrips tend to be caught on the bottom half of the traps, while leafminers are caught more often along the top half. Wasps and

whiteflies, on the other hand, have a tendency to be spread uniformly throughout the trap. Aphids tend to be caught in the middle vertical columns.

Setting Thresholds and Timing Actions in the Greenhouse

A certain number of insects, mites, and other pests can be tolerated on greenhouse crops. The degree of tolerance depends on many factors, including the stage of growth in the plant cycle, the plant species, the amount of time until market, and the intended market audience. For example, if the market audience is parents of horticulture students growing the plants, tolerance for the presence of insects may be high, especially if students can reassure parents that these pests will not noticeably harm the plant. However, most people have very low thresholds if they are paying for plants. A University of Maryland study showed that garden center customers could discern that a plant was injured at a mere 5% injury level. In general, as the time of marketing a crop for the general public grows nearer, tolerance for obvious pest presence grows very low.

Few, if any, action thresholds have been published for pest levels on greenhouse crops. For some pests and diseases the threshold is relatively easy: no tolerance at all. One example is the western flower thrips (WFT) and the tospovirus that causes Impatiens Necrotic Spot Virus (INSV). The tolerance level for the disease and for its insect vector, WFT, is near zero because once this disease and its vector are established in a greenhouse, many or all of the plants can potentially be destroyed.

The large number of species and cultivars grown in the greenhouse makes it difficult to set specific thresholds. Goals of the end user also influence the choice of threshold levels. For example, flower thrips cause a small amount of stippling damage to foliage and flowers that most customers would not notice. A greenhouse manager may tolerate a number of flower thrips on plants leaving the greenhouse if the customer is a plant- and insect-savvy consumer. Since flower thrips are not vectors of INSV, as the western flower thrips are, growers can be more tolerant of populations of the former on most flowering bedding plants. However, if the crop is to be sold to a garden center (where the plants may be held for a week or more and then sold to the general public), the flower thrips may become noticeable on the flowers and foliage, which could deter sales for the garden center.

How can the threshold level be determined that prompts some sort of action? It is suggested to closely monitor one plant species at a time, and follow that crop for an entire growing cycle, taking judicious records to determine what pests you noted on the plants (and when) during the season. Note at what population levels damage begins to be detected on the plants. This data, collected over several crop cycles, will help with pest control decisions such as when the insect population is no longer tolerable or when it is time to start treatment. Knowing the susceptibility of common greenhouse crops to specific insects and mites can help identify which plants to monitor closely for potential insect or mite activity. Monitoring efforts can therefore be focused upon the plants with apparent pest problems, and pests can accordingly be predicted for future monitoring.

When using biological control, start treatment at the first detection of the pest in the greenhouse. Using biological control with low threshold levels is the most effective way to approach pest management in a greenhouse. If chemical control is used, start treatments when populations are visible and a small amount of damage is detected. If that point occurs well before market time, foliar sprays can be applied to many pests to ensure that most minor pest populations are reduced by a well-directed spray.

Yellow sticky cards can also be used to set insect thresholds. For example, fungus gnat adults attracted to the sticky cards could be used for a pansy crop. Because this crop is highly susceptible to damage from fungus gnat larvae, card counts of adult fungus gnats can indicate a growing problem in the crop. If large numbers of fungus gnat adults are detected early in the crop cycle a grower may decide that adult activity indicates

egg laying by adult females, which in turn will result in high larval populations in the crops' root system. Therefore, treat when adult levels on sticky cards are high (50 or more per 7-day period).

IPM Decision Making

Each week, the IPM scout summarizes all generated monitoring information in order to make control decisions. The monitoring records will also indicate whether or not these control measures were successful, or if they need to be repeated. Before deciding upon a control tactic, make absolutely sure of the identity of the specific target pest present. Accurate diagnosis is the key to management, regardless of the specific control choice. Many pesticides and most natural enemies are often specific to just one pest or group of pests. If you are having trouble diagnosing a problem, contact your Extension Educator or Extension Specialist.

If you suspect a disease, determine if you can identify the causal agent or take a plant sample for further diagnosis and testing to the University diagnostic lab in your state (Appendix A). Entire plants are the best samples to send to a lab for diagnosis. Fasten a plastic bag around the root ball and wrap the entire plant in dry newspaper or paper towels. Include information on severity of the problem, timing of symptom development and pesticides applied. Send samples showing a range of symptoms.

Use the following questions to help make the necessary treatment decisions:

Is the population increasing, decreasing, or remaining the same?
Is it absolutely necessary to spray to prevent unwanted damage?
Are insects migrating from weeds under the benches to your crops?
Is the treatment from last week working?

At the end of each week, the scout should review the monitoring information with the greenhouse owner/grower. Use the summary records (numbers of pests recorded from sticky card counts and foliar inspections, any resulting pest population trends, and the use of indicator plants and located reservoirs of pests) to settle on the pest-management strategy.

Summary

Monitoring ensures the early detection of pests, which in turn results in better pest management. When problems are detected early, there will be better pesticide coverage due to a smaller plant canopy. Problem crops, and problem areas within a crop can be identified and spot treated which reduces the need for blanket pesticide applications. In addition, bio-pesticides and natural enemies (biological control organisms) tend to be more successful on immature or low level pest populations.

Table 1.2 Samples of Greenhouse IPM Crop Information Collection Forms

The following are sample templates that can be used to record scouting data. When developing a form, be sure to include the **date**, **reporting person** (if an additional scout is hired) and the **greenhouse**. Different areas within a greenhouse can be identified as 'Greenhouse Management Units (GMU). Examples include 'Greenhouse Area 1 (left side)', 'Greenhouse Area 2 (back)', and 'Greenhouse Area 3 (front)'.

Be sure to make a map of each greenhouse to be able to track the progress of each crop and insect, disease and cultural problems.

Crop Information Form:

Plant Species	Number of Plants or Containers	Planting Date	Expected Harvest Date

Fertility Information Form:

Application Date	Applicator	Plants or Areas Treated	Fertilizer Source	Applicaton Rate (PPM)	Comments

Insect Control Information Form:

Date Applied	Greenhouse Designation	Product Applied	Applicator	Application Rate	Evaluation Comments	Evaluation Method (Card count decrease or reduction of pests on plants)

Disease Control Information Form:

Date Applied	Greenhouse Designation	Product Applied	Applicator	Application Rate	Evaluation Comments	Evaluation Method (Card count decrease or reduction of pests on plants)

Weed Control Information Form:

Application Date	Greenhouse Designation (or outdoors)	Applicator	Product Applied	Application Rate

Electroconductivity (EC) and pH Levels Form:
Date: _____

Plant Species	EC Levels	pH Levels	Reasons For Testing

Note pH and EC testing method (i.e. 1 = saturated pest method or 2 - PourThru Method

Root Health Form:
Date: _____

Location	Plant	Rating (good, fair, poor)	Comments

Insect and Mite Activity Form: Sticky Card Counts
Date: _____

Location	Card Number	Whitefly Count per Card	Thrips Count per Card	Fungus Gnat Count per Card	Shorefly Count per Card	Winged Aphid Count per Card
	1					
	2					
	3					
	4					
	5					

Insect and Mite Activity Form: Whole Plant Counts
Date: _____

Location	Plant	Numbers of Plant Sampled	Pest	Number of Pests Found per Plant	Average Number of Pests Found	Increase or Decrease from Previous Count	Plant Damage Noted (%)

Disease Activity Form:
Date: _____

Location	Plant	Disease	Increase or Decrease in Severity	Plant Damage (%)

Table 1.3 Monitoring Pests In The Greenhouse

Pest	Best Monitoring Method	Identification Features	Potential Biological Control
Aphids (general)	Yellow sticky cards to indicate aphid migration into greenhouses in spring, summer, and fall. Inspect plant foliage weekly. Presence of cast skins and/or honeydew is a good indicator of aphids.	Each species differs in size, color, location on plant, and crop preference. Most aphids are 1–4 mm in size, pear-shaped and soft bodied with 2 cornicles (tailpipes) at rear of abdomen. Legs and antennae are typically long and slender. Winged forms found on cards; wingless forms found on plants.	Green lacewings (*Chrysoperla carnea* and *Chrysoperla rufilabris*), Aphid midge (*Aphidoletes aphidimyza*), Parasitic wasp (*Aphidius colemani*) Entomopathogenic fungus (*Beauveria bassiana* - Naturalis-O and BotaniGard).
Aphid, Chrysanthemum (*Macrosiphoniella sanborni*)	Found only on chrysanthemum species.	Shiny, reddish-brown to blackish-brown. Cornicles are short, stout, and black. No indentation between antennae as with green peach aphid.	See aphid section above.
Aphid, Green peach (*Myzus persicae*) May damage plants through disease transmissions as well as from feeding	Inspect plant foliage weekly. Found on wide range of perennials. Prefer new growth.	Range in color from light green, light yellow, green, gray-green, pink to reddish. Pronounced indentation between antennae on front of head. Cornicles are long, thin, and slightly swollen in the middle. Tip of cornicles are dark and slightly flared.	See aphid section above.
Aphid, Melon (*Aphis gossypii*)	Found on a wide range of perennials.	Color varies from light yellow to dark green. No indentation between antennae as with green peach aphid. Distinct cornicles always dark in color for entire length.	See aphid section above.
Caterpillars (general)	Several species feed on greenhouse crops. Most adult butterflies and moths overwinter outdoors and migrate into greenhouses in the fall. Regular monitoring of adult flight activity alerts growers when to look for eggs laid on foliage or stems.	Most caterpillars have appendages, called prolegs, on abdomen. All have mouthparts for chewing foliage and stems or boring into stems.	Microscreening over vents and greenhouse openings excludes migrating adult moths and butterflies. Several species of moths and butterflies are susceptible to applications of *Bacillus thuringiensis kurstaki* (Bt) in early caterpillar stages. Bt is sold under several brand names.

Table 1.3 Monitoring Pests In The Greenhouse (continued)

Pest	Best Monitoring Method	Identification Features	Potential Biological Control
Fungus gnats *Bradysia* spp.	Sticky cards will capture adults. Lay potato slices (1" by 1") on soil surfaces. Larvae will migrate to potato disk surface facing soil.	Adults are small, humpbacked flies with long legs, beaded antennae, and a single pair of wings with characteristic forked vein near wing tips. Larvae are opaque to white with black head capsule.	Keep soil on dry side. Entomopathogenic nematodes, including *Steinernema feltiae* and *S. carpocapsae*, control larval stages. *Bacillus thuringiensis* var. serotype H14 (Gnatrol) control larvae. Several IGRs control larvae, including dimilin (Adept), Neem (Azatin, Neemazad) and S-kinoprene (Enstar II).
Leafhoppers	Sticky cards will occasionally capture adults. In outdoor beds, sweep nets can sometimes capture adults.	Small, slender insects that disperse rapidly when disturbed. Both adults and nymphs run sideways and are good jumpers. Most are wedge-shaped and vary in color: shades of green, yellow, brown, or mottled.	Microscreening should exclude leafhoppers that migrate into greenhouse. Outdoors, control may not be necessary on most crops. Treat plants susceptible to viruses transmitted by leafhoppers with a systemic insecticide to kill the feeding insects.
Thrips Chilli thrips (*Scirtothrips dorsalis*) Flower thrips (*Franklinellla tritici*) Onion thrips (*Thrips tabaci*) Western flower thrips (WFT) (*Frankliniella occidentalis*)	Adults congregate in open flowers and can be easily tapped or blown out of flowers. Many thrips species, especially WFTs, are found in tight, hidden parts of plants; others such as flower thrips feed on open leaf surfaces. Feeding thrips deposit minute black fecal spots in circular shapes on leaf surfaces. Yellow sticky cards capture thrips, but blue sticky cards are more attractive to WFT.	Adults are small, generally 1–2 mm in length. Bodies of adults are tubular with narrow, pointed, fringed wings. Two larval stages feed on plant parts above ground. Prepupal and pupal stages occur in soil. Mount adult species on microscope slide for identification.	Microscreening over vents and greenhouse openings can exclude migrating adults. Predacious mites, *Amblyseius cucumeris* and *Iphiseius* (= *Amblyseius*) *degenerans*, are used for first instar thrips larvae. Minute pirate bugs, *Orius* sp., feed on larvae and adults. Entomopathogenic fungus, *Beauveria bassiana*, infects thrips; direct fine mist spray onto pests.

Table 1.3 Monitoring Pests In The Greenhouse (continued)

Pest	Best Monitoring Method	Identification Features	Potential Biological Control
Twospotted spider mites (*Tetranychus urticae*)	Pests tend to build up under hot conditions. Examine plants in warmest section of greenhouse for early infestations. Look for stippling of foliage. In heavy infestations, look for webbing on stems, flowers, and upper leaves.	Larvae are very small and pale green with 6 legs. Protonymphs and deutonymphs are pale green to brown with 8 legs. Adults have 2 large black spots on each side and 8 legs.	The predacious mite, *Phytoseiulus persimilis*, is an effective control. *Amblyseius californicus* is also used for control.
Whiteflies Bandedwinged whitefly (BWWF) (*Trialeurodes abutilonea*) Greenhouse whitefly (GHWF) (*Trialeurodes vaporariorum*) B strain and Q strain (*Bemisia tabaci)*	Use yellow sticky cards to monitor for adults. Place sticky cards near intake vents and doors to detect inward-migrating adults. Plant inspection should detect immature stages on under-surface of foliage.	Adults are short in length (1–2 mm), white, and flylike. Eggs are tiny, spindle-shaped, and laid on undersides of leaf surfaces. SLWF eggs start out white but turn amber-brown. GHWF eggs start white and turn to gray with time. Crawlers and other nymphal stages are oval, flattened, and translucent.	Release *Encarsia formosa* early in crop cycle to suppress greenhouse whiteflies before population build-up. Suppress *Bemesia tabaci* whitefly by using *Eretmocerus eremicus*. An entomopathogenic fungus, *Beauveria bassiana* (Naturalis-O and BotaniGard), is effective against nymph stages of *B. tabaci* and GHWF.

Chapter 2
Screening Out Insect Pests

David S. Ross, Extension Agricultural Engineer

Introduction

Screening, which is an IPM practice for blocking the movement of thrips, whiteflies, and aphids into greenhouses, can be very effective if you start with clean plants and keep doors closed. Place fine screening material over vents to block the entry of insects into the greenhouse. The screen will reduce crop damage caused by insects that normally migrate into the growing area. Be careful when you size the screening material because the screen's small openings can block airflow. The area of screening material has to be 2 to 5 times the area of the existing vents for air to have enough open space to pass through a screen's openings. Existing greenhouses require structural modifications to support the screening material.

Management makes the difference when it comes to the effectiveness of the screening material. Do not leave doors open. Do not move contaminated plants into the greenhouse to populate it with the very insects the screening is meant to keep out. Maintain a clean house or the value of the screening material is lost.

Greenhouse Static Pressure Considerations

Fans have to overcome resistance as air moves around obstacles in the greenhouse and through the vents to pass through the greenhouse; this resistance is measured as a pressure loss. A static pressure loss of 0.03inch water gauge (w.g.) pressure is typical for fan ventilation systems. Evaporative cooling pads add resistance (Fig. 2.1). Fans are sized at a static pressure loss of 0.10- or 0.125-inch water gauge pressure. Because insect screening adds to the static pressure load, designers try to hold its pressure loss to 0.03-inch water gauge pressure. These design guidelines allow for some clogging before the fan static pressure sizing limit is reached. A manometer is a simple device that measures is the pressure drop in the house caused by the resistance to air flow (Fig. 2.2). One end of tube is inside and one end is outside. Liquid is pushed to lower pressure. Energy loss causes slight vacuum inside as air is pulled through it.

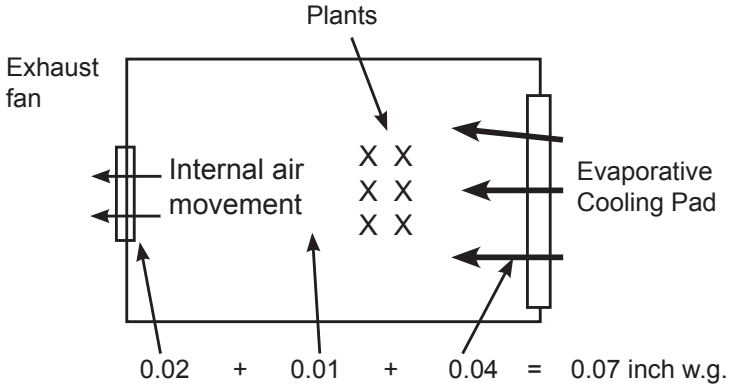

Figure 2.1 Evaporative Cooling Pad
Restrictions cause pressure losses as air moves through greenhouse.

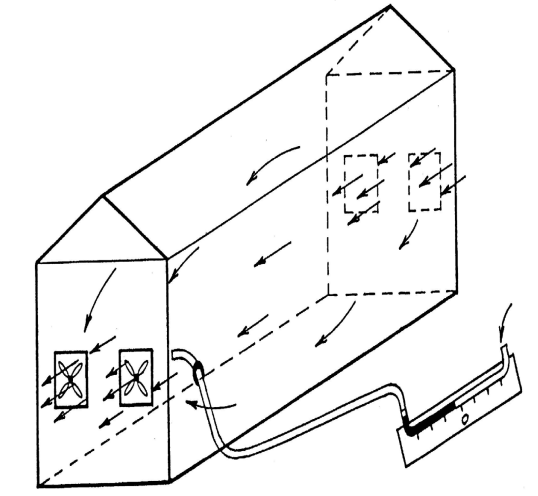

Figure 2.2 Manometers
A manometer meausures static pressure drop of airflow through greenhouse.

Approach Velocity Determines Area

Some screening-material manufacturers have measured the static pressure loss of their material at different airflow rates or air velocities. The results show that as the air velocity (of the air moving through the screening material) increases the airflow resistance and static pressure increase. To avoid a reduction in the ventilation airflow, the velocity of air through the screening material must be limited to that velocity at which the static pressure is 0.03-inch w.g. This is called the approach velocity and is the maximum air velocity allowed (Fig. 2.3). Some manufacturers provide two or more screening materials. Hole sizes vary as do the applications for which they are suited. The anti-thrips material, which usually has openings that are smaller than the norm, generally is more restrictive to airflow; therefore its use requires more surface area. A variety of materials are available in various opening sizes and designs; for this reason the restriction on airflow varies considerably. You need data about the material you will be using in order to make an informed decision about required surface area (Fig. 2.4).

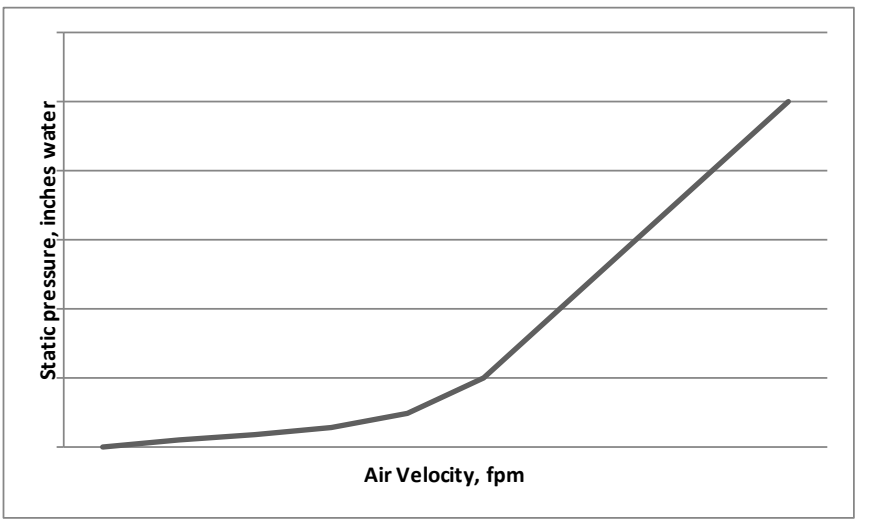

Figure 2.3 Resistance Curve
Curve showing pressure loss for air movement at different velocities through screening material.

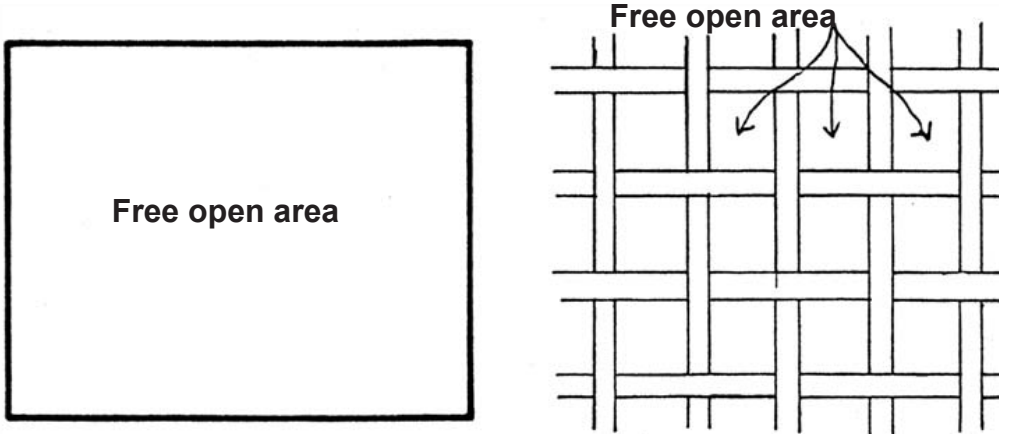

Figure 2.4 Air Movement With Screening
The free open area for air movement is reduced by the threads of the screening material.

Sizing the Screening

Some manufacturers provide the air velocity vs. static pressure information, which makes material selection easy. For example, a manufacturer states that a screening material reaches a static pressure drop of 0.03inch water gauge pressure at an approach velocity of 350 feet per minute (fpm). This represents the pressure drop or resistance to airflow through the material at the stated velocity. In other words we must spread the incoming air out over enough area to obtain the required ventilation rate, cubic feet per minute (cfm), without exceeding 350 fpm. Use the relationship of Airflow Rate equals Velocity times Area (Fig. 2.5).

Example: *A greenhouse that requires 30,000 cfm ventilation rate.* If the approach velocity is 350 fpm, the total screening area must be at least 30,000 divided by 350 or 85.7 square feet of screened area. The actual existing inlet louver area for this house is likely less than half that area. The screening material cannot simply cover the inlet louvers. A box must be designed to provide a larger surface cover for air to enter before passing through the smaller inlet louver openings. For winter ventilation, the inlet design velocity is 700 fpm, which suggests that most greenhouses will need at least double the inlet area for the screening material used in this example. The design numbers will vary for each screen material.

CFM = fpm x ft²

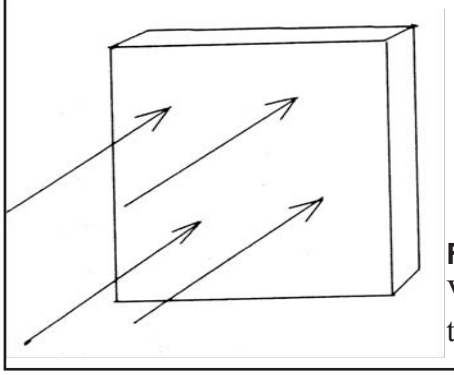

Figure 2.5 Ventilation Air Flow
Ventiliation air flow (CFM) is air velocity (fpm), times open area of louver (ft^2)

Retrofitting a Greenhouse with Screening

The use of insect screening materials usually means retrofitting the greenhouse so the material can be properly installed. Since structures by different manufacturers vary somewhat, there is no one method for retrofitting. However, the addition of another hoop on the end of a Quonset house is one way of providing a surface to hold the screening material. Large gutter-connected houses use a second wall on one side to hold the screening material. The inside wall holds the inlet vents or vents plus pad cooling system for the house. Screening material can hang down from side vents to move with the vent as it opens and closes to protect the opening. Professional design assistance is recommended for major retrofitting.

Roof Ventilation and Screening

Although screening materials have been developed for roof vents, most materials do not provide much extra surface area for the necessary air movement. A pleated screening material is available that provides extra surface area when the vents are open. Naturally ventilated greenhouses are difficult to deal with because only temperature differences and wind—usually at their lowest values during the worst summer heat—cause the air to move. Adding the screening only further blocks the heat's escape.

The relatively new open-roof greenhouse structure is the ultimate in natural or roof ventilation by being fully open during warm days. Insect screening would have to be installed similarly to a heat curtain in order to be effective in these houses. The screening would restrict airflow. An alternative is to use low-percentage shade fabric made with silver reflective material as a movable shade curtain to try to repel the inward migration of adult thrips, winged aphids, and whiteflies. This method has not been proved yet but is being tried as a low airflow restrictive method.

Summary

Insect screening can be effective in reducing insect entry into greenhouses. With fan systems, sufficient screening surface area is required to maintain an air velocity low enough to keep the static pressure to about 30 percent of the static pressure capability of the exhaust fans. Screening is not effective if doors are left open or contaminated plants are moved into the house. Naturally ventilated houses are difficult to operate using screening. Open-roof houses offer a new challenge to the grower for repelling insects.

Chapter 3
Disinfecting a Greenhouse: Keeping Diseases and Insects in Check

Stanton Gill, Extension Specialist

Introduction

A key element in developing an Integrated Pest Management (IPM) approach to disease and insect control in greenhouses is to regularly disinfect all working surfaces and equipment used in the greenhouse. The objective should be to reduce the movement of pathogens and pests on tools, mechanical equipment, flats, pots, and bench surfaces. It is a good idea to slow the development of resistance by rotating your use of disinfectants. Periodically, change from one disinfectant to another. The following disinfectants can be part of your rotation:

Alcohol (70% isopropyl)
Common isopropyl alcohol is an effective disinfectant that kills microbes on contact. The volatility of alcohol makes it best suited for dipping or swiping propagation equipment or shears. It is generally not practical as a soaking material.

Chlorine Bleach (sodium hypochlorite)
Sold under several brand names, chlorine bleach is the most widely used and least expensive disinfectant on the market. Once you mix chlorine bleach, it must be used within 2 hours or the chlorine will evaporate as chlorine gas. Chlorine solution exposed to sunlight or high levels of organic material will break down rapidly. Mix chlorine outside and avoid breathing the fumes from concentrated formulas. The Clorox brand of chlorine bleach is the only brand sold that has an Environmental Protection Agency registration number for use as a disinfectant.

Most household bleach has a chlorine concentration of 6.00 – 6.25 percent. A 0.6 percent final solution concentration will kill most microbes that infest surfaces. To obtain a 0.6 percent concentration use one part household bleach with nine parts water. Sodium hypochlorite can accelerate corrosion of some metals and may damage some plastic surfaces.

Hydrogen Dioxide
Sold under the brand name ZeroTol, hydrogen dioxide can be used as a surface sanitizer for greenhouse structures, benches, pots, and tools. Use the ratio of one part hydrogen dioxide to 49 parts water.

Quaternary Ammonium Chloride Salt
Quaternary salts, which are sold under the brand names Geenshield, Physan 20, and Prevent, are much more stable than alcohol and chlorine bleach. Soak objects for at least 10 minutes for proper disinfecting. Quaternary salts are inactivated by organic material. Flats and pots should have all organic material removed before disinfecting with quaternary salts.

Chapter 4
Pesticide Application Equipment: Selection and Calibration

David S. Ross, Extension Agricultural Engineer

Introduction

Proper application of pesticides is essential for achieving the desired control. Applying pesticides is an unpopular and time-consuming task. You must use the correct application equipment. No one type of sprayer can do all tasks. Calibrate the equipment to ensure that the proper amount of chemical reaches the target. Reaching the target does not happen automatically; the operator influences the success or failure of the task. Actually, the operator must time the spraying and accurately proportion the chemical over the target area, being careful to direct the spray in a manner that achieves good coverage of all the plant parts, foliage and flowers.

While spraying is a principal means of controlling insects and disease, growers must identify and eliminate the source of the insect or disease problem to reduce the frequency of sprayings. Weeds or grasses near the greenhouse may harbor the insects or disease carriers. A compost or discard pile of noncomposted plants located near the inlet vents can also be a source of insects or disease. Sites that might harbor pests that can move into the greenhouse must be kept clean. Insect screening, if properly used, can help to reduce the quantity of insects entering the greenhouse. Rotating the classes of chemicals you use will help delay resistance to chemical control from developing.

Droplet Size Versus the Pest

One of the primary differences among the several different types of sprayers available is the size of the droplet each produces. Your ultimate goal is to reach the target with pesticide. Reaching the smallest insects, mites, and disease organisms requires complete coverage with tiny droplets or wetting to the point of runoff. For good coverage a contact insecticide or fungicide must come in direct contact with the target; a systemic pesticide must be absorbed by the plant. Weeds are killed by herbicides that are absorbed by foliage; large droplets supply adequate coverage of the plant for absorption to take place and reduce the chances of the herbicide drifting onto the desired crop.

There are optimum spray drop sizes for specific targets (Table 4.1). Note the small droplet sizes for small, flying insects and larger droplets for herbicides. The reason for these droplet sizes is illustrated by looking at the coverage of different size droplets on some surface areas. Droplet sizes are given in microns or one-millionth (0.000001) of a meter. For reference, 1 micron is 0.00003937 inch, and a human hair is about 100 microns (0.0039 inch) in diameter.

Table 4.1 Optimum Spray Drop Sizes For Various Targets

Source: Adapted from Matthews 1979

Target	(in microns)
Flying insects	10 to 50
Insects on foliage	30 to 50
Diseases on foliage	40 to 100
Growing medium and weeds	250 to 500 (avoids spray drift)

There is a relationship between droplet size and the number of droplets per unit area (Table 4.2). A great number of small droplets give better coverage than a few large droplets. To reach a small target (insect or mite), therefore, use small droplets; the more droplets that fill a given area, the more likely the target is to make contact with a droplet. Note that 1 square inch equals 6.45 square centimeters; 19,099 drops per square centimeter equals 123,189 drops per square inch.

The mathematical relationship between diameter of a droplet and its volume is a cubic one. A 100-micron droplet reduced to a 50-micron size results in eight 50-micron droplets. In other words, the volume of one 100-micron droplet equals the volume of eight 50-micron droplets. A 100-micron droplet reduced to 10-micron droplets results in 1,005 10-micron-size droplets. Although a small insect or mite may walk around a 100-micron droplet on a leaf, 1,005 10-micron droplets will cover the leaf, which makes the insect unable to avoid them. The increased coverage makes it hard to avoid the chemical.

Table 4.2 Theoretical Spray Coverage

Applying one liter per hectare with various spray drop sizes.

Drop Diameter (microns)	Number of Drops Per Square Centimeter
10	19,099
20	2,387
50	153
100	19
200	2.4
400	0.3
1,000	0.02

Types of Sprayers

The three primary types of sprayers used in greenhouses are 1) Hydraulic or high-volume hydraulic, 2) Targeted low volume, and 3) Fog or ultralow volume. Each sprayer has a purpose; a greenhouse operation will require two or more types of sprayers for various tasks. Primary differences among sprayers are the quantity of water used, the operating pressure, and the size of droplets produced.

Hydraulic

A hydraulic or high-volume sprayer uses a high flow rate of water to wet the foliage to the point of runoff. This sprayer uses standard rates of chemicals and large volumes of water. The droplets coming from the sprayer are generally more than 100 microns in size. The sprayer applies herbicides in large droplets of 200 to 400 microns at a low pressure of 15 to 60 pounds per square inch (psi) to avoid drift. Insecticides and fungicides are applied at higher pressures— more than 60 psi—to achieve droplets of 100 microns or less in diameter. The lower-volume greenhouse sprayers use 500 psi and 2 to 4 gallons per minute (gpm) flows to wet to runoff.

The quantity of water to use depends on the specific sprayer and nozzle, the spraying technique of the operator, and the size of the crop. Calibrating the sprayer according to the operator and the crop is essential for mixing the correct amount of spray mix. Ten thousand square feet of crop early in its growth may require 15 to 20 gallons of water. As the crop reaches maturity and has more foliage, achieving good coverage may require 30 to 50 gallons of water.

The hydraulic sprayer can do a good job of covering foliage. The operator can see the spray on the foliage and know whether or not the target has been hit. The larger flow of water provides force to move foliage aside in order to penetrate the canopy and stir the leaves. By using a low application rate the operator can hold the spray nozzle onto a target long enough to achieve penetration without excessive wetting.

Low Volume

The targeted low-volume sprayer may be hydraulic, air assisted, electrostatic air assisted, or rotary. The object of using this type of sprayer is to use small droplets and a low quantity of water to carry the chemical to the crop. The low-volume hydraulic sprayer utilizes high pressures between 1,000 and 3,000 psi to break the droplets into roughly 50-micron size or smaller; however, these sprayers use less water and produce a mist that is too fine to show a wetting pattern. There is no wet-to-runoff pattern to observe. The operator aims the sprayer at the target and sprays until the air volume under the foliage is filled with spray. The operator is responsible for obtaining full coverage. A concentrated chemical mix (chemical plus water) can be used because less water will be applied.

The calibration process is more difficult for low-volume sprayers because the spray does not wet the foliage as visibly as the high-volume hydraulic sprayer does. Special water-sensitive paper that indicates coverage is available (from some sprayer or chemical suppliers). The paper changes color when droplets of water land on it. Attach pieces of this paper to plants in various places before spraying and examine the paper afterward to observe how well the spray droplets were distributed during calibration or normal spraying. The calibration process also helps to determine the amount of water needed to cover a given area. Calibration is still very important for spray mix preparation to avoid costly waste. Calibration information may also be useful in determining legal amounts of chemical to use with a measured amount of water for covering a given area. It may be necessary to consult the chemical producer for the allowable mixing ratios.

Air-assisted low-volume sprayers use air as the primary carrier of the chemical. High-speed air strikes the stream of liquid chemical or chemical and water being injected into the sprayer and breaks the stream into small droplets. The air then carries the liquid to the plants. The speed at which the sprayer moves past the foliage determines the penetration of air into the foliage to deliver the chemical. Slow movement may be necessary to allow the air mass created by the sprayer to penetrate into thick foliage, pushing the air in the foliage out the other side. The sprayer air volume must displace the air volume under the foliage.

Electrostatic sprayers produce fine droplets that 30- to 60-micron in size, which are electrically charged and then air-blasted into the crop foliage. The negatively charged particles are attracted to any surface and can provide coverage that is as good as the coverage from a high-volume sprayer. A sprayer with a spinning or rotary disk is used to impact and break a stream of water into droplets that are 60 to 80 microns in diameter. A variety of sizes are available for greenhouse use.

Fog or Ultra-Low Volume

The fogger uses little water (2 liters per 10,000 square feet) and produces fine droplets less than 25 microns in diameter. When you distribute pesticides in very small droplets as a fog your rate of application is reduced. Some chemicals are not labeled for reduced rates and some formulations are not intended to be used in ultralow-volume sprayers. Clogging will occur with some chemicals; special carriers are needed with some pesticides.

Mechanical cold foggers operate between 1,000 and 3,000 psi to force the mixture of chemical and a small amount of water through the nozzle. Thirty-micron droplets drop out of the air fairly quickly, but 5micron droplets float in air currents for hours. These sprayers use no chemical additives.

Thermal foggers use a pulsing jet engine to produce a highly visible fog that can stay suspended in the air for up to 6 hours. Inside the thermal fogger, a gasoline and air mixture explodes in an enclosed resonator. The explosion rushes out as a jet stream. A chemical solution is injected into the jet stream and is blown apart into very small 0.5- to 30-micron particles. A carrier solution added to the mix causes a visible fog, eliminates the evaporation of droplets, and ensures uniform particle sizes.

An aerosol micro-particle generator sprayer is available. It uses an oilless air compressor to produce high-pressure air. The air flows through a special nozzle to produce superfine fog particles of 0.5 to 10 microns in diameter. These particles can stay suspended for up to 6 hours. No special carrier solution is required.

One commercial company packages a pure technical active ingredient in a container that emits the material as a fog. You open an aerosol can or cans and set them down in the greenhouse, starting at the point farthest from the exit and walking toward the exit. The company claims 40 percent of the material reaches the undersides of foliage.

Some sprayers have a fan to move the air around the greenhouse; if not, use the HAF (horizontal airflow fans) to distribute the fog throughout the building.

Calibration

Proper sprayer use involves following a procedure that measures the amount of water or spray used to cover a given area or volume at a known rate of operator travel speed. Calibration, which tells you the amount of liquid that was applied to a known unit area, enables you to prepare chemical spray mixes properly.

For a hydraulic sprayer fill the sprayer with water, spray a known area of the greenhouse crop, and then record the time required for spraying. The goal is to spray the water to achieve uniform coverage. Next, measure the water required to refill your sprayer. Calculate the spray rate by dividing the gallons used by the area covered. Adjust the rate by adjusting the nozzle or your walking rate.

If a nozzle wears out or an operator rushes and does a poor job of coverage, the amount of spray used should alert the owner or operator to a problem. The operator's movement is critical to applying the correct amount of spray.

Measuring the output of a nozzle will verify its rate of flow. The manufacturer can provide information about the discharge rate (gallons per minute) of each nozzle at several pressures. A good quality sprayer should have a pressure gauge to tell if the sprayer is operating properly (on all sprayers moving liquid at pressure). Set and/ or record the pressure of liquid going to the nozzle. Catch the discharge of the nozzle in a container for a measured period of time. Measure the amount of liquid collected.

Calculate the flow through the nozzle in gallons per minute using the measured volume and time. Compare this value to the manufacturer's discharge rate for the pressure observed. If you follow the procedure fairly accurately, the measured discharge rate should approximate the rate presented in the manufacturer's data. Small differences may be caused by wear.

You can calibrate a low-volume sprayer in a similar manner. Carefully direct the low-volume sprayer into the foliage to exchange the air under the foliage with the air containing the pesticide. Practice and calibration help the operator to establish the amount of water and chemical to use for large jobs.

Wear chemical-resistant personal protective equipment (PPE) during the calibration and during the spraying—the operator needs to experience the same environment during calibration as during actual spray application. Protective equipment is a must during pesticide application.

Part 2
Insect and Mite Management

Chapter 5
Insecticide and Miticide Classes

Stanton A. Gill, Extension Specialist

Introduction
Insecticides and miticides are tools used by growers to manage insects and mites. Generally these products do not eliminate the problems, but they maintain mite and insect populations at acceptable levels. The biological world is designed to modify and adapt to overcome any challenge to its survival. With this in mind, use insecticides and miticides correctly to manage pest problems and to delay the development of resistance to chemicals.

IRAC
The Insecticide Resistance Action Committee (IRAC) is an organization dedicated to slowing the development of pest resistance. It was founded in 1984 as a specialized technical group to help prevent or delay the development of resistance in insect and mite pests.

Resistance Defined
Resistance to insecticides, miticides and fungicides is defined by IRAC as "a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendations for that pest species."

Rotation – Ways to Delay Resistance Development
The assumption is that rotations of compounds from different mode of action (MoA) classes remain the most viable resistance management technique. Most insecticides and miticides affect insects and mites in specific ways. IRAC currently classifies insecticides and miticides into 28 different modes of action. This publication identifies only those insecticides and miticides used in greenhouses by their modes of action Table 5.1).

Timing for chemical class rotation is slightly different for insects and mites compared to disease control. To delay the onset of resistance to pesticides, it is usually recommended to rotate from one pesticide to another one that has a different mode of action after 1 to 2 insect or mite generations. This chart may be used to identify the mode of action of a pesticide and to determine other pesticides with different modes of action that may be used in a pesticide rotation plan.

Table 5.1 Mode of Action (MoA) Classification of Insecticides and Miticides Used in Maryland Greenhouse Operations

Please Note: IRAC created 28 groups. We have not included groups that do not have any chemicals registered for use in greenhouses and nurseries.

Group	Main Group and Primary Site of Action	Chemical Class	Trade Name (Active Ingredient)
1A	Acetylcholine - nerve action	Carbamates	Mesurol (methiocarb)
1B	Esterase inhibitors – nerve action	Organophosphates	Orthene TT&O 97, 1300 Orthene TR (acephate) DuraGuard ME (chlorpyrifos) *Duraplex TR (chlorpyrifos + cyfluthrin) Fulex DDVP Fumigator (dichlorvos) *Tame/Orthene TR (fenpropathrin + acephate) Dibrom 8 Emulsive (naled)
2A	GABA-gated chloride channel antagonists	Cyclodiene organo-chlorines	Thiodan 50 WP (endosulfan)
3A	Sodium channel modulator	Pyrethroids Pyrethrins	Talstar, Attain, Menace GC(bifenthrin) Decathlon 20 WP (cyfluthrin) *Discus (cyfluthrin+imidacloprid) *Duraplex TR (chlorpyrifos + cyfluthrin) Scimitar GC (lambda-cyhalothrin) Tame (fenpropathrin) *Tame/Orthene TR (Fenpropathrin + acephate) Mavrik Aquaflow (tau-fluvalinate) Astro, Fulex Permethrin Fumigator (permethrin) Pyrethrum TR, Pyrenone, Pyreth-It (pyrethrin + piperonyl butoxide) *Pyrellin EC (pyrethrin + rotenone)
4A	Nicotine acetylcholine receptor disruptors- nerve action	Neonicotinoids	TriStar (acetamiprid) Celero (clothianidin) *Discus (cyfluthrin+ imidacloprid) Marathon, Benefit 60WP (imidacloprid) Safari (dinotefuran) Flagship (thiamethoxam)
4B		Nicotine	Fulex Nicotine Fumigator (nicotine alkaloid)

Group	Main Group and Primary Site of Action	Chemical Class	Trade Name (Active Ingredient)
5	Nicotine acetylcholine receptor agonist (nerve action)	Spinosyns	Conserve SC(spinosad) Entrust (spinosad)
6	Chloride channel activator	Avermectins	Avid 0.15EC, Flora-Mek 0.15EC, Lucid (abamectin)
7A	Juvenile hormone mimic	Juvenile hormone analogues	Enstar II (kinoprene)
7B		Fenoxycarb	Preclude, Precision Accu-Pack (fenoxycarb)
7C		Pyriproxyfen	Distance (pyriproxyfen)
9B	Selective feeding blocker	Pymetrozine	Endeavor (pymetrozine)
9C		Flonicamid	Aria (flonicamid)
10A	Mite growth and embryogenesis inhibitor	Clofentezine Hexythiazox	Ovation (clofentezine) Hexygon DF (hexythiazox)
10B		Etoxazole	TetraSan (etoxazole)
11A1	Microbial disruptors of insect midgut membrane	*B.t.* var *israelensis*	Gnatrol
11B2		*B.t.* var *kurstaki*	Dipel, Biobit HP, Deliver, Thuricide
12B	Inhibitors of oxidative phosphorylation, disruptor of ATP formation	Organotin miticides	ProMite (fenbutatin oxide)
13	Uncoupler of oxidative phosphorylation via disruption of H proton gradient	Chlorfenapyr	Pylon (chlorfenapyr)
15	Inhibitors of chitin biosynthesis, type 0, Lepidopteran	Benzoylureas	Adept, Dimilin SC (diflubenzuron) Pedestal (novaluron)
16	Chitin synthesis inhibitor	Buprofezin	Talus (buprofezin)
17	Molting disruptor	Cyromazine	Citation (cyromazine)
20B	Mitochondial electron transport inhibitor	Acequinocyl	Shuttle (acequinocyl)
21A	Site 1 Mitochondrial electron transport inhibitor	METI acaricides	Akari (fenpyroximate) Sanmite (pyridaben)
21B		Rotenone	*Pyrellin EC (pyrethrin and rotenone)
23	Inhibitors of lipid synthesis	Tetronic and tetramic acid derivatives	Judo (spiromesifen) Kontos (spirotetramat)
Unclassified: listed but not classified by the IRAC	Compounds of unknown mode of action	*Beauveria bassiana*–fungus	BotaniGard, Naturalis, Mycotrol O
		Bifenazate	Floramite (bifenazate)
		Pyridalyl	Overture (pyridalyl)
		Azadirachtin	Azatin, Ornazin, Aza-Direct, Ornazin, Neemix 4.5 (azadirachtin)
		Dicofol	Kelthane 50 WSP (difocol)

Group	Main Group and Primary Site of Action	Chemical Class	Trade Name (Active Ingredient)
Insecticides used in greenhouse not classified by IRAC	Desiccation of membrane disruptor	Oil	Triact (Neem oil)
			SunSpray Ultra-Fine Oil, JMS Stylet Oil (paraffinic oil)
			PureSpray Green, Saf-T-Side, SuffOil-X, Ultra-Pure Oil (petroleum oil)
			Golden Pest Spray Oil (soybean oil)
		Insecticidal Soap	Insecticidal Soap 49.52, M-Pede (potassium salts of fatty acids)

** Modes of action (MoA) – see IRAC Web site for additional information: www.irac-online.org
* Mixed IRAC groups

Chapter 6
Biological Control of Greenhouses Pests

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Introduction

When using biological control organisms to control plant pests, it is necessary to release the beneficial insects or apply entomopathogenic fungi or nematodes early in the crop cycle before plant pests are present or established in high numbers. The turnover time for bedding plant crops is short so there is a limited time for predators or parasitoids to reproduce. Regular monitoring is important when using beneficial organisms. Inspect plug shipments closely to avoid bringing pests into the greenhouse. The egg or sessile stages of insects are especially difficult to detect so when plants reach the production area, pest populations may explode. Long-term and high value greenhouse grown crops such as hanging baskets, poinsettia, pansy, and chrysanthemums are good choices for biological control programs. The diversity of crops in any one greenhouse can make biological control use a challenge. Be sure to know the crops and plant pests that typically infest them and plan a biological control program accordingly. Certain pesticides are compatible with biological control organisms (Table 6.1).

Several widely available arthropod pathogens are discussed below. Insect pathogens are more cost-effective compared to releasing predators and parasitoids.

Bacillus thuringiensis (Bt)

Bacillus thuringiensis is a widely-used pathogen for controlling early instars of caterpillars. Under cool, dry conditions, Bt can be stored for up to 2 years. Insects must feed on the bacterium so when applying Bt thorough coverage of the plant is important. *Bacillus thuringiensis* var *kurstaki* and *B. thuringiensis* var *aizawai* control caterpillar pest species that include cabbage looper, corn earworm, European corn borer, Florida fern caterpillar, and saltmarsh caterpillar), and the variegated fritillary caterpillar. *B. thuringiensis* var *kurstaki* can be used to control most caterpillars. It works best when it is applied while early instar larvae are actively feeding. Some strains of *B. thuringiensis* are more effective against select species than other strains of the pathogen.

Bacillus thuringiensis (serotype 14) applied to the soil can kill fungus gnat larvae occurring in moist soil. To control fungus gnats, repeat applications are often necessary because fungus gnats often have overlapping generations and the bacteria is only effective against early instar larvae. Propagation areas kept under mist maintain soil conditions best suited to using *B. thuringiensis* (serotype 14).

Entomopathogenic Nematodes

Entomopathogenic nematodes thrive in moist conditions and can be lethal to insects such as fungus gnats, pupating thrips, and black vine weevil larvae. Commercial producers use two different methods for rearing entomopathogenic nematodes. Nematodes may be produced in vitro on an artificial diet or they may be reared in vivo in living hosts. Nematodes such as *Steinernema carpocapsae* and *S. feltiae* produced in vitro are usually formulated in a manner enabling them to be stored for up to 6 months. Nematodes such as *Heterorhabditis bacteriophora* that are produced in vivo may be stored for up to 3 months. To maintain the nematodes' effectiveness it is important to ask the supplier about the method of production and recommendations for storage.

Nematode formulations include slurries, granules within inert clay carriers, gels, and sponges. Water must be added all formulations in order to rehydrate the nematodes. Apply nematodes as a soil drench for even distribution throughout the substrate and to maximize their contact with soil-dwelling insects. Keep soils moist and soil temperatures above 16 °C (60 °F) and below 32 °C (90 °F).

The infective nematode finds a susceptible host and enters the insect's body through natural openings such as the mouth, spiracles, or anus. The nematodes feed and release bacteria which live symbiotically in the insect's gut. The bacteria rapidly multiply, killing the insect. The nematodes mature and reproduce in the colonized insect cadaver. These infective stages leave the insect's body and return to the soil or substrate to search for other hosts when no more food is available.

Entomopathogenic Fungi

Entomopathogenic fungi are pathogens that infect and kill insects. Insects are killed when they come into contact with these fungi. *Beauveria bassiana* (Balsamo) Vuillemin is an entomopathogenic fungus that may control infestations of whiteflies, some thrips, and certain aphid species. Available as suspensions and wettable powders, the active ingredients are conidia (spores) which are sprayed directly onto the pests. The spores must contact the host directly to be effective so good spray coverage is critical. Hyphae, small tubes that grow from the conidia, use a combination of mechanical pressure and enzymes to break through the exoskeleton of the pests to enter the body cavity and attack the internal organs. The infected insect stops feeding and dies within a few days.

Table 6.1 Compatiblity of Pesticides and Biological Control

Chemical	Trade Name	Effects on Beneficials
Abamectin	Avid	Immediate contact kills mites. Less harmful to insects. Relatively long residual toxicity.
Acephate	Orthene	Immediate contact kills beneficial organisms. Some residual toxicity.
Azadirachtin	Azatin XL Ornazin, AZA-Direct	Immediate contact is somewhat harmful. No long residual toxicity.
Beauveria bassiana	BotaniGard	Should not impact mobile predators, but parasites such as *Encarsia formosa* and other parasitic wasps may be killed when the internal parasite is infecting the target pest.
Bacillus thuringiensis Serotype 14 (+Bti)	Gnatrol	No impact on beneficial organisms. Needs 3 applications at 7-day intervals for best efficacy.
Bacillus thuringiensis (Kurstaki strain)	Dipel, Caterpillar Attack	No impact on beneficial organisms.
Dicofol	Kelthane	Immediate contact kills predaceous mites. Long residual activity continues to kill mites.
Entomopathogenic nematodes: *Steinernema feltiae*, *Steinernema carpocapsae*, and *Heterorhabditis bacteriophora*	Nemasys, Entonem	No known impact on parasites or predators. Entomopathogenic nematodes are usually applied as a soil drench for fungus gnat larvae control.
Imidacloprid	Marathon	Immediate contact is not very harmful. No long-term residual activity.
Insecticidal soap	M-Pede and Insecticidal Soap	Immediate contact is somewhat harmful. Little or no residual toxicity.
Oils	UltraFine Oil, Neem oil, and JMS Stylet Oil	Immediate contact is somewhat harmful. Little or no residual toxicity.
Pyrethrin	Pyreth-It	Immediate contact kills beneficials. Has relatively short residual toxicity.

Aphids

Introduction

Various species of aphids are a problem in greenhouses on both vegetable and ornamental crops, particularly on young plants, between late fall and early spring. Aphids are one of the most difficult insects to control with sprays because of their remarkable reproductive ability. Females, which do not mate or lay eggs during the summer, are parthenogenic (do not need a male to reproduce) and give birth to as many as 5 live young per day. If even one aphid survives a pesticide application (some always do), she can generate a new colony and reinfest the crop. Aphids feed on plant sap, secrete honeydew onto the plant, and inject toxic substances into it. Plant damage can be seen as curled leaves, honeydew growing on fungus, and virus symptoms.

Biological Control For Aphids

Before attempting to use biological control for aphids in a greenhouse, investigate the economics, shipping routes, availability, suitable species, release rates, and timing. It also helps to know which species of aphid you are trying to control because some predators and parasites are better for certain aphid species (Table 6.2).

The predatory aphid midge, *Aphidoletes aphidimyza*, is excellent for controlling more than 60 aphid species, especially green peach aphid. Midges are shipped as pupae. Place one to two pupae on each potted plant; for bedding plants place 3 to 5 larvae per square yard of bench area. Continue biweekly releases until the aphids are controlled. This predator thrives under humid conditions.

For controlling melon aphids, the parasitic wasp, *Aphidius colemani*, is the preferred beneficial species to use. Try one to three aphid midge cocoons per square foot of growing area. In northern greenhouses during the short days of fall and winter, this predator requires supplemental lighting to stay active.

Aphidius matricariae is a parasitic wasp used for controlling potato aphid and green peach aphid. These parasitic wasps reproduce by laying eggs in aphids and typically produce tan or gold aphid mummies. There will be a round hole where the adult parasite has chewed its way out of the aphid mummy.

Another method of control is using pathogens that infect aphids. One of the most effective entomopathogenic fungi for aphid control is *Beauveria bassiana*. This insect is sold under two brand names, BotaniGard and Naturalis T&O. Conidia of the fungus are mixed with water and applied as a fine spray. Making direct contact with the aphids is important. Use a fine mist sprayer with droplet sizes of 100 microns or less to ensure the best contact. The conidia that make contact with the aphid germinate, penetrate the body of the aphid, and kill the pest. In the spring and summer, aphids shed their skins every 3 to 4 days which may reduce the efficacy of the fungus. Repeated applications at 3- to 5-day intervals usually ensures that conidia are present on the skin long enough to cause infection. Some growers use *Beauveria bassiana* applications in combination with one or more chemical controls.

Table 6.2 Biological Control of Aphids

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Aphidius colemani (parasitic wasp)	Green peach aphid, melon aphidss	50–76 °F; tolerates cool temperatures, low light	Adults: tiny wasp lays eggs in aphids (for green peach aphids).	Granular carrier: aphid mummies and adults. Release 2–8 per yd^2 of growing area.
Aphidius ervi (aphid parasitoid)	Good for controlling potato aphids	68–81 °F; 50–75% relative humidity	Adults: tiny wasp lays eggs in aphids (for potato aphids).	Shipped in carrier as adults. Release 1–3 per yd^2 of growing area.
Aphidoletes aphidimyza (gall-midge)	Aphids, including green peach aphid, cotton aphids	68–81 °F; 50–75% relative humidity	Adults lay eggs close to aphid colonies. Adults are active at night, attracted to aphid colonies by smell of honeydew. Larvae are orange, develop in aphid, bite aphid knee joints, inject a paralyzing toxin and suck out body contents. Eggs are deposited in aphid colonies.	Need soil or gravel floor for larvae to pupate. Release 2–9 per yd^2; 2–3 releases one week apart. Aphid midge cocoons packed in moist vermiculite. Mature larvae drop to ground and burrow into soil to pupate. Go dormant under short-day conditions.
Chrysoperla carnea (lacewings)	Aphids (also feed on mealybugs, scales, spider mites, thrips, small caterpillars)	60–80 °F	Adults: pale green, evening fliers. Larvae: aphid lions (alligator-like) can eat 60 aphids per hour; will cannibalize each other. Eggs: laid on the end of a long silk stalk on leaves near aphids.	Shipped in bran as eggs, young larvae, or adults; shipped as eggs on cards or in corrugated cardboard wafers. Adults tend to fly away and do not stay to lay eggs). Noticeable control in 2 weeks. Release 2–12 per yd^2; repeat every 2 weeks.
Hippodamia convergens (lady beetle)	Aphids (also feed on scales, thrips, small caterpillars)	At least 68 °F	Adults and larvae are predacious. Larvae: alligator-like. Eggs: orange, bullet-shaped.	Avoid residual chemical applications. Oil or soap can be applied before a release.

Caterpillars

Biological Control For Caterpillars

The larvae of various species of moths and butterflies that feed on plants in greenhouse production areas can be controlled with biologicals (Table 6.3). It is common to see the variegated fritillary feeding on pansies in the fall as well as imported cabbageworm, cabbage looper and the cross-striped caterpillar on cabbage and kale. *Bacillus thuringiensis* var *kurstaki* is a bacterium that offers good control of the early instar stages of caterpillars. The larvae ingest the bacterium. There are several species of *Trichogramma* (parasitic wasp) that feed on caterpillar eggs. The female oviposits into the caterpillar egg and the parasite kills the egg as it feeds. A parasitized egg usually turns black. *Cotesia glomerata* was introduced to North America in 1883. It is a small braconid wasp that parasitizes early instar larvae of imported cabbageworm caterpillars. It is currently not commercially available, but is often found parasitizing the cabbageworm larvae.

Table 6.3 Biological Control of Caterpillars

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Bacillus thuringiensis kurstaki (beneficial bacterium)	Early instar caterpillars	See label instructions	Bacterium must be ingested by insect.	Only kills larvae.
Trichogramma spp.	Caterpillars, including European corn borer, cutworm, and imported cabbageworm	Moderate temperatures (not mid-day sun or cold mornings)	Release when first see flight of moths whose caterpillars damage crops.	Feed on the eggs of many species. Night releases may slow dispersal.

Fungus Gnats

Biological Control For Fungus Gnats

Beneficial organisms attack only insects in moist soils or borer tunnels; as a result, be careful not to allow the environment to dry out. Apply as a spray concentrate or a moist granular carrier (Table 6.4).

Beneficial (entomopathogenic) nematodes

Entomopathogenic nematodes are microscopic, multicellular, worm-like organisms. Three species of entomopathogenic nematodes, *Steinernema carpocapsae*, *S. feltiae*, and *Heterorhabditis bacteriophora*, are used to control the larvae of fungus gnats. Several suppliers now market nematodes for use in the greenhouse and nursery (Exhibit, Scanmask, Vector, and Guardian are examples of several brand names). In trials conducted by University of Maryland Extension, *S. feltiae* was found to be the most effective of the three nematodes. Commercial availability of *S. feltiae* is currently limited to a few sources, but the costs of nematode application are now competitive with the costs of using many conventional insecticides.

The moist environment of greenhouse media is ideal for entomopathogenic nematodes. Apply the nematodes as a media drench and to soil below the bench. Once applied to the potting media, the nematodes search for soil-inhabiting insects. When they locate an insect, they enter it. Once inside the host, the nematodes release bacteria into the insect's bloodstream. The bacteria multiply, and the nematodes feed on the bacteria. The insect then dies of bacterial infection.

In the greenhouse potting media, these nematodes complete their life cycle within the infected host in a few days. Large numbers of infective-stage nematodes are produced from each dead insect. These nematodes then leave the dead insect and move into the soil media in search of new insects to attack. Entomopathogenic nematodes and their associated bacteria have been tested extensively for toxicity to non-target organisms. Research has shown that they are harmless to humans, wildlife, fish, and plants.

Beneficial mites

Hypoaspis miles (formerly known as *Geolaelaps miles*) are tiny predatory mites native to the United States. They commonly inhabit the upper layers of soil. The mite is 0.5 millimeters (1/50-inch) long and light brown and has eight legs. *Hypoaspis* feed upon a variety of microscopic soil-inhabiting insects and mites. They are well adapted to moist conditions and will survive in greenhouses in a variety of growing media throughout the year.

In greenhouses, *Hypoaspis miles* has been used to control fungus-gnat larvae. It is also reported to contribute to the control of thrips by feeding primarily on the thrips pupating in the soil. Like most biological control agents, *Hypoaspis* should be applied when the fungus-gnat population is low. It is best to apply the mites to the soil within the first few weeks after planting. *Hypoaspis* populations include both sexes, but the males are much smaller and rarely seen. Using a hand lens with 10x to 15x magnification, you should be able to see the nymphs and adults of the mites which move rapidly across the soil surface. The mites reproduce in the greenhouse environment, completing their life cycle in 7 to 11 days. Barring the application of a soil-drench insecticide, the mites should not need to be reintroduced into the crop after the initial release.

Hypoaspis are usually supplied in a pasteurized sawdust mixture in 1-liter containers generally containing about 10,000 mites. Containers have shaker lids to ease distribution over the soil. Use mites immediately because they do not store well. You can examine the mites for viability by shaking a small amount of sawdust onto a sheet of paper and examining it with a hand lens. If present and healthy, nymphs and adults should move rapidly. Numerous eggs are included in these shipments and will survive poor shipping conditions better than the adults. Therefore, sprinkle them on the soil even if you do not see active forms.

According to research on greenhouse-grown vegetables in Europe, appropriate mite release rates for tomatoes grown in in-ground beds are 5 to 8 mites per square foot of greenhouse space. For floriculture production, in which plants are grown in market packs, pots, or hanging baskets, exact release rates have not been determined. We suggest a rate of 10,000 mites per 1,000 square feet of greenhouse. It is easiest to mix the mites in the soilless media just before you fill the pots or container. *Hypoaspis* are compatible with releases of beneficial nematodes or the use of *Bacillus thuringiensis* var *israeliensis*.

Limestone or copper sulfate applied to the soil may reduce the *Hypoaspis* population and should be avoided. The use of *Hypoaspis* in the greenhouse environment is relatively new, and it has not been thoroughly tested for sensitivity to specific fungicides. Generally, foliar sprays should be less harmful than soil drenches.

Bacillus thuringiensis

Bacillus thuringiensis var *israeliensis* (Bti) is a highly effective spore-forming bacterium that produces a toxic protein crystal that kills maggots in the fungus-eating gnat families. Bti is produced by fermentation, a process similar to that used in manufacturing natural antibiotics. An organism commonly found in nature, this insecticide poses no danger to greenhouse workers, and there is no reentry restriction time.

Bti formulations for greenhouse use are sold under the trade name ‘Gnatrol’ and are applied as soil drenches. Treat soil in pots, market packs, and areas beneath benches. Treatment for severe infestations requires the higher rates at 3- to 5-day intervals. Obtain season-long control through a weekly maintenance treatment at a lower rate.

Table 6.4 Biological Control of Fungus Gnats and Shore Flies

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Atheta coriaria (predatory beetle)	Sciarid fly larvae, shore fly larvae, fungus gnat larvae (Also thrips pupae)	Adapt well to assorted growth media (including rock wool and coconut fiber) and capillary mats; do not survive freezing or flooding.	Can be applied along with other predators.	Kills all immature life stages including eggs.
Bacillus thuringiensis israelensis (Bti)- Beneficial bacterium (Gnatrol)	Fungus gnat larvae	Apply with adequate water to wet soil surfaces.	Applied as a soil drench to kill the larval stage.	Only kill larvae. Larvae must ingest; will stop feeding immediately and die within ~24 hours. Three applications at 7-day intervals are necessary. OMRI certified.
Hypoaspis miles (predaceous mite)	Fungus gnats, shore fly larvae, (Also thrips pupae and springtails)	Do not refrigerate.	Soil-dwelling predaceous mite. Adults: tiny brown mite; lay eggs in the soil.	Release rate: 45 to 100 per yd^2; one per season (rate determined by greenhouse size and pest infestation).
Steinernema carpocapsae (Ecomask)	Fungus gnats	60–85 °F	Mobile; actively seek out their prey if temperature and humidity are right. Carry insect-pathogenic bacteria in their gut.	Refrigerate until use. Apply as a soil drench. Keep nematode suspension agitated. Water plants before and after application. Apply early or late in the day. Need protection from desiccation, the sun, ultraviolet radiation, and temperature extremes. Infected insects turn brownish-yellow and usually die within 1 or 2 days, .
Steinernema feltiae (Nemasys)	Fungus gnats, shore flies, root maggots	Substrate needs to be moist.		Only kill larvae. Available in a very fine clay formulation.

Mealybug

Biological Control For Mealybugs

Natural enemies are available for controlling mealybug species that occur in conservatories or greenhouses with specialty ornamental crops (Table 6.5). The combination of the mealybug destroyer (a lady beetle), *Cryptolaemus montrouzieri*, and the parasitic wasp, *Leptomastix dactylopii*, is effective against citrus mealybug, *Planococcus citri*, which is the most common mealybug in greenhouses.

Table 6.5 Biological Control of Mealybug

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Chrysoperla carnea (green lacewing)	Aphids, mealybugs, immature scales, thrips, spider mites, immature whiteflies		Feed on immature eggs and pests. Larvae are cannibalistic.	Disperse well. Release 2–2 larvae per yd^2.
Cryptolaemus montrouzieri (mealybug destroyer)	Mealybugs (also aphids, whiteflies, scales	62-91 °F	Both larvae and adults feed on mealybugs.	Avoid residual pesticides for at least 1 month before release.
Leptomastix dactylopii (wasp)	Citrus mealybugs (not long-tailed mealybug).		Best control when mealybug population is high.	Release 2 per m^2 of infested area or 5 per infested plant.

Mites: Broad Mites, Cyclamen Mites and Spider Mites

Biological Control for Broad and Cyclamen Mites and Spider Mites

Choose the predatory mite species best suited to the environmental conditions and pest mite species present in your greenhouse (Tables 6.6 and 6.7). Consult an Extension entomologist or biological supplier to be sure to get the correct species for each pest mite situation. Start releases soon after the first sign of spider mites. On crops or in greenhouses where mites have been a problem in the past, release the predaceous mites while plants are still small. Place predators directly onto infested leaves. Predatory mites are shipped mixed in grain or vermiculite so they can be easily distributed throughout the greenhouse. Most organophosphate, carbamate, and pyrethroid insecticides are toxic to predatory mites.

Table 6.6 Biological Control of Broad and Cyclamen Mites

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Amblyseius barkeri *A. californicus* *A. cucumeris* (predatory mites)	Broad mites		*A. californicus* can survive long periods without prey.	Apply early in crop cycle. 10 to 30 per plant.
Amblyseius cucumeris (predatory mite)	Cyclamen mites			Release 2 – 10 per ft^2 of growing area

Table 6.7 Biological Control of Spider Mites

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Amblyseius fallacis (predatory mite)	Twospotted spider mites	70–90 °F	Shiny body with few hairs.	When prey level is low, it leaves the area to search for more food.
Feltiella acarisuga (predatory midge)	Twospotted spider mites, carmine spider mites, European red mites		Larvae are creamy yellow-brown; larval stage feeds on spider mites.	Cocoons found along leaf veins.
Galendromus occidentalis (predaceous mite)	Spider mites, European red mites	70–95 °F Minimum relative humidity: 50%.	Consumes pollen and honeydew and are also cannibalistic.	Resistant to organophosphate insecticides. Starvation-resistant.
Amblyseius californicus (predaceous mite)	Twospotted spider mites, broad mites, cyclamen mites	70–90 °F Minimum relative humidity: 60%. Tolerates high temperatures and low humidity.	Adults are straw-colored, fast-moving, droplet-shaped with short legs. Eggs are oblong, transparent, and attached to hairs along leaf veins.	Can survive longer in the absence of prey (feeds on other mites and pollen). Sprinkle onto leaves. Consumes fewer spider mites than *P. persimilis*.
Phytoseiulus persimilis (predacious mite)	Twospotted spider mites, carmine spider mites	65–80 °F Minimum relative humidity: 60%.		

Scale

Biological Control For Scale

Natural enemies are commercially available for controlling scale species that occur in conservatories or greenhouses with specialty ornamental crops (Table 6.8). The parasitic wasp, *Metaphycus helvolus*, is effective against the hemispherical scale, *Saissetia coffeae*, and useful against soft brown scale, *Coccus hesperidum*.

Table 6.8 Biological Control of Scale

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Aphytis melinus (wasp parasite)	Armored scales, oleander scales, California red scales, yellow scales	76–85 °F	Adults are tiny yellow wasps that lay eggs under the covering of mid-sized scales.	Before release, wash off or use a 1% solution of insecticidal soap to reduce honeydew.
Metaphycus helvolus (wasp parasite)	Soft scales, brown soft scales, black scales, nigra scales, hemispherical scales	75–85 °F	Adults are tiny black/yellow wasps.	Lay eggs on newly hatched crawlers and also feed on older scale.

Biological Control For Thrips

Various predators and a biofungicide are available for thrips control (Table 6.9). Two species of predatory phytoseiid mites, *Amblyseius cucumeris*, and *Iphiseius* (=*Amblyseius*) *degenerans*, appear to be well suited for controlling immature thrips preying on greenhouse crops. Similar to thrips, these mites prefer small niches where contact between predator and prey is likely even without specific searching. These predators are pollenphagous (pollen feeding) when thrips populations are low. More questions remain to be answered about the best timing and frequency of releases and usefulness of these predators on various crops and on various thrips species.

These mites must be introduced before a thrips population has built up to damaging levels. The mites establish themselves on leaves, usually on the undersides, and are most effective in attacking young (1st instar) larvae of thrips. The mites use their chelicerae to pierce the thrips and suck out the cellular fluids. The predaceous mites will establish themselves on a crop in the greenhouse and then mate and reproduce. The major limitation of their use is that these mites are susceptible to many insecticide sprays; growers must use biological control against other pests or be selective in pesticides used, selecting insect growth regulators or using biorational chemicals that have minimal impact on predators. Note that the beneficial pathogen, *Beauveria bassiana* GHA strain (BotaniGard), does not affect phytoseiid mites and could possibly be used in combination with beneficial mite releases. Apply predatory mites with shaker bottles. Growers shake the mites and a grain carrier onto the crop. Another option is to apply the mites using paper sachets. Hang the sachets on plants or on marker stakes. An adult *A. cucumeris* feeds on one thrips per day during its 30-day life. For releases during the short days of winter the best choice is *I. degenerans*. Alternatively, obtain *A. cucumeris* from biological suppliers that carry selections that do not go into diapause in winter. If using predaceous mites for controlling western flower thrips, it is essential to combine this treatment with INSV-monitoring plants or use on-site INSV serological testing kits.

The release rates for *A. cucumeris* range from 90 to 270 per yd^2 of growing area for floriculture crops. If using mite sachets we have found that 60 sachets (with 50 mites per sachet) placed in 3,000 square feet generally provide good control for 5–6 weeks. Replace the sachets when a new crop is placed in the greenhouse.

Predatory true bugs - There are about 70 species of predatory true bugs in the genus *Orius*, minute pirate bugs. Three species are generally available from commercial insectaries for thrips control: *O. insidious* (insidious flower bug), *O. tristicolor* (minute pirate bug), and *O. albidipennis*. Pirate bugs are voracious, reproduce well in greenhouses, and may provide the best thrips control because they are able to attack all stages of thrips, including adult thrips. In floriculture crops apply 2–6 *Orius* per square yard of production area.

Beneficial pathogens - Several pathogens have been investigated for controlling thrips. The entomopathogenic fungus, *Beauveria bassiana*, applied as a fine mist spray directly onto thrips, is used to control western flower thrips in greenhouses. Some growers use *Beauveria bassiana* in combination with insecticides to improve the control of thrips.

The entomopathogenic fungus, *Metarhizium anisopliae*, is probably one of the more promising biological controls for thrips control. When spores land on thrips, the spores break through the insect's exterior to the inside, using enzymes and mechanical force. The insect dies within a few days. Presently, Novozyme has a label pending with EPA for the product, Met52.

Table 6.9 Biological Control of Thrips

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Amblyseius degenerans (predatory mite)	Thrips	68-77 °F; tolerates low humidities	Highly mobile predaceous mite.	Also feeds on pollen.
Amblyseius swirskii (predatory mite)	Good for chili thrips	Begins development at 68-72 °F	Not susceptible to diapause so can introduce in winter.	Tolerant of high temperature.
Beauveria bassiana (entompathogenic fungus)	Thrips (and whitefly, aphids, mites and mealybugs)	Humidity above 60%.	Naturally occurring fungus in soils.	Repeated application with fine mist.
Chrysoperla spp. (green lacewing, predator)	Thrips (aphids, mealybugs, immature scales, spider mites immature whiteflies)		Feeds on immature eggs and pests. Larvae are cannibalistic.	Disperse well. Release 2–12 larvae per yd^2.
Hypoaspis miles (predatory mites)	Thrips (fungus gnat larvae, shore fly larvae, and springtails)	Do not refrigerate.	Soil-dwelling. Adults are tiny and brown and lay eggs in the soil.	Release 45–100 per yd^2 according to pest population and greenhouse size.
Amblyseius cucumeris (predatory mite)	Western flower thrips, onion thrips (twospotted spider mites and eggs, broad mites, cyclamen mites)	70–90°F. Minimum relative humidity: 60%.	Adults are fast-moving, teardrop-shaped, and tan. Females consume an average of one thrips per day over a 30-day life span. Eggs are transparent white on leaf hairs along veins or leaf underside. Alternate food sources are fungi, honeydew and pollen. Attacks thrips eggs and immatures.	Mites are found on the underside of the leaves near the mid-vein. Release between 10–200 predators per plant. Release before or soon after the first thrips are found. Adults and nymphs shipped in sachets and bottles, flower mites, and bran. Repeat applications are necessary.
Orius insidiosus (predaceous bugs)	Thrips preferred (also feed on mites, aphids, scales, whitefly pupae, and soft-bodied arthropods [spiders])	70–90°F. Long days.	Nymphs are yellow with red eyes. Adults and nymphs are predaceous bugs. Adults black are attracted to flowers and can eat 5–20 thrips per day.	Go dormant during short days (need supplemental lighting to extend day September to April). Release 1 per 10 ft^2 as a preventative or 1 per 2 ft^2 if thrips present.

Whitefly

Biological Control For Whitefly

Whiteflies are common pests of some greenhouse ornamentals, tomatoes, and cucumbers. Chemical control is difficult because the eggs and immature larvae have a waxy coating that resists chemicals. Whitefly populations have also developed resistance to commonly used pesticides, even to the recently introduced synthetic pyrethrins. Whitefly adults are found at the top of the plant or on the leaf underside. Plant damage is seen as yellowing of the foliage beginning around the midvein. Parasitoids and pathogens are commercially available for whitefly control (Table 6.10).

Parasitoids

Two parasitoids that have been used successfully to control whitefly on greenhouse crops are tiny wasps of the *Encarsia* and *Eretmocerus* species. These wasps attack whitefly nymphs (not adults), killing them in one of two ways. The first attack method is when the female wasp uses her needlelike ovipositor to lay an egg within or beneath a whitefly nymph. *Encarsia* sp. prefers the third to fourth instar whiteflies. The egg hatches and the parasitoid larva feeds on the whitefly nymph. Wasp pupation occurs within the nymph. When the adult wasp emerges from the whitefly pupa, it chews a round exit hole through the cuticle at one end of the whitefly pupa. The other way wasps attack whitefly nymphs is through a phenomenon called host feeding in which the female wasp punctures the whitefly nymph with her ovipositor, killing the nymph, and then she feeds on the fluids that exude from the wound. For whitefly control on short-term floral crops, these wasps are usually released weekly in large quantities. When wasps inundate the pests, the wasps kill whitefly nymphs primarily by host feeding rather than parasitism, leaving behind dead whitefly nymphs that appear collapsed and dry.

Several species of whitefly parasitoids occur naturally in the U.S., and these may migrate into unsprayed greenhouses and attack whiteflies. However, the degree of control provided by these parasitoids is usually insufficient. Repeated releases of commercially reared parasitoids which augment the population are typically more effective.

Encarsia formosa (Gahan) is a tiny wasp (0.6 mm) with a black head and thorax and pale yellow abdomen. Its wings are transparent. Females produce mostly other females; males are rare. Greenhouse whitefly pupae that have been parasitized by *E. formosa* turn black; *Bemesia tabaci* whitefly pupae turn amber brown. Adult wasps are rarely noticed and should not deter the sale of the plants. This parasitoid is widely used for biological control of greenhouse whitefly on greenhouse vegetables. Release rates vary from three to six wasps per square foot of growing area with repeated releases at 7- to 14-day intervals. *E. formosa* will reproduce on many greenhouse crops once populations are established. *E. formosa* is more successful at suppressing whitefly in summer than in winter. For maximum reproduction, wasps require a higher light intensity and warmer temperatures than the whitefly. The cost of *E. formosa* can be equal to foliar pesticide applications or slightly higher. Multiple releases of *E. formosa* are more expensive than a single application of a long residual systemic insecticide such as imidacloprid.

Eretmocerus eremicus (=*californicus*) Rose and Zolnerowich is also a tiny wasp, but differs from *Encarsia formosa* in having an adult that is entirely yellow. These wasps have green eyes and clubbed antennae. Males have longer, more prominent antennae than females. Parasitized whitefly nymphs appear beige in color. Release rates are 2–3 per square foot of growing area. Repeated releases at 7- to 14-day intervals are often necessary. *Eretmocerus* will not reproduce on many greenhouse crops, so repeated applications are necessary until the whitefly population is reduced to a desired level. Unfortunately, this parasite is relatively expensive and costs significantly more for controlling whiteflies than applications of pesticides.

Pathogens

A naturally occurring insect pathogen, *Beauveria bassiana*, is found to be effective in controlling whiteflies, certain aphid species, mites, and thrips. Two different strains of the fungus are commercially available. BotaniGard (GHA strain), is formulated as a wettable powder and an emulsifiable suspension. Naturalis-O (JW-1 strain) is a flowable formulation. *B. bassiana* spores are formulated to mix readily in water and are applied using standard high-volume spray equipment. The fungus kills insects either by direct contact with the spray or through secondary contact with spores on foliage. When spores come in contact with an acceptable host, a germ tube penetrates the insect's cuticle and feeds from the host body, resulting in the death of the host. In most cases, it takes 8 to 10 fungal spores on an insect to cause fungal infection and subsequent death of the insect. The warm temperatures and relatively high humidity in greenhouses present an ideal environment for using this fungal pathogen. Because fungal spores kill insects through direct contact, good spray coverage is essential for achieving adequate control.

Table 6.10 Biological Control of Whiteflies

Beneficial	Target Pest	Favorable Environment	Characteristics	Comments
Beauveria bassiana (beneficial fungus)	Whiteflies (and thrips, mealybugs and aphids)	Humidity above 60%	Naturally occurring fungus in soils.	Repeated application with fine mist.
Delphastus pusillus (lady beetle)	Greenhouse whiteflies, sweet potato whiteflies, *Bemesia tabaci* whiteflies	65–90°F	Adults are minute black lady beetles that eat whitefly eggs, larvae, adults.	Require 100–150 whitefly eggs per day to maintain egg-laying. Consume 11–15 settled whiteflies per day.
Encarsia formosa (wasp parasitoid)	Greenhouse whiteflies	Above 70 °F; 70% relative humidity (If temperature is below 62 °F, wasps will not fly).	Adults are tiny wasps that develop faster than the whitefly. Adults lay 50–100 eggs in immature stages of whitefly, parasitizing and killing them.	Shipped inside blackened whitefly scales attached to cards. Attach to the foliage. Release at first sign of whiteflies on yellow sticky cards. Release rate: 3–4 releases with 1- to 2 week intervals.
Eretmocerus eremicus (wasp parasitoid)	Sweet potato whiteflies, *Bemesia tabaci* whiteflies	77-84 °F	Adults are tiny wasps that lay their eggs under whitefly larvae .	Release rate: 3–5 releases with 1- to 2 week intervals.
Eretmocerus mundus (wasp parasite)	Sweet potato whiteflies, *Bemesia tabaci* whiteflies	Adapts to both high and low temperatures.	Adults: tiny wasps; lay their eggs under whitefly larvae.	Make a minimum of 3 releases.

Chapter 7
Biopesiticides and Reduced-Risk Pesticides

Stanton A. Gill, Extension Specialist

Introduction

Biopesticides are types of pesticides derived from such natural materials as animals, plants, bacteria, fungus, and certain minerals (Table 7.1). Examples include entomopathogenic nematodes used for fungus gnat control and potassium bicarbonate which acts as a pesticide against powdery mildew.

Why Growers Should Use Biopesticides

Biopesticides are usually inherently less toxic than conventional pesticides. Most nursery and greenhouse operations have workers constantly entering the growing area to water, move plant material, fertilize, or conduct other plant maintenance chores. Most pesticides have a required Re-entry Interval (REI) that restricts employees from entering a greenhouse or nursery area unless they are wearing the Personnel Protective Equipment (PPE) required on the label. This adds time and additional expense to the nursery or greenhouse operation. Biopesticides generally have REIs of only 4 to 12 hours.

Some biopesticides such as entomopathogenic nematodes have no REI. Growers who can control insects or disease by selecting an effective biopesticide with minimal or no REI will save time in labor. Not needing PPE equipment makes the selection highly attractive. It also makes sense to use biopesticides in residential and commercial landscapes where there is an increasing demand for least-toxic pest control methods as part of an Integrated Pest Management (IPM) approach. Re-entry intervals are not presently used in landscape settings.

The disposal of leftover biopesticides is less restrictive than the disposal of more toxic compounds which is an additional benefit. Biopesticides often decompose quickly, thereby resulting in lower environmental and human exposure. Pollution problems caused by conventional pesticides are largely avoided. The disposal of old pesticides, which currently creates problems for growers, will likely be an expensive and major problem for greenhouse and nursery growers and landscape managers in the near future.

Biological control has been used only in a limited manner in the nursery, greenhouse, and landscape industries. Biopesticides will help managers make the transition to using beneficial organisms relatively smooth. Biopesticides generally affect only the target pest and closely related organisms in contrast to broad spectrum, conventional pesticides. Many of the biopesticides can be used in combination with biological releases to control insect or mite pests. Biopesticides used to control fungi often have to be pre-incorporated into substrate or inoculated early in the growth stages of a plant.

Biopesticides are the trend of the future. Generally, they pose fewer risks to the environment and to workers than conventional chemicals. When a pesticide is registered with the Environment Protection Agency, EPA generally requires less data about a biopesticide than it does about conventional chemicals. Biopesticide registration also generally takes less time—an average of less than one year compared to at least three years. Chemical companies, well aware of the cost savings, are working on several new biopesticides that should be registered during the next decade. Companies registering a new pesticide must submit a variety of data about its composition, toxicity, and degradation to the environment before it is approved for use.

Three Main Categories of Biopesticides

Microbial Pesticides

Microorganisms, including bacterium, fungus, and virus, are the active ingredient of microbial pesticides. Some microbials control plant pathogens, usually on a preventative basis, and some control insects and mites. In some cases the microbial insecticide may be specific, such as *Bacillus thuringiensis* Serotype 14 (Bti), which controls fungus gnat larvae and mosquito larvae. Others, such as the fungus, *Beauveria bassiana*, control several species of insects including whiteflies, aphids, and some caterpillars. The most widely known microbial pesticide is *Bacillus thuringiensis* (Bt), which is used to control a variety of early-stage caterpillars.

Reduced-Risk Pesticides

Starting in 1993 the federal EPA has expedited the registration of conventional pesticides with the following characteristics: very low toxicity to humans and nontarget organisms including fish and birds, low risk of groundwater contamination or runoff, low potential for pesticide resistance, and a demonstrated efficacy and compatibility with IPM. EPA refers to materials meeting these criteria as reduced risk. The reduced-risk designation applies only to certain uses of a particular pesticide which may not include all label uses for that product. Reduced-risk products/uses must be registered with EPA and labels will bear EPA registration numbers. Manufacturers, however, are not permitted to label materials as "reduced risk".

Floramite (EPA# 400-481) miticide and Endeavor (100-613) insecticide are two reduced-risk pesticides labeled for use on ornamentals. Fenpyroximate (Akari 5SC) from SePRO Company is a reduced-risk miticide. Tebufenozide (Confirm), from Dow AgroSciences, an insect growth regulator (IGR) for caterpillars, is also a reduced-risk pesticide for ornamentals. Some insecticides such as spinosad (Conserve) are considered reduced risk for certain nonornamentals applications only. Conserve is not presently classed as a reduced-risk pesticide. Other reduced-risk pesticides for use on ornamentals include Heritage Fungicide (10182-408) for turf; Subdue GR (100-794), Subdue 2X WSP (100-795), and Subdue Maxx (100-796) for ornamentals; and Compass Fungicide (100-920) for ornamentals.

Minimum-risk pesticides are certain products exempted from EPA registration (and therefore carry no EPA registration number), containing only active ingredients outlined in FIFRA 40 CFR 152.25(g) ("the 25b list") and inert ingredients currently identified on Federal Register Notice 59 FR 49400 ("the 4A list"). The lists can be seen on the web at http://www.epa.gov/opprd001/inerts/ inerts2003list4A-CAS.pdf.

Biochemical Pesticides

Biochemical pesticides are naturally occurring substances that control pests. Materials such as insecticidal soap, composed of fatty acids, alcohol, and water, are good examples of a biochemical. Empower, a garlic extract, is an insect repellent that can be used to flush cryptic insects such as thrips out of tight, hard-to-penetrate areas on the plants. This biochemical is often used in combination with a contact material that kills the thrips once they are in the open.

Because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide, EPA has established a special committee to make such decisions. In 1994 the Biopesticide and Pollution Prevention Division (BPPD) was established in the Office of Pesticide Programs to facilitate biopesticide registration. For updates on new biopesticides check the following website: http://www.epa.gov/oppbppd1/biopesticides/. Living organisms are not regulated by EPA and include entomopathogenic nematodes, beneficial mites, and insects.

Table 7.1 Biopesticides, Reduced-risk Pesticides and Their Uses

Chemical Name	Trade Name/ Common Name	Application Method	Type of Biopesticide	Re-Entry Interval (hours)	Pest and Usage
Azadirachtin	Azatin XL	Foliar spray application	Biological	4	Works best on immature insects. Feeding deterrent for some insects.
	Aza-Direct	Foliar spray application	Biological	4	Works best on immature insects.
	Neemix 4.5	Foliar spray application	Botanical	12	May be used on vegetables and herbs.
	Nemmazad 1.0% EC	Foliar spray application	Botanical	4	May be used on vegetables and herbs.
	Ornazin	Foliar spray application	Botanical	12	Works best on immature insects.
Bacillus thuringiensis	Dipel 2X, Biotrol, Thuricide, Bactur, Attack Bt, Victory, Caterpillar Killer, Bug Time	Foliar spray application	Microbial	4	Early instar caterpillars.
Bacillus thuringiensis Serotype H–14 (=var. *israelensis*)	Gnatrol	Soil drench application	Microbial	4	Applied to (early instar) fungus gnat larvae.
Beauveria bassiana	BotaniGard, Naturalis T&O	Apply to foliage and insect as a fine mist at 3- to 5-day intervals.	Microbial	4	Repeated sprays usually necessary.
Bifenazate	Floramite	Foliar application	Reduced-risk pesticide	12	21–28 day mite control. Minimal impact on beneficial mites.
Capsaicin	Hot pepper wax	Foliar application	Botanical	4	Feeding deterrent for some insects.
Fenpyroximate	Akari	Foliar application	Reduced-risk pesticide	12	21–24 day mite control. Minimal impact on beneficial mites.

Table 7.1 Biopesticides, Reduced-risk Pesticides and Their Uses (continued)

Chemical Name	Trade Name/ Common Name	Application Method	Type of Biopesticide	Re-Entry Interval (hours)	Pest and Usage
Heterorhabditis bacteriophora	HETEROMASK, J-3 Max	Soil drench application to moist soil.	Biological	0	Black vine weevil larvae in container plants.
Horticultural oil	Organic JMS Stylet Oil, PureSpray Green, Saf-T-Side, SuffOil-X, Ultra-fine Spray Oil, Ultra-Pure Oil	Apply to foliage and directly to insect.	Biochemical	4	Must make contact with insect or mite. No residual control.
Milbemectin	UltraFlora	Foliar application	Biochemical	12	Mite control
Pyrethrin	Pyreth-It	Foliar application	Biochemical	4	Apply directly to insects or mites. No residual control.
Potassium salts of fatty acids	M-Pede, Insecticidal Soap 49.52	Foliar application directly to the insect.	Biochemical	4	Must make contact with insect or mite. No residual control.
Saccharopolyspora spinosa	Conserve	Foliar application	Reduced-risk pesticide	4	Thrips, Lepidopterous caterpillars, sawfly larvae
Steinernema carpocapsae	Ecomen, Scanmask	Soil drench application or foliar application in high humidity.	Biological	0	Used for several caterpillar species.
Steinernema feltiae	Nemasys, Entomen	Soil drench application or foliar application in high humidity.	Biological	0	Used effectively as a drench for fungus gnat larvae control. Experimental work indicates foliar application reduces thrips in greenhouses.
Tebufenozide	Confirm	Foliar application	Reduced-risk pesticide	4	IGR for caterpillar and sawfly larvae control.

Chapter 8
Understanding Insect Growth Regulators

Stanton A. Gill, Extension Specialist

What Is an Insect Growth Regulator?

Insect growth regulators (IGRs) can stop the development of insects, and effectively kill them. To understand how this works you must understand that arthropods, such as insects and mites, have an exoskeleton, which is a skeleton on the outside, made up of chitin. To grow, an insect or mite must shed its skin repeatedly throughout its youthful development. It also must change from an immature stage to a sexually mature adult. These processes are controlled by IGR juvenile hormones, chitin synthesis, and ecdysone production. The chemistry of how these insects form their exoskeleton and molt has been studied and materials have been developed that mimic these natural processes in the insect. Since birds, reptiles, and other animals including humans do not form chitinous exoskeletons we are not affected by these chemicals. Not all insect and mite growth regulators work on insects in the same way and they do not work on all pests.

Table 8.1 Product Names and Distributors of Commonly Found IGR's for Greenhouse Use

Brand Name	Chemical Name	Distributor
Adept	diflubenzuron	UniRoyal
Aza-Direct	azadirachtin	Gowan Company
Azatin	azadirachtin	Olympic
Citation	cyromazine	Syngenta Professional Products
Confirm	tebufenozide	UniRoyal
Distance	pyriproxyfen	Valent USA Corporation
Enstar II	kinoprene	Wellmark International
Hexygon	hexythiazox	Gowan Company
Nemix	azadirachtin	Certis USA
Ornazin	azadirachtin	SePRO Company
Pedestal	novaluron	UniRoyal
Precision	fenoxycarb	Whitmire
Talus	buprofezin	SePRO Company

Are All Insect Growth Regulators the Same?

Not all IGRs are the same. We can group the growth regulators into three main classes: chitin synthesis inhibitors, ecdysome inhibitors, and juvenile hormone mimics. Below is a short explanation of how the IGR classes differ from one another, followed by a list IGRs that are commercially available (Table 8.2):

Chitin synthesis inhibitors (Adept, Citation, Pedestal, Talus) disrupt molting by inhibiting chitin biosynthesis. Hexygon, the only mite growth regulator, falls under the class of chitin synthesis inhibitor. Although Hexagon is an ovicide, it controls newly laid eggs and eggs laid after application.

Ecdysone inhibitors (Azatin, Ornazin) trigger moltings in insects and interfere with the metabolism of molting hormones, preventing molting by indirectly disrupting chitin biosynthesis in larva and pupa.

Juvenile hormones (Confirm, Distance, Enstar II, Precision) imitate molting hormones causing a premature molting. This action determines whether the insect stays as a larva or moves into the pupal or adult stage.

How Do Growers Manage Resistance?

Repeated use of IGRs with similar modes of action may lead to the build-up of resistant strains of insects. Be sure to rotate IGR use among the different classes of IGRs. It has been noted that insects and mites cannot development resistance to IGRs. When it comes to applying any constant pressure (e.g. sprays) to suppress a pest population, the biological world develops ways to mutate around material preventing its survival.

When using IGRs for insect control select one of the chemicals from a class and use this product for one life cycle of the insect or mite. If you need to continue applications to control the pest after one life cycle, switch to another class. For example, if using Adept (chitin synthesis inhibitor), switch to Distance (juvenile hormone mimic). Do not rotate within a class. For example, if using Enstar II, do not switch to Distance.

Table 8.2 Insect Growth Regulators And The Pests They Control

Brand Name	Pest Controlled	Re-Entry Level	Comments
Adept	Leafminers, armyworms, whiteflies, fungus gnat larvae, shore fly larvae	12 hours	Rates are 2 oz/100 gallons water and 4–8 oz/100 gallons water, depending on the pest.
Aza-Direct	Aphids, beetles, fungus gnats, caterpillars, psyllae, thrips, weevils, whiteflies	4 hours	The esters and fats have been removed which reduces the tendency of rancidity. Product shelf-life is up to 3 years.
Azatin	Aphids, beetles, fungus gnats, caterpillars, psyllae, thrips, weevils, whiteflies	4 hours	
Citation	Leafminers, fungus gnat larvae, shore fly larvae	12 hours	Rates 2 and 6 oz/100 gallons water
Confirm	Caterpillars	12 hours	
Distance	Whiteflies, psyllae, soft and armored scales, fungus gnat larvae, caterpillars, mealybugs; Aphids suppression	12 hours	2 oz/100 gallon water for fungus gnats; 6–8 oz/100 gallons water for foliar sprays
Enstar II	Mealybugs, whiteflies, fungus gnat larvae	12 hours	
Hexygon	Immature spider mites	12 hours	
Neemix	Aphids, beetles, fungus gnats, caterpillars, psyllae, thrips, weevils, whiteflies	4 hours	1-year shelf life

Table 8.2 Insect Growth Regulators And The Pests They Control (continued)

Brand Name	Pest Controlled	Re-Entry Level	Comments
Ornazin	Aphids, beetles, fungus gnats, caterpillars, psyllae, thrips, weevils, whiteflies, scales, and nematodes	12 hours	One difference between Azatin and Ornazin is the level of limonoids in the products. Limonoids are extracted from the neem seed coat.
Pedestal	Thrips, caterpillars, leafminers, whiteflies	12 hours	Rates 6–8 oz/100 gallons water
Talus	Whiteflies, soft and armored scales, leafhoppers, mealybugs, fungus gnats, planthoppers, glassy-winged sharpshooter	12 hours	Chitin synthesis inhibitor. Also reduces adult egg laying/egg viability. Rates from 9 to 21 oz/100 gal., depending upon pest.

Chapter 9
Insecticides Registered for Greenhouse Ornamentals

Stanton A. Gill, Extension Specialist

The following tables in this chapter list those insecticides currently labeled for the most commonly found insect pests of greenhouses (Tables 9.1 to 9.13). The trade names are those most readily available for use on commercial ornamental plants in Maryland. (**Note:** This list may not include all brands sold, nor does it imply any preference whatsoever).

Formulation Key:
WSP - Water soluble packets;
G - Granule; WP - Wettable powder;
SG - Soluble granular;
EC/ES - Emulsifiable concentrate/Emulsifiable suspension;
F - Flowable;
WDP - Water dispersible granular

NC = not classified

DISCLAIMER

The USER is always responsible for the effects of pesticide residues, as well as for problems that could arise from drift or movement of the pesticides to the property of others. Use pesticides only according to the directions on the label. Follow all directions, precautions, and restrictions that are listed. Do not use pesticides on plants or sites that are not listed on the label.

The pesticide rates in this publication are recommended only if they are registered with the Environmental Protection Agency and your state department of agriculture. If a registration is changed or cancelled, any rates listed here are no longer recommended. Before you apply any pesticide, fungicide or herbicide, check with your Extension agent for the latest information.

Trade names are used only to give specific information. This publication does not endorse nor guarantee any product and does not recommend one product instead of another that might be similar.

Aphid Control

Identification and damage: Aphids are generally small (1–3 mm), soft-bodied insects that may or may not have wings. More than 20 aphid species can infest a range of greenhouse crops. Aphids have the ability to reproduce without mating or egg production, causing populations to increase almost explosively in greenhouses year-round.

Monitoring: Aphid control is much more successful when an infestation is detected and controlled early in a crop cycle. Certain plants (salvia, petunias, and pepper transplants) tend to have recurring aphid problems. Many aphid species prefer to feed on the undersides of foliage so make sure the foliage is flipped over and inspected carefully. Ants are also often found feeding on the honeydew of aphids; so if large populations of ants are detected, check closely for the presence of aphids.

Winged forms of aphids can be monitored using sticky cards. Winged forms are produced in a greenhouse when the population has reached high levels on individual plants and the aphids are dispersing to establish new colonies on other plants. Place 1 to 2 yellow sticky cards per 1,000 square feet of growing area. Examine the yellow sticky cards at least once per week and replace them after a count is taken.

Treatment: Make sure that weeds are controlled under benches and in surrounding areas. Using microscreening on intake vents helps prevent winged aphids from flying into the greenhouse. Aphids can be carried into greenhouses on clothing, infested cuttings, or plugs. Carefully examine plants such as salvia and verbena, known to be preferred by aphids, before moving the plants into a clean greenhouse.

Aphids have many naturally occurring predators and parasites, including lady beetles, lacewings, and Aphelinidae wasps, just to name a few. Growers releasing beneficial organisms should only use pesticides listed as having minimal impact on beneficials.

Aphids in the upper foliage canopy are easiest to contact with foliar sprays. Systemic insecticides will be most effective against those feeding on new growth. Aphids on older growth -- lower in the canopy -- are the most difficult to kill chemically and may be responsible for producing new aphids that reinfest the upper canopy. Remember to rotate aphid insecticides, as resistance is common.

Table 9.1 Insecticides for Aphid Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Abamectin	6	Avermectin	Abamectin E-Pro 0.15 EC	12	Do not apply through any type of irrigation system. Do not use product for suppression of aphids, whiteflies, and thrips on roses, chrysanthemums, and gerbera. Do not use on ferns or shasta daisies.
			Ardent 0.15 EC		
			Avid 0.15 EC		
			Flora-Mek 0.15 EC		
			Lucid 2F		
			Minx		
			Quali-Pro Abamectin 0.15 EC		
			Timectin 0.15EC T&O		
Acephate	1B	Organophosphate	Avatar	24	Do not apply to poinsettia after bract formation or to roses and chrysanthemums with open blooms. See label for specific foliage plants with precautions.
			Orthene TT&O WSP		Do not apply to poinsettia after bract formation, roses or chrysanthemum in flower. Phytotoxicity concerns: *Bletchum gibbum*, *Cissus*, *Ficus*, *Fittonia*, *Maranta*, *Pachystachya*, *Plectranthus*, *Polypodium*, *Polystichum*, *Pteris*, and *Tolmiea*. Do not treat chrysanthemum in flower.
			Orthene TT&O 97 (Tree, Turf and Ornamental) WP		
			Acephate Pro 75 WSP		Ready-to-use fogger. Apply when foliage is dry and greenhouse is completely closed. Do not apply to chrysanthemums and roses in flower or to poinsettia in bract.
			Precise 4% G		Systemic controlled-release for use only on 3 to 12” diameter pots. Do not apply to freshly rooted cuttings. Limited plants listed.

Table 9.1 Insecticides for Aphid Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acetamiprid	4A		TriStar 70 WSP	12	Do not irrigate overhead for at least 6 hours.
Azadirachtin	18B	Botanical	Azatin XL	4	Repellant, IGR. Controls larvae and pupae on contact or by ingestion. Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Use within 8 hours. Reduce irrigation water pH if it exceeds 7.0.
			Aza-Direct		
			Ecozin Plus 1.2% ME		
			Ferti-Lome Triple Action Plus		
			Ornazin 3% EC	12	
			Neemix 4.5		
			Neemazad 1.0% EC	4	
			Triact 70		
Beauveria bassiana GHA Strain	NC	Entomopatho-genic fungus	Botanigard 22 WP	4	Insect-specific fungus. Compatible with some fungicides; some may kill the spores. Do not treat poinsettia in bract.
			Mycotrol O (WP)		Insect-specific fungus. Do not tank mix with fungicides. Do not apply with insecticides such as Metasystox R, Neemazad or Thiodan EC. Apply when foliage is dry.
			Naturalis L (JW-1 strain)		
			Naturalis H&G		
Bifenthrin	3A	Pyrethroid	Attain Greenhouse	12	Do not apply through any kind of irrigation system.
			Attain TR		Apply when foliage is dry.
			Menace GC 7.9% Flowable (F)		Preventative, curative topical drench. Wait 30 days to reapply.
			Talstar P (Professional) (F)		May be tank mixed with insect growth regulators and other products.
			Talstar Select		
			Up-Star SC (F)		Restricted use. Do not apply through irrigation system.
			Wisdom F		Do not treat wet foliage or during high humidity periods due to injury to tender foliage. Do not use on Boston ivy, maidenhair fern or Virginia creeper.

Table 9.1 Insecticides for Aphid Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Carbaryl	1A	Carbamate	Carbaryl 4L		Do not spray kalanchoes.
Chlorpyrifos	1B	Organophospate	DuraGuard ME	24	Do not mix with alkaline materials (e.g. Bordeaux and lime). Some varieties of azaleas, poinsettias, camellias, roses, and variegated ivies have shown phytotoxicity. Do not use on kalanchoes. Direct treatment to some open blooms may cause petal drop.
Chlorpyrifos and Cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR (WP)	24	Restricted use product. Apply when foliage is dry.
Cyfluthrin	3A	Pyrethroid	Decathlon 20WP	12	Do not apply through any type of irrigation system.
Dichlorvos	1B	Organophosphate	DDVP (Fulex)		Do not apply when foliage or blossoms are wet as injury may result.
Dinotefuran	4A	Neonicotinoid	Safari 20 SG	12	Only apply to moist soil media. Do not apply to dry or saturated media.
Fenoxycarb	7B	Fenoxycarb	Prescription Treatment Preclude TR	12	Do not use more often than every seven days. Not for use on any food crops within a greenhouse. Labeled to be mixed with Orthene for aphid control.
Fenpropathrin	3A	Pyrethroid	Tame 2.4 EC	24	Apply when foliage is dry. Do not use in greenhouses less than 500 ft^2.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Prescription Treatment Tame/ Orthene TR	24	Do not use in greenhouses < 900 ft^2. Do not apply product within 48 hrs of a previous application. Cans must be stored at room temperature for 24 hrs before application.

Table 9.1 Insecticides for Aphid Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Flonicamid	9C	Flonicamid	Aria (WSP)	12	Spray water should be buffered to pH 5–7. Can be used as a dip for flower and foliage cuttings. Control of green peach aphid may vary because of insecticide resistance.
Fluvalinate	3A	Pyrethroid	Mavrik Aquaflow (F)	4	May work slowly on some species. Allow 3–4 days to evaluate performance. Piperonyl butotoxide will aid in the control of some pest species such as whiteflies, aphids, thrips, and mealybugs. Caution on roses and poinsettias.
Imidacloprid	4A	Neonicotinoid	Areca (EC)	12	Systemic. Media with >30% bark may confer a shorter protection period
			Benefit 60WP		Systemic. Protection period is shorter if media has >30–50% bark content. Do not use packets in a tank mix with products that contain boron or release free chlorine.
			Imida E-Pro 2F		
			Lada 2F		Media with 30–50% or more bark content may confer a shorter period of protection. Do not apply to ferns, crassula, petunias, and lantana.
			Majesty		
			Mallet 2F		
			Mantra 1G		Protection period is shorter if media has >30–50% bark content.
			Mantra 2F		
			Marathon 1% G		Systemic; soil treatment only. Not to be used more than once every 16 weeks. Media with 30–50% or more bark content may shorten protection period.
			Marathon II (F)		
			Quali-Pro Imidacloprid (1G Nursery & Greenhouse; 2F Nursery & Greenhouse)		

Table 9.1 Insecticides for Aphid Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Insecticidal soap	NC	Potassium salts of fatty acids	Bonide Concern DES-X M-Pede Natural Guard Insecticidal Soap	12	Contact insecticide so complete coverage is essential. Do not use on new transplants, unrooted cuttings or plants stressed by drought or under hot, humid, or drought conditions. Avoid spraying in greenhouses under overcast conditions. Caution if pH of final solution is below 8.0. Caution if treating euphorbias. Do not use on bleeding heart, jade, lantana, lily, and sweet pea, or on poinsettia in bract or chrysanthemum after bloom.
Kinoprene	7A	Juvenile hormone analogues	Enstar II (F)	4	IGR. Do not use on some poinsettia and rose varieties. May cause some damage to blooms under certain conditions.
Lambda-cyhalothrin	3A	Pyrethroid	Scimitar GC (EC) Quali-Pro lambda GC-O	24	A spreader-sticker is recommended. Do not apply through any type of irrigation system
Methiocarb	1A	Carbamate	Mesurol 75WP	24	Restricted Use. Do not apply with foliar fertilizers or oils.
Naled	1B		Dibrom 8E	Meet WPS vent. criteria	Vapor treatment of roses and other ornamentals. Has good fumigant action. Can be corrosive. Avoid over treatment and direct application to plants. May injure certain rose and chrysanthemum varieties, wandering Jew, poinsettia, and Dutchman's pipe. Do not apply when air temperature is above 90°F due to phytotoxicity.

Table 9.1 Insecticides for Aphid Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Neem oil	NC	Oil	Triact 70	4	Kills immatures and adults. Do not apply to wilted or stressed plants or to new transplants prior to root establishment. Caution if applying to impatiens flowers, fuchsia, hibiscus, some rose flowers, or some carnation varieties.
Nicotine	4B		Fulex Nicotine Fumigator	Meet WPS vent. criteria	Restricted use. Do not use on violets.
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate (mineral oil)	4	To be effective completely cover target pest with product. Do not apply if plants are under stress or during periods of prolonged high temperatures combined with high relative humidity. Avoid spraying in greenhouses under overcast conditions. Do not exceed label rates or apply more often than recommended. At temperatures below 50 °F effectiveness is reduced. Do not use within 2 weeks of sulfur or within 7 days of Captan. Do not apply through any irrigation system.
			Golden Pest Spray Oil (soybean oil)		
			Organic JMS Stylet Oil (paraffinic oil)		
			PureSpray Green (petroleum oil)		
			Saf-T-Side (petroleum oil)		
			SuffOil-X (paraffinic oil)		
			Summit Year Round Superior Horticulture Spray Oil (mineral oil)		
			Ultra-fine Spray Oil (paraffinic oil)		
			Ultra-Pure Oil (petroleum oil)		
Permethrin	3A	Pyrethroid	Astro 3.2EC	12	Avoid spraying blooms of chrysanthemum; not all cvs. have been tested for phytotoxicity. Marginal leaf burn on salvia, pteris fern and *Dieffenbachia*. May damage petals.
			Perm-Up 3.2Ec		

Table 9.1 Insecticides for Aphid Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Pymetrozine	9B	Pyridine	Endeavor (WDG)	12	Insects will remain on plant for 2–4 days after application and will stop feeding, but will take a few days to die.
Pyrethrins and Piperonyl butoxide	3A	Pyrethrin	Pyrenone Prentox Pyronyl Crop Spray Pyreth-It (Prescription Treatment Brand)	12	A botanical insecticide plus a synergist to flush insects out of hiding and into contact with spray residues. See label for details. Apply when foliage is dry. Do not use on cyclamen or nasturtium.
Lambda-cyhalothrin	3A	Pyrethroid	Scimitar GC	24	Do not apply through any type of irrigation system.
Pyriproxyfen	7C	Pyriproxyfen	Distance (EC)	12	Insect growth regulator for control of immature insects only. Apply no more than two times per cropping cycle or no more than two times per six months. Do not apply to Boston fern, coral bells, gardenia, ghost plant, salvia, or schefflera. Do not apply to poinsettia after bract formation.
Pymetrozine	9B	Pyridine	Endeavor (WDG)	12	Insects will remain on plant for 2–4 days following the application. Product has some residual activity. Do not apply to poinsettia in bract.
Tau-fluvalinate	3A	Pyrethroid	Mavrik Aquaflow (F)	12	Contact, good coverage needed. Labeled for broadcast, fogger, ULV, or bench application in greenhouses.
Thiamethoxam	4A	Neonicotinoid	Flagship 0.22G Flagship 25WDG	12	Foliar and soil applications, but soil applications work as a preventative measure or where population is low.

Caterpillar Control

Identification and damage: Caterpillars are the immature forms (larvae) of Lepidoptera (moths and butterflies) pests. This group includes armyworms, cutworms, leaftiers, leafrollers, loopers and sawfly larvae. These insects are only damaging in the immature larval stage; the adults either do not feed or feed only on nectar. Feeding damage includes small holes to totally consumed plant foliage (including defoliation of stems and flowers). This causes either the total loss of plants, or tattered, totally unsalable plants.

Adult moths can be attracted to the greenhouse by lights and fly in from the outdoors to lay their eggs (e.g. cabbage loopers). Some caterpillars prefer to hide in the soil during daylight and emerge to feed only at night; others remain on the plants at all times; and still others fold leaves around themselves for protection. It is necessary to identify the pests properly before beginning a control program.

Monitoring: Examine foliage for presence of caterpillars. Examine the base of the plant for frass (caterpillar excrement). Look for early damage symptoms.

Treatment: Spray when caterpillars are small for the most effective control. This is very important, especially when using biological and botanical controls, e.g. *Bacillus thuringiensis*, azadirachtin, *Beauveria bassiana*, and *Saccharopolyspora spinosa*. The larger the caterpillar, the more damage occurs and the harder it is to control. Timing is therefore very important.

Table 9.2 Insecticides for Caterpillar Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acephate	1B	Organophosphate	Orthene TT&O 97 (Turf, tree, and Ornamental) WP	24	Do not apply to roses or chrysanthemum in flower or poinsettia in bract. Caution if treating the following foliage plants due to phytotoxicity concerns: *Bletchum gibbum*, *Cissus*, *Ficus*, *Fittonia*, *Maranta*, *Pachystachya*, *Plectranthus*, *Polypodium*, *Polystichum*, *Pteris*, and *Tolmiea*.
Acetamiprid	4A	Neonicotinoid	TriStar 70 WSP	12	Do not irrigate overhead for at least 6 hrs after application.
Azadirachtin	18B	Botanical	Aza-Direct (EC)	4	Does not control adult insects. Kills by ingestion or contact. May also reduce damage by repelling and deterring feeding of all insect stages. Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Reduce irrigation water pH if it exceeds 7.0.
			Azatin XL (EC)		
			Ecozin Plus 1.2% ME		
			Ornazin 3% EC	12	
			Neemix 4.5 (EC)		
			Neemazad 1.0% EC	4	
Bacillus thuringiensis aizawai strain *Bacillus thuringiensis* kurstaki strain	11 B2	Bacterium	Agree WG	4	Used only to control small, immature caterpillars. Must be ingested to be effective, so thorough coverage is essential.
			XenTari DF		
			Biobit XL		
			Condor		
			Crymax WDG		
			Deliver		
			Dipel Pro DF		
			Dipel ES		
			Green Light Dipel Dust		
			Foray 48B		
			Foray XG		
			Javelin WG		

Table 9.2 Insecticides for Caterpillar Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Beauveria bassiana GHA Strain	NC	Entomopathogenic fungus	BotaniGard ES BotaniGard 22 WP Mycotrol O (WP) Naturalis L (JW-1 strain) Naturalis H&G	4	Contains spores that attach to cuticle of pest, then penetrate to kill. Do not apply through a thermal pulse fogger. Can be used with ultra-low volume equipment and chemigation. Can be used as pre-plant dips for cuttings. Do not apply to pointsettia in bract. Begin applications at first sign of pest; may take 7-10 days for control. Do not tank mix with fungicides or apply with insecticides such as Metasystox R, Neemazad or Thiodan EC. Sticking agents, insecticidal soaps or emulsifiable oils may improve control.
Bifenthrin	3A	Pyrethroid	Attain TR	12	Apply when foliage is dry.
			Attain Greenhouse		Do not apply through any kind of irrigation system.
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% (F)		Wait 30 days between greenhouse applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any kind of irrigation system.
			Talstar Nursery F Talstar Select (FC)		Do not apply through any type of irrigation system. Spreader stickers are not necessary. Do not use on edible plants. Can be tank mixed with plant growth regulators.
			Up-Star SC		Do not use more than 1 fl. oz. per 1000 ft^2.
			Wisdom F		Restricted use. Do not apply through irrigation systems.

Table 9.2 Insecticides for Caterpillar Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Chlorfenapyr	13	Pyrrole	Pylon	12	Translaminar activity. May be applied twice consecutively, but no more than three times within a season. Not ovicidal. Controls immature mites. Apply prior to bloom or avoid blooms where possible. Do not apply to carnations, dianthus, kalanchoe, poinsettia, roses, salvia and zinnia.
Chlorpyrifos	1B	Organophospate	DuraGuard ME	24	Do not mix with alkaline materials (e.g. Bordeaux and lime). Some varieties of azalea, camellia, poinsettia, rose and variegated ivy have shown phytotoxicity. Do not use on kalanchoes. Direct treatment to open blooms may cause petal drop.
Chlorpyrifos and cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR	24	Restricted use product. Apply when foliage is dry.
Diflubenzuron	15	Benzoylureas	Dimilin SC (WP) Adept (WSP)	12	Insect growth regulator; has little to no effect on beneficial insects.
Fenoxycarb	7B	Fenoxycarb	Prescription Treatment Preclude TR	12	Micro-release. Do not use more often than every seven days. Not for use on any food crops within a greenhouse. Labeled to be mixed with Orthene for aphid control.
Fenpropathrin	3A	Pyrethroid	Tame 2.4 EC	24	Do not use in greenhouses less than 500 ft^2. Apply when foliage is dry.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Prescription Treatment Tame/ Orthene TR	24	Do not use in greenhouses < 900 ft^2. Do not apply product within 48 hr of a previous application. Spray cans must be stored at room temperature for 24 hrs before application.

Table 9.2 Insecticides for Caterpillar Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Fluvalinate	3A	Pyrethroid	Mavrik Aquaflow	12	Spray water should be buffered to pH 5–7. Can also be used as a dip for flower and foliage cuttings.
Imidacloprid	4A	Neonicotinoid	Areca (EC)	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.
			Benefit 60WP		
			Imida E-Pro 2F		
			Majesty (F)		
			Marathon 1% G		
			Marathon II (F)		
			Quali-Pro Imidacloprid 1G Nursery & Greenhouse		Systemic. Protection period is shorter if media has >30–50% bark content. Do not tank mix with products that contain boron or release free chlorine. Media with 30–50% or more bark content may decrease protection period. Do not apply to ferns, crassula, petunias, and lantana
			Quali-Pro Imidichloprid 2F Nursery & Greenhouse Insecticide		
Insecticidal soap	NC	Potassium salts of fatty acids	Concern	12	Contact insecticide; complete coverage is essential. Do not use on new transplants, unrooted cuttings or plant material stressed by drought or under hot, humid, or dry conditions. Caution using on euphorbias or if pH of final solution is <8.0.
			M-Pede		
			Natural Guard Insecticidal Soap		
Lambda-cyhalothrin	3A	Pyrethroid	Scimitar GC (EC)	24	Do not apply through any type of irrigation system.
			Quali-Pro lambda GC-O		
Novaluron	15	Benzoylureas	Pedestal	12	Controls immatures (not adults). Do not apply more than twice a year. Do not apply to poinsettia.

Table 9.2 Insecticides for Caterpillar Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate (mineral oil) Golden Pest Spray Oil (soybean oil) Summit Year Round Superior Horticulture Spray Oil (mineral oil)	4	Completely cover target pest to be effective. Do not apply if plants are under stress (prolonged high temperatures combined with high relative humidity). Avoid spraying under overcast conditions. Effectiveness at temperatures below 50 °F is reduced. Do not use within 2 weeks of sulfur or within 7 days of Captan. Do not apply through any irrigation system.
Permethrin	3A	Pyrethroid	Astro (EC) Permethrin (roses only) Permethrin 3.2EC Perm-Up 3.2EC	12	Avoid spraying chrysanthemum blooms. Marginal leaf burn has been noticed on salvia, *Dieffenbachia*, pteris fern. Application to blooms may cause petal browning. See label for cultivar sensitivity.
Pyrethrins and Piperonyl butoxide	3A	Pyrethrin	Pyrenone (EC) Prentox Pyronyl Crop Spray Pyreth-It (Prescription Treatment Brand)	12	Botanical insecticide plus a synergist to flush insects out of hiding and into contact with spray residues. Apply when foliage is dry. Do not use on cyclamen or nasturtium.
Pyridalyl	NC	Pyridalyl	Overture 35WP	12	Apply when small larvae are feeding. Thorough coverage is necessary.
Spinosad	5	Spinosyn	Conserve SC (EC)	4	Minimum impact upon beneficials. Make no more than two consecutive applications. See label for crops that can be chemoirrigated. Caution when spraying African violet blooms.

Foliar Nematode Control

Identification and damage: Foliar nematodes (*Aphelenchoides* spp.) are microscopic plant-parasitic nematodes found within leaf tissue. Populations can build very rapidly in greenhouses where there are no interruptions in their life cycle. Foliar nematodes are most damaging on *Ageratum* spp.; *Anthurium andraeanum*; *Begonia* spp. and hybrids; *Coleus* spp. and hybrids; *Cyclamen persicum* (florist's cyclamen); ferns, *Ficus* spp. (rubber plant); *Hibiscus rosa-sinensis*; *Impatiens* spp.; *Lilium* spp. and hybrids; orchids; *Pelargonium* x *hortorum* (florist's geranium); *Peperomia* spp.; *Saintpaulia ionantha* (African violet) *Salvia* spp.; *Sinningia* x (florist's gloxinia); and *Vanda* spp. (vanda orchid).

Foliar nematode feeding kills leaf tissue and causes browning of foliage and leaf blotches. The main leaf vein acts as a barrier to nematodes within leaf tissue. To reach other leaf sections, foliar nematodes emerge from stomata under moist conditions, and migrate over the leaf surface. The damaged leaf therefore appears with different stages of discoloration from pale green, to yellow, and eventually brown. On plants with parallel veins, the brown blotchy symptoms appear as long stripes; on plants with netted veins, they appear like angular patchwork. At low population densities, no symptoms may be apparent on plants. Once symptoms appear, the nematodes have increased to large population levels. Populations often build over the course of the growing season, with higher levels (and increased damage) in late summer/fall vs. the spring.

Monitoring: Look for damage especially on lower leaves. Closely inspect areas prone to splashing water, particularly from new transplants. Nematodes can survive in dead foliage (that often cling on plant stems) for several months so remove dead foliage promptly. Foliar nematodes are extremely small and cannot be seen unless examined under a dissecting microscope. Suspected leaf tissue can be sent to an Extension specialist or a diagnostic lab for identification.

Treatment: Remove infested plants and dead foliage promptly. Soil, containers, and tools should be fumigated or steamed before use. Sanitation of previous crop debris is important.

Table 9.3 Nematicides for Foliar Nematode Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Azadiractin	18B	Botanical	Ecozin Plus 1.2% ME Amazin Plus 1.2%ME	4	Do not use with Bordeaux mixture, triphenyltin, lime sulfur, hydroxide, or other highly alkaline materials. Use within 8 hours. Reduce irrigation water pH if it exceeds 7.0.
Chlorfenapyr	13	Chlorfenapyr	Pylon	12	Translaminar. Can apply twice consecutively, but no more than three times within a season. Apply before bloom or avoid blooms if possible. Do not apply to carnations, roses, dianthus, kalanchoe, poinsettia, salvia or zinnia.

Fungus Gnat Control

NOTE: Separate charts are listed below for controlling fungus gnat LARVAE vs. ADULTS.

Identification and damage. Fly species belonging to the closely related Sciaridae and Mycetophilidae families are known as longhorned flies, or fungus-eating gnats. They are slender, long-legged, mosquito-like insects with long antennae. Species of fungus-eating gnats can carry plant pathogenic fungi and feed on roots and stems. Those belonging to the Sciaridae family are commonly called dark-winged fungus gnats because the wings and bodies of most species are gray to black. Those belonging to the Mycetophilidae family are commonly called fungus gnats. Most of these species have clear wings and yellow-brown bodies. The immature maggots of dark-winged fungus gnats are translucent and wormlike in shape, with a black head capsule.

Fungal diseases are spread primarily by dark-winged fungus gnats. The diseases can be spread throughout a greenhouse through spores that may be carried from plant to plant as flies migrate through the greenhouse. Fly larvae of some fungus-eating gnat species can also directly damage plants by feeding on root hairs and tunneling into the roots and stems of susceptible plants.

Extended periods of cloud cover cause high humidity, which promotes high soil moisture. These conditions are ideal for the development of fly maggots (larvae) in greenhouse growing media. For example, crops such as poinsettia are often damaged by fungal root rots and root feeding while under mist during propagation and when growing in containers in overwatered soils.

Monitoring. Monitor larvae of fungus gnats by using 1-inch diameter potato disks placed on the surface of the potting medium. Place disks at the rate of 10 disks per 1,000 square feet of greenhouse production area. The maggots will migrate to the underside of the potato disk where they feed. Pick up and examine the disk 1 to 2 times a week, and record the number of maggots found. The maggot count can be used to determine if treatment is necessary or whether a biological or chemical treatment has been effective in reducing the number of maggots in the media.

Adult fungus-eating gnats are attracted to yellow sticky cards. Use a hand lens (10x to 15x magnification) for field identification. Sticky cards laid flat on the soil surface capture 50–60% more adult fungus-eating gnats than cards placed vertically. Take the yellow sticky card counts on a weekly basis to determine whether the population is increasing or decreasing.

Treatment: Because fungus-eating gnats prefer moist soils, avoid keeping soils wet for extended periods of time. Use of horizontal air flow (HAF) fans improves circulation in the greenhouse and helps keep soil drier. Controlling algae on the bench surface and in the areas under the bench will help reduce the nuisance population of shore flies.

Repeat applications of many pesticides are necessary since they do not control fungus gnat eggs or pupae. The biological control, Gnatrol, is effective only on young larvae vs. mature larvae. It should be applied before population levels are high, as should any beneficial insect release. Insect growth regulators are very effective on fungus gnats.

Table 9.4a Insecticides for Fungus Gnat Larvae Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acetamiprid	4A	Neoniconotoid	TriStar 70 WSP	12	Do not make more than 5 applications per year; do not reapply more than once every 7 days. Apply as a foliar spray with thorough coverage. Do not irrigate overhead for at least 6 hrs after application.
Azadirachtin	18B	Botanical	Aza-Direct (EC)	4	Does not control adult insects. Kills by ingestion or contact. May also reduce insect damage by repelling and deterring feeding of all insect stages. Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Use within 8 hours. Reduce pH of irrigation water if pH exceeds 7.0.
			Azatin XL (EC)		
			Ecozin Plus 1.2% ME		
			Ornazin (EC)	12	
Bacillus thuringiensis Serotype 14 (=israelensis)	11A1	Bacterium	Gnatrol Biological Larvicide (F)	4	Soil drench for control of immatures. Do not apply with fertilizers or fungicides containing copper or chloride.
			Gnatrol WDG		
Beauveria bassiana	NC	Entomopatho-genic fungus	Naturalis L (JW-1 strain) (WP)	4	Contains spores that attach to cuticle of pest, then penetrate to kill. Do not apply through a thermal pulse fogger. Can be used with ultra-low volume equipment and chemigation. Can be used as pre-plant dips for cuttings. Compatible with some fungicides such as Neemazad or Thiodan EC; Fungicides may kill the spores. Do not apply to pointsettia in bract.
			Naturalis H&G		

Table 9.4a Insecticides for Fungus Gnat Larvae Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Bifenthrin	3A	Pyrethroid	Attain Greenhouse	12	Microemulsion. Do not apply through any kind of irrigation system.
			Attain TR		Apply during when foliage is dry.
			Menace GC 7.9% Flowable		Restricted use. Can be used as a drench.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any kind of irrigation system.
			Talstar Nursery F		Do not apply through any type of irrigation system. The addition of spreader stickers is not necessary.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through any irrigation system. May not control some aphid populations due to resistance.
			Wisdom F		
Chlorfenapyr	13	Pyrrole	Pylon	12	Translaminar activity. May be applied twice consecutively, but no more than three times within a season. Do NOT apply to consecutive crops. Not ovicidal. Controls immature mites. Apply prior to bloom or avoid blooms where possible. Do not apply to carnation, dianthus, kalanchoe, rose, zinnia, poinsettia or salvia.
Chlorpyrifos	1B	Organophospate	DuraGuard ME	24	Not compatible with alkaline materials such as Bordeaux mixtures and lime. Some varieties of azalea, camellia, poinsettia, roses and variegated ivy have shown phytotoxicity.
Cyromazine	17	Molting disruptor	Citation 75 WP	12	May adversely affect some predatory mites and leafminer parasitoids.

Table 9.4a Insecticides for Fungus Gnat Larvae Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Diflubenzuron	15	Benzoylureas	Adept (WSP)	12	IGR. Do not reuse potting media. Do not apply to poinsettia, hibiscus, Reiger begonia or to pots grown on capillary water mats.
Dinotefuran	4A	Neonicotinoid	Safari 20 SG Safari 2 G	12	For control of nymphs only. Only apply to moist soil media. Do not apply to dry or saturated media.
Fenoxycarb	7B	Fenoxycarb	Preclude TR Total Release Insecticide	12	Micro-release insect growth regulator. Apply when foliage is dry.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Prescription treatment Tame/ Orthene TR	24	Do not use in greenhouses <900 ft^2. Do not apply product within 48 hrs of a previous application. Cans must be stored at room temperature for 24 hrs before application. Apply to dry foliage. Do not treat poinsettia in bract.
Imidacloprid	4A	Neonicotinoid	Areca Benefit 60WP Imida E Pro 2 F Lada 2F Majesty Mallet 75 WSP Mallet 7.1% PF Mallet 2F Mallet 75 WSP Mantra 1G Mantra 2F Marathon II (F) Quali-Pro Imidacloprid 1G Nursery & Greenhouse Quali-Pro Imidichloprid 2F Nursery & Greenhouse Insecticide	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.

Table 9.4a Insecticides for Fungus Gnat Larvae Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Kinoprene	7A	Juvenile hormone mimic	Enstar II (EC)	4	IGR. Apply before bract formation in poinsettia. Some varieties of roses show delayed damage.
Nematodes, beneficial (= Entomo-pathogenic)	NC		Ecomen (*Steinernema carpocapsae*) Entonem (*S. feltiae*) Nemasys (*S. feltiae*) ScanMask (*S. feltiae*)		Biological control. Preventive or curative control. Apply to moist growing media as soon as possible after potting. Works best at 50–85 °F.
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate (mineral oil) Golden Pest Spray Oil (soybean oil) PureSpray Green (petroleum oil) Organic JMS Stylet Oil (Paraffinic oil) SuffOil – X (paraffinic oil) Ultra-fine Spray Oil (paraffinic oil)	4	Thorough coverage needed. Do not apply to plants under stress, during periods of prolonged high temperatures and high relative humidity or under overcast conditions. Do not exceed label rates or apply more often than recommended. Effectiveness is reduced below 50 °F. Do not use within 2 weeks of sulfur or within 7 days of Captan. Do not apply through irrigation system.
Permethrin	3	Pyrethroid	Astro 3.2 EC Perm-Up 3.2EC (restricted use)	12	Use sufficient water to obtain full coverage. May cause petal browning. Do not spray chrysanthemum blooms, salvia, pteris fern, and *Dieffenbachia*.
Pyriproxyfen	7C	Pyriproxyfen	Distance (F)	12	IGR. Apply no more than twice per crop cycle or twice per six months. Do not apply to Boston fern, coral bells, gardenia, ghost plant, salvia or schefflera or to poinsettia in bract.
Thiamethoxam	4A	Neonicotinoid	Flagship 25WG (WDG)	12	Soil applications take at least 1 week to translocate to foliage for control.

Table 9.4b Insecticides for Fungus Gnat Adult Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Bifenthrin	3A	Pyrethroid	Attain TR	12	Insecticide fogger. Apply when foliage is dry.
			Talstar (F)		Do not apply through any type of irrigation system. Addition of spreader stickers is not necessary. Do not use on edible plants. Can be tank mixed with plant growth regulators.
			Talstar Nursery (F)		
			Talstar Professional Insecticide		
			Talstar Select (FC)		
			Up-Star SC		
Chlorpyrifos	1B	Organophosphate	DuraGuard ME	24	Do not mix with alkaline materials (e.g. lime). Do not use on kalanchoes. Some varieties of azalea, camellia, poinsettia, rose, and variegated ivy have shown phytotoxicity. Treatment to some open blooms may cause petal drop.
Chlorpyrifos and Cyfluthrin	1B 3A	Organophosphate	Duraplex TR	24	Restricted use. Micro total release insecticide. Apply when foliage is dry.
Cyfluthrin	3A	Pyrethroid	Decathlon (WP)	12	Do not apply through any type of irrigation system.
Fenpropathrin and Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR	24	Do not use in greenhouses less than 500 ft^2. Best to apply during early evening when foliage is dry and greenhouse is between 60° and 80° F.
Permethrin	3A	Pyrethroid	Astro (EC)	12	Avoid spraying blooms of chrysanthemum; not all cultivars have been tested for phytotoxicity. Marginal leaf burn has been noted on salvia, *Dieffenbachia*, pteris fern. May cause petal browning.
			Perm-Up 3.2EC		
			Permethrin E-Pro		
Pyrethrins and Piperonyl butoxide	3A	Pyrethrin	Prentox Pyronyl Crop Spray	12	Apply when foliage is dry. Do not use on cyclamen or nasturtium.
			Pyrenone		

Leafminer (Larvae) Control

Identification and damage: Leafminer flies are tiny (2 mm) flies that resemble small yellow and black fruit flies.

Adult flies puncture foliage to feed on plant juices. The punctures turn white with time and give leaves a speckled appearance. Eggs are laid on upper leaf surfaces; newly hatched larvae migrate within the leaf where they feed for 4 to 6 days. Larvae destroy leaf cells as they feed, leaving behind winding trails ("mines"). The mines increase in length and width as the insects grow. The appearance of these larval mines reduces the aesthetic value of a plant. Third instar larvae drop to the soil or onto lower leaves to pupate.

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

Treatment: High populations may require sprays every 3 to 4 days to kill new adults as they emerge from the soil. Early morning sprays can kill adult females before they lay eggs. Use products with translaminar activity to kill immature larvae within foliage. Remember to rotate insecticides, as resistance is common.

If releasing beneficial insects, remember to only use pesticides listed as having minimal impact on natural enemies.

Table 9.5 Insecticides for Leafminer (Larvae) Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Abamectin	6	Avermectin	Abamectin E-Pro 0.15 EC	12	Do not apply through any type of irrigation system. Do not use product for suppression of aphids whiteflies, and thrips on roses, chrysanthemums, and gerbera. Do not use on fern or shasta daisies.
			Ardent 0.15EC		
			Avid 0.15EC		
			Flora-Mek 0.15 EC		
			Lucid		
			Minx		
			Quali-Pro Abamectin 0.15 EC		
			Timectin 0.15EC T&O		
Acephate	1B	Organophosphate	Orthene TT&O WSP	24	Do not apply to roses in flower, poinsettia in bract or chrysanthemum in flower. See label for specific cultivars cautions. Caution if applying to the following: *Bletchum gibbum*, *Cissus*, *Fittonia*, *Maranta, Pachystachya*, *Ficus*, *Plectranthus*, *Polypodium*, *Polystichum*, *Pteris*, and *Tolmiea*.
			Orthene TT&O 97 WP		
			Precise		Controlled-release systemic. Do not apply to freshly rooted cuttings. Use only on 3 to 12" diameter pots.
Acetamiprid	4A	Neonicotinoid	TriStar 70 WSP	12	Do not irrigate overhead for at least 6 hrs after application.
Azadirachtin	18B	Botanical	Aza-Direct (EC)	4	Repellant, IGR. Controls by contact or ingestion. Use within 8 hours. Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Reduce pH of irrigation water if pH exceeds 7.0.
			Azatin XL (EC)		
			Ecozin Plus 1.2% ME		
			Ferti-Lome Triple Action Plus		
			Neemix 4.5 (EC)	12	
			Neemazad 1.0% EC		
			Ornazin 3% (EC)		
			Triact 70	4	

Table 9.5 Insecticides for Leafminer (Larvae) Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Beauveria bassiana GHA Strain	NC	Microbial	Botanigard ES	4	Contact insecticide; spores attach to cuticle of pest, then penetrate to kill. Begin applications at first sign of pest; may take 7–10 days to see control. Do not apply through a thermal pulse fogger. Can be used with ultra-low volume equipment and chemigation. Compatible with some fungicides. Do not apply to poinsettia in bract.
Bifenthrin	3A	Pyrethroid	Attain Greenhouse	12	Apply when foliage is dry.
			Attain TR		Do not apply through any kind of irrigation system.
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% (F)		Restricted use. Wait 30 days between greenhouse applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any kind of irrigation system.
			Talstar Nursery (F)		Do not apply through any type of irrigation system or to edible plants. Spreader sticker is not necessary. Can tank mix with plant growth regulators.
			Talstar Professional Insecticide		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through any type of irrigation system. Do not apply to wet foliage or during periods of high humidity due to injury to tender foliage. Do not use on Boston ivy, Virginia creeper, or maidenhair fern.
			Wisdom F		

Table 9.5 Insecticides for Leafminer (Larvae) Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Chlorpyrifos	1B	Organophosphate	DuraGuard ME	24	Do not mix with alkaline materials (e.g. lime). Some varieties of azalea, camellia, poinsettia, roses and variegated ivy have shown phytotoxicity. Do not use on kalanchoe. Direct treatment to some open blooms may cause petal drop.
Cyromazine	17	Cyromazine	Citation (WSP)	12	Molting disruptor. Will not kill adults. Mandatory rotation details on label.
Diflubenzuron	15	Benzoylurea	Adept (WSP) Dimilin SC (F)	12	IGR. Do not reuse potting media. Do not apply Adept to poinsettias, hibiscus, or Reiger begonia. Do not apply to pots grown on capillary water mats.
Dinotefuran	4A	Neonicotinoid	Safari 20 SG Safari 2G	12	Systemic; only apply to moist soil media, not to dry or saturated media. No more than two foliar or broadcast applications and/or one soil application per crop per year.
Fenoxycarb	7B	Fenoxycarb	Prescription Treatment Brand Preclude TR	12	Micro-release insect growth regulator. Apply when foliage is dry.
Fenpropathrin	3A	Pyrethroid	Tame 2.4EC	24	Restricted use.Apply when foliage is dry. Do not apply to roses and chrysanthemums with open flowers or to poinsettia in bract.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR	24	Do not use in greenhouses <900 ft^2. Must store spray cans at room temperature for 24 hrs. before application. Apply when foliage is dry. Do not apply to poinsettia in bract.

Table 9.5 Insecticides for Leafminer (Larvae) Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Imidacloprid	4A	Neonicotinoid	Areca	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.
			Benefit 60 WP		
			Imida E-Pro 2F		
			Lada 2F		
			Mallet 75 WSP		
			Mallet 7.1% PF		
			Mallet 2F		
			Mallet 75 WSP		
			Mantra 1G		
			Mantra 2F		
			Marathon 1% G		
			Marathon II		
			Quali-Pro Imidacloprid 1G Nursery & Greenhouse		
			Quali-Pro Imidichloprid 2F Nursery & Greenhouse Insecticide		
Lambda-cyhalothrin	3A	Pyrethroid	Scimitar GC	24	Restricted use. A spreader-sticker is recommended. Do not apply through any irrigation system. See label for details. Quali-Pro is labeled for adults only.
			Quali-Pro lambda GC-O		
			Scimitar GC		Do not apply through any type of irrigation system.
Novaluron	15	Benzoylurea	Pedestal	12	Insect growth regulator; control immatures (not adults). Do not apply more than twice a year. For suppression of serpentine and citrus leafminers.

Table 9.5 Insecticides for Leafminer (Larvae) Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate (mineral oil) Golden Pest Spray Oil (soybean oil) Organic JMS Stylet Oil (Paraffinic/ mineral oil) PureSpray Green (petroleum oil) Saf-T-Side (petroleum oil) SuffOil-X (paraffinic oil) Summit Year Round Superior Horticulture Spray Oil (mineral oil) Ultra-fine Spray Oil (paraffinic oil) Ultra-Pure Oil (Petroleum oil)	4	For adult control – contact only. Target pest must be completely covered with product to be effective. Do not apply if plants are under any kind of stress. Do not apply during periods of prolonged high temperatures combined with high relative humidity. Avoid spraying in greenhouses under overcast conditions. Do not exceed label rates or apply more often than recommended. Effectiveness at temperatures below 50 °F is reduced. Do not use within 2 weeks of sulfur or within 7 days of Captan. Do not apply through any type of irrigation system.
Permethrin	3A	Pyrethroid	Astro 2 EC Permethrin E-Pro Perm-Up 3.2EC (restricted use) Waylay 3.2 AG (Restricted use)	12	Avoid spraying blooms of chrysanthemum; not all cultivars have been tested for phytotoxicity. Marginal leaf burn has been noticed on salvia, *Dieffenbachia*, and pteris fern. May cause petal browning.
Pyrethrins and Piperonyl butoxide	3A	Pyrethrin	Pyrenone Crop Spray (EC) Prentox Pyronyl Crop Spray	12	Has a synergist to flush insects out to make contact with spray. Apply when foliage is dry. Do not use on cyclamen or nasturtium.
Spinosad	5	Spinosyn	Conserve SC (EC)	4	Minimum impact on beneficials. Limit of two consecutive applications. Caution when spraying African violet blooms.

Mealybug Control

Identification and damage: Mealybugs are small (1–8 mm long), elongate-oval, soft-bodied insects that are covered with a layer of white, cottony wax. They can be found infesting all parts of a plant, including roots. Most produce short, spine-like filaments along the margins of their bodies, and on some species the posterior filaments can be quite long. Some mealybug pests of greenhouse crops include the citrus mealybug, obscure mealybug, and long-tailed mealybug.

Mealybug infestations cause leaf distortion, particularly on new growth. Some species inject a toxin as they feed that can produce brown/necrotic areas on foliage, general yellowing, or leaf drop. Their production of white cottony wax and their very presence on leaf axils or undersides of leaves detract from the appearance of the plant.

Monitoring: Early detection is important. Examine foliage, petioles, and stems of plants for presence of mealybugs. Inspect the lips of containers as well as drainage holes. Mealybugs produce copious amounts of honeydew which can be found on foliage before the resulting sooty mold. Because ants can be attracted to honeydew as with soft scales, their presence may signal a mealybug infestation.

Treatment: Beneficial insects tend to attack specific mealybug species, so identification of the mealybug is important prior to release. If releasing beneficial insects, do so prior to damaging pest population levels and remember to only use pesticides listed as having minimal impact on natural enemies.

Immature mealybugs lack their protective waxy coating and are easier to control, especially with contact insecticides. Systemic products are often applied preventatively on a 3 to 4 week schedule.

Table 9.6 Insecticides for Mealybug Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acephate	1B	Organophosphate	Acephate Pro 75 WSP	24	Do not apply to roses in flower or poinsettia in bract. Caution if applying on the following foliage plants due to phytotoxicity concerns: *Bletchum gibbum*, *Cissus*, *Ficus, Fittonia, Maranta, Pachystachya, Plectranthu, Polypodium, Polystichum, Pteris, Tolmiea*. Do not treat chrysanthemum in flower; see label for caution on specific chrysanthemum cultivars.
			Acephate 90 Prill		
			Acephate 97Up		
			Avatar		Do not apply to roses in flower or poinsettia in bract. Caution if applying on the following foliage plants due to phytotoxicity concerns: *Bletchum gibbum, Cissus, Ficus, Fittonia, Maranta, Pachystachya, Plectranthu, Polypodium, Polystichum, Pteris, Tolmiea*. Do not treat Chrysanthemum in flower.
			Orthene TT&O (Turf, tree, and Ornamental) WSP		
			Orthene TT&O 97 (Turf, tree, and Ornamental) WP		
			Precise 4% G		Controlled-release systemic product. For use only on 3” to 12” diameter pots. Do not apply to freshly rooted cuttings. Limited plants listed for use.
Acetamiprid	4A	Neonicotinoid	TriStar 70WSP	12	Do not irrigate overhead for at least 6 hrs after application.

Table 9.6 Insecticides for Mealybug Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Azadirachtin (neem/ neem oil)	18B	Botanical	Azatin XL	4	Repellant, IGR. Controls larvae and pupae on contact or by ingestion Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Use within 8 hours. Reduce pH of irrigation water if the pH exceeds 7.0.
			Aza-Direct		
			Ecozin Plus 1.2% ME		
			Ferti-Lome Triple Action Plus		
			Ornazin 3% EC	12	
			Neemix 4.5	4	
			Neemazad 1.0% EC		
			Triact 70		
Beauveria bassiana	NC	Microbial	Botanigard 22 WP	4	Insect-specific fungus. Do not apply through a thermal pulse fogger. Do not apply with pesticides such as Metasystox R, Neemazad or Thiodan EC.
			Mycotrol O (WP)		
			Naturalis L (JW-1 strain)		
			Naturalis H&G (WP)		
Bifenthrin	3A	Pyrethroid	Attain TR	12	Apply when foliage is dry.
			Attain Greenhouse		Do not apply through any kind of irrigation system.
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% F		Restricted use. Wait 30 days between applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any irrigation system.
			Talstar Nursery F		Do not apply through irrigation system. Spreader sticker is not necessary. Can be tank mixed with PGRS.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through irrigation system. Do not apply to wet foliage or when humidity is high. Do not use on Boston ivy, Virginia creeper or maidenhair fern.
			Wisdom F		

Table 9.6 Insecticides for Mealybug Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Buprofezin	16	Buprofezin	Courier 40 SC Talus 40SC	12	IGR: suppresses egg-laying as well as reduces egg viability. Not disruptive to beneficial insects and mites. Apply no more than 2 applications per season. Do not apply this product through any type of irrigation system.
Chlorpyrifos	1B	Organophospate	DuraGuard ME	24	Do not mix with alkaline materials (e.g. lime). Do not use on kalanchoe. Some azalea, camellia, poinsettia, rose and variegated ivy varieties have shown phytotoxicity. Treating open blooms may cause petal drop.
Chlorpyrifos and Cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR	24	Restricted use. Micro total release insecticide. Apply when foliage is dry. .
Cyfluthrin	3A	Pyrethroid	Decathlon 20WP	12	Do not apply through any type of irrigation system
Dichlorvos	1B	Organophosphate	DDVP (Fulex)		Total release fumigant smoke. Do not apply when foliage or blossoms are wet as injury may result.
Dinotefuran	4A	Neonicotinoid	Safari 20 SG Safari 2G	12	Systemic; only apply to moist soil media, not to dry or saturated media. No more than two foliar or broadcast applications and/or one soil application per crop per year.
Fenoxycarb	7B	Fenoxycarbs	Prescription Treatment Preclude TR	12	Micro-release insect growth regulator. Apply when foliage is dry.
Fenpropathrin	3A	Pyrethroid	Tame 2.4 EC	24	Restricted use. Apply when foliage is dry Do not apply to rose or chrysanthemum flowers or to poinsettia in bract.

Table 9.6 Insecticides for Mealybug Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR (Prescription Treatment)	24	Do not use in greenhouses <900 ft^2. Do not apply within 48 hrs of previous application. Must store cans at room temperature for 24 hrs before application. Apply when foliage is dry. Do not apply to poinsettia in bract.
Fenpyroximate	21A	METI-acaricides	Akari 5SC	12	Spray water should be buffered to pH 5–7. Can be used as a dip for flower and foliage cuttings. Do not use through any irrigation system.
Flonicamid	9C	Flonicamid	Aria	12	Buffer spray water to pH 5–7. Can be used as a dip for flower and foliage cuttings. Do not use through irrigation system
Fluvalinate	3A	Pyrethroid	Mavrik Aquaflow (F)	4	Buffer spray water to pH 5–7. Can also be used as a dip for flower and foliage cuttings. Caution on rose and poinsettia.
Imidacloprid	4A	Neonicotinoid	Areca (EC) Benefit 60WP Imida E-Pro 2F Lada 2F Majesty Mallet 2F Mantra 1G Mantra 2F Marathon 1% G Marathon II (F) Quali-Pro Imidacloprid (1G Nursery & Greenhouse and 2F Nursery & Greenhouse)	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.

Table 9.6 Insecticides for Mealybug Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Insecticidal soap	NC	Potassium salts of fatty acids	Bonide Insecticidal Soap Concern M-Pede DES-X M-Pede Natural Guard Insecticidal Soap	12	Contact insecticide so complete coverage is essential. Use soft water for best results. Do not use on new transplants, unrooted cuttings or plant material stressed by drought or under hot, humid, drought or overcast conditions. Do not use on bleeding heart, jade, lantana, lily, and sweet pea, chrysanthemum in bloom or poinsettia in bract. Caution on euphorbias or if final pH solution is < 8.0.
Kinoprene	7A	Juvenile hormone analogues	Enstar II	4	IGR. Apply before bract formation in poinsettia. Some varieties of roses show delayed damage.
Lambda-cyhalothrin	3A	Pyrethroid	Quali-Pro lambda GC-O	24	Restricted use. A spreader-sticker is recommended. Do not apply through any type of irrigation system.
			Scimitar GC		Do not apply through any type of irrigation system.
Naled	1B	Organophosphate	Dibrom 8E	WPS Vent. Req's met	Vapor treatment of roses and other ornamentals. Good fumigant action. May be applied to steam pipes or in open pans on hot plates, but can be corrosive. Avoid over treatment and direct application to plants. May injure certain rose and chrysanthemum varieties, wandering Jew, poinsettia, and Dutchman's Pipe. Do not apply when air temperature is above 90 °F due to phytotoxicity.

Table 9.6 Insecticides for Mealybug Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Neem oil	NC	Clarified hydrophobic extract of neem oil	Triact 70	4	Kills immature and adult insects. Do not apply to wilted or stressed plants, or to transplants before root establishment. Caution if applying to flowers of impatiens, fuchsia, hibiscus, and some rose or carnation varieties.
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate, Summit Year Round Superior Horticulture Spray Oil (mineral oil) Golden Pest Spray Oil (soybean oil) PureSpray Green, Saf-T-Side (petroleum oil) Organic JMS Stylet Oil, SuffOil-X, Ultrafine Spray Oil (paraffinic oils)	4	Contact insecticide; Target pest must be completely covered with product to be effective. Do not apply if plants are under any kind of stress. Do not apply during periods of prolonged high temperatures combined with high relative humidity. Avoid spraying under overcast conditions. Below 50 °F, effectiveness is reduced. Do not use within 2 weeks of sulfur or within 7 days of Captan fungicide. Do not apply through irrigation system.
Permethrin	3A	Pyrethroid	Astro Permethrin E-Pro Perm-Up 3.2EC	12	Marginal leaf burn has been noted on salvia, *Dieffenbachia*, and pteris fern. Avoid spraying chrysanthemum blooms; not all cultivars have been tested for phytotoxicity. May cause petal browning.
Pyrethrins and Piperonyl butoxide	3A	Pyrethrin	Prentox Pyronyl Crop Spray Pyrenone Crop Spray	12	Apply when foliage is dry Do not use on cyclamen or nasturtium.
Thiamethoxam	4A	Neonicotinoid	Flagship 0.22 G Flagship 25 WG	12	Soil applications take at least 1 week to translocate to foliage for control

Mite Control

Mites are closely related to spiders. Since they are not an insect, many insecticides do not control them effectively. Two different types of mites are typically found in the greenhouse: Tarsonemid mites (broad mites, cyclamen mites), and Tetranychid mites (twospotted spider mites, Lewis mites, and carmine mites). A separate control chart appears for each mite group.

A. Tarsonemid Mites: Broad mite and Cyclamen mite

Identification and damage: Broad mites and cyclamen mites are closely related and look very similar. Both are white colored and very small with setae covering their body. The males have 6 legs that used for walking and the two hind legs turn upward to grasp females and carry immature females around. Both stages cause similar damage. Broad mite can be distinguished from cyclamen mites by their egg stage. Broad mite eggs are covered with bumps that look like a row of diamonds and are best seen using a dissecting microscope. Adults and larvae are smaller than the cyclamen mites and walk rapidly on the underside of leaves. The development of broad mites is favored by high temperatures of 70° to 80°F. Broad mites can complete their life cycle in as little as one week. Females lay from 30 to 75 eggs.

Monitoring: Broad mites can affect a number of ornamentals including sweet potato vine, gerbera daisy, New Guinea impatiens, salvia, ivy, verbena and zinnia. They may migrate to peppers or tomatoes. Look for characteristic damage to new growth or leaf edges: curling and twisting of new growth on plants/curling downward. Terminal buds may be killed. As they feed, broad mites inject toxic saliva, which causes the characteristic twisted and distorted growth. Do not confuse broad mite injury with herbicide injury, boron deficiency or physiological disorders. With a 20X hand lens, inspect the curled and cupped leaves for mites.

Treatment: Sprays must be fine mists to penetrate the cryptic areas in plants where mites are found.

Table 9.7 Miticides for Mite Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Abamectin	6	Avermectin	Abamectin E-Pro 0.15 EC	12	Not for use on roses, chrysanthemums, gerbera, ferns or shasta daisies. Do not apply through any type of irrigation system.
			Ardent 0.15EC		
			Avid 0.15EC		
			Flora-Mek 0.15 EC		
			Lucid		
			Minx		
			Quali-Pro Abamectin 0.15 EC		
Bifenthrin	3A	Pyrethroid	Attain TR	12	Micro total release insecticide. Apply when foliage is dry.
			Attain Greenhouse		Microemulsion. Do not apply through any irrigation system.
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% F		Restricted use. Wait 30 days between applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any irrigation system or exceed maximum label rate.
			Talstar Nursery F		Do not apply through any irrigation system. Spreader sticker is not necessary. Not for use on edible plants. Can tank mix with plant growth regulators and use as a topical drench or bare root dip for some pests.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through irrigation system, to wet foliage or during high humidity periods. Do not treat Boston ivy, Virginia creeper or maidenhair fern.
			Wisdom F		

Table 9.7 Miticides for Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Chlorfenapyr	13	Chlorfenapyr	Pylon	12	Translaminar activity. May be applied twice consecutively, but no more than three times within a season. Chemical is not ovicidal. Controls immature mites. Apply prior to bloom or avoid blooms where possible. Do not apply to dianthus, kalanchoe, poinsettia, roses, salvia, or zinnia.
Fenpyroximate	21A	METI-acaricides	Akari 5SC	12	Do not apply through any type of irrigation system. Do not use in successive miticide applications. Do not apply lower than label rates.
Insecticidal soap	NC	Potassium salts of fatty acids	M-Pede	12	Contact insecticide so complete coverage is essential. Use soft water for best results. Do not use on new transplants, unrooted cuttings, or plant material stressed by drought or under hot, humid or drought conditions. Avoid spraying under overcast conditions. Caution if using on euphorbias or if pH of final solution is <8.0. Do not use on bleeding heart, jade, lantana, lily, and sweet pea. Do not apply to pointsettia in bract or to chrysanthemum after bloom

Table 9.7 Miticides for Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Lambda-cyhalothrin	3A	Pyrethroid	QualiPro Lamda GC- O Scimitar GC	24	Do not apply through any type of irrigation system.
Pyridaben	21A	METI-acaricides	Sanmite WP	12	May be fatal if inhaled. Do not use in successive miticide applications . Do not apply this product through any type of irrigation system
Spiromesifen	23	Tetronic and tetramic acid derivatives	Judo	12	Provides knockdown and residual control of all mite life stages, including eggs and pupae. Do not apply this product through any type of irrigation system. See label for restrictions on use on specific plants/ cultivars, including rose, geranium, primrose, etc.

Mite Control (continued)

B. Tetranychid Mites: Twospotted spider mite, Lewis mite and Carmine mite

Identification and damage: Tetranychid mites include twospotted spider, Lewis mite and carmine mites. Adult are slightly orange in color and very small (1/50th inch or 0.5mm). Most spider mites are found on the underside of leaves. Feeding injury (called stippling) often gives the top leaf surfaces a mottled/speckled, dull appearance. Leaves then turn yellow and drop. Large populations produce visible webbing that can completely cover the leaves. Buds may become distorted.

Eggs are laid singly, up to 100 per female, during her 3- to 4-week life span. Eggs hatch into larvae in as few as 3 days. The egg to adult life cycle can be completed in 7 to 14 days depending upon temperature. Hot and dry conditions (>81 °F) favor rapid spider mite development.

Monitoring: Pay close attention to plants growing on the south side of a greenhouse as well as warm locations near heaters or steam pipes. Hanging baskets in the upper canopy of the greenhouse also tend to be very susceptible. Check for mites weekly by examining foliage using a hands-free magnifier (Optivisor) or hand lens. Be sure to examine the undersides of leaves.

Adult mites are not found on sticky cards. Mites often develop as localized infestations on particular groups of plants. Weeds should be removed/controlled as they can harbor two spotted mites.

Treatment: Avoid overfertilization. If using beneficial predaceous mites or other natural enemies, release prior to damaging pest population levels. If using mite growth regulators (TetraSan), application must occur prior to mite population buildup.

Sprays must be fine mists to penetrate the cryptic areas in plants where mites are found. Translaminar miticides are therefore recommended. Thorough coverage is necessary with repeated applications. Most miticides are not effective against the egg stage, so repeat applications are necessary. Remember to rotate insecticides, as resistance is common.

Table 9.8 Miticides for Spider Mite Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Abamectin	6	Avermectin	Abamectin E-Pro 0.15 EC Ardent 0.15EC Avid 0.15EC Flora-Mek 0.15 EC Lucid Minx Quali-Pro Abamectin 0.15 EC Timectin 0.15EC T&O	12	Translaminar properties. Do not apply through any type of irrigation system. Not for use on roses, chrysanthemums, gerbera, ferns, or shasta daisies.
Acequinocyl	20B	Acequinocyl	Shuttle 15SC	12	Allow a minimum of 14 days between applications.
Azadirachtin (neem oil)	18B	Botanical	Aza-Direct Ferti-Lome Triple Action Plus Triact 70	4	Repellant, insect growth regulator. Controls larvae and pupae on contact or by ingestion. Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Reduce pH of irrigation water if the pH exceeds 7.0.
Beauveria bassiana ATCC 74040	NC	Entomopathogenic fungus	Botanigard ES Botanigard 22 WP Naturalis L	4	Contact insecticide; insect-specific fungus. Do not apply through a thermal pulse fogger. Some fungicides, but not all, may kill the spores. Do not tank mix with Neemazad or Thiodan EC; Do not apply to poinsettia in bract.
Bifenazate	UN	Bifenezate	Floramite SC	12	Residual control for up to 28 days after application. Do not use in successive applications; apply at least two alternative products between treatments. Some ovicidal activity.

Table 9.8 Miticides for Spider Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Bifenthrin	3A	Pyrethroid	Attain TR	12	Micro total release insecticide. Apply when foliage is dry. Do not apply through any kind of irrigation system.
			Attain Greenhouse		
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% F		Restricted use. Wait 30 days between applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any irrigation system or exceed max. label rate.
			Talstar Nursery F		Low-volume application permitted. Do not apply through any type of irrigation system. Spreader sticker is not necessary. Not for use on edible plants. Can tank mix with plant growth regulators. Can be used as a topical drench or bare root dip for certain pests.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through any irrigation system, to wet foliage or during high humidity periods. Do not treat Boston ivy, Virginia creeper or maidenhair fern.
			Wisdom F		
Chlorfenapyr	13	Chlorfenapyr	Pylon	12	Translaminar activity. May be applied twice consecutively, but no more than three times within a season. Do not apply to consecutive crops. Controls immature mites-not ovicidal. Avoid blooms if possible. Do not treat carnation, dianthus, kalanchoe, zinnia, rose, poinsettia or salvia.

Table 9.8 Miticides for Spider Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Chlorpyrifos	1B	Organophosphate	DuraGuard ME	24	Restricted use. Do not mix with alkaline materials (e.g. lime). Do not use on kalanchoe. Phytotoxicity on some varieties of rose, azalea, camellia, poinsettia, and variegated ivy. Treating open blooms may cause petal drop.
Chlorpyrifos and cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR	24	Restricted use. Micro total release insecticide. Apply when foliage is dry.
Clofentezine	10A	Clofentezine	Ovation SC	12	Growth inhibitor; highly active on immature mites and eggs. Persistent up to 45 days after application. Magenta product may leave a residue on light colored flowers or foliage. Use once per crop cycle.
Dichlorvos	1B	Organophosphate	DDVP (Fulex)	WPS Vent. reqs. met	Total release fumigant smoke. To avoid injury, apply to dry foliage and blossoms.
Etoxazole	10B	Etoxazole	TetraSan 5WDG	12	Translaminar. Kills nymphs and eggs. Treated adults do not produce viable eggs. Do not apply to poinsettia in bract.
Fenbutatin-oxide	12B	Organotin miticide	Vendex 50 WP	48	Restricted use. Must clean tank of any products containing chlorine or boron. Do not add oil to spray solution. Only apply pre-bloom to chrysanthemum and poinsettia.
			ProMITE 50WP		Do not use in sprayers with boron or chlorine residues. Works best when daily temperatures average >70 °F. Only apply pre-bloom to chrysanthemum and poinsettia.

Table 9.8 Miticides for Spider Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Fenoxycarb	7B	Fenoxycarbs	Prescription Treatment Brand Preclude TR	12	Juvenile hormone mimics. Micro-release insect growth regulator. Apply when foliage is dry.
Fenpropathrin	3A	Pyrethroid	Tame 2.4EC	24	Restricted use. Apply when foliage is dry. Do not apply to chrysanthemums and roses with open flowers or to poinsettia in bract.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR (Prescription Treatment)		Do not use in greenhouses <900 ft^2. Do not apply within 48 hrs of a previous application. Cans must be stored at room temperature for 24 hrs before application. Apply when foliage is dry. Do not apply to poinsettia in bract.
Fluvalinate	3	Pyrethroid	Mavrik Aquaflow	12	Spray water should be buffered to pH 5–7. Can also be used for immersing of basket of flower and foliage cuttings. Caution on roses and poinsettias.
Hexythiazox	10A	Insect growth regulator	Hexygon DF	12	Mite growth inhibitors. Not labeled for chemigation. Will control immature active stages that are sprayed/move onto treated surfaces. Will not kill adults, but treated adults will not produce viable eggs.

Table 9.8 Miticides for Spider Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Insecticidal Soap	NC	Potassium salts of fatty acids	Bonide Insecticidal Soap Concern DES-X M-Pede Natural Guard Insecticidal Soap	12	Contact insecticide; complete coverage is essential. Use soft water for best results. Do not use on new transplants, unrooted cuttings, or plant material stressed by drought, under hot or humid or overcast conditions. Caution if using on euphorbias or if the pH of final solution is below 8.0. Do not use on bleeding heart, jade, lantana, lily, and sweet pea. Do not apply to poinsettia in bract or to chrysanthemum after bloom.
Lambda-cyhalothrin	3A	Pyrethroid	Quali-Pro lambda GC-O Scimitar GC	24	Restricted use. A spreader-sticker is recommended. Do not apply through any type of irrigation system.
Methiocarb	1A	Carbamate	Mesurol 75WP	24	Restricted use. Do not apply with foliar fertilizers or oils.
Naled	1B	Organophosphate	Dibrom 8E	WPS Vent. Req's met	Vapor treatment of roses and other ornamentals. Has good fumigant action. May be applied to steam pipes or in open pans on hot plates, but can be corrosive to metals. Avoid over treatment and direct application to plants. May injure certain rose and chrysanthemum varieties, wandering Jew, poinsettias, and Dutchman's Pipe. Do not apply this product when air temperature is above 90 °F due to phytotoxicity issues.

Table 9.8 Miticides for Spider Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Neem oil	NC	Botanical	Triact	4	Kills immature and adult insects. Do not apply to wilted or stressed plants, or to new transplants prior to root establishment. Caution if applying to flowers of impatiens, fuchsia, hibiscus, some roses, ornamental olive trees or some carnation varieties.
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate Summit Year, Round Superior Horticulture Spray, All Seasons Horticultural Spray Oil concentrate (mineral oils)	4	Complete covereage necessary for product to be effective. Do not apply if plants are under any kind of stress, during periods of prolonged high temperatures combined with high relative humidity or under overcast conditions. Do not exceed label rates or apply more often than recommended. Effectiveness at temperatures below 50°F is reduced. Do not use within 2 weeks of sulfur or within 7 days of Captan. Do not apply through any irrigation system.
			Golden Pest Spray Oil (soybean oil)		
			Organic JMS Stylet Oil (Paraffinic/ Mineral oil)		
			SuffOil-X, Ultra-fine Spray Oil (paraffinic oils)		
			PureSpray Green, Saf-T-Side, Ultra-Pure Oil (petroleum oils)		
Paecilomyces fumosoroseus		Microbial	PFR-97 20% WDG	4	Entomopathogenic fungus. Provides high levels of control in greenhouses where humidity levels are relatively high. Apply in late morning or early evening (cloudy, overcast days are optimal). Do not tank mix with fungicides.

Table 9.8 Miticides for Spider Mite Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Pyridaben	21A	METI-acaricides	Sanmite	12	May be fatal if inhaled. Do not use in successive miticide applications. Do not apply this product through any type of irrigation system. Do not use fertilizers containing boron.
Spinosad	5	Spinosyn	Conserve SC	4	Not recommended for use against mites unless control is also needed for other labeled pests (caterpillars, leafminers, thrips). Direct contact can cause significant mortality to *Phytoseiulus persimilis*. Maximum of two consecutive applications. See label for crops that can be chemoirrigated. Caution when spraying African violet blooms.
Spiromesifen	23	Tetronic and tetramic acid derivatives	Judo	12	Provides knockdown and residual control of all mite lifestages, including eggs and pupae. Do not apply this product through any type of irrigation system. See label for restrictions on use on specific plants or cultivars, including rose, geraniums, primrose, etc.
Tau-fluvalinate	3A	Pyrethroid	Mavrik Aquaflow (F)	12	Contact, good coverage needed. Labeled for broadcast, fogger, ULV, or bench application in greenhouses.

Scale Control

Identification and damage: Scale insects are classified as either soft scales or armored scales. Soft scales are larger (2–5 mm) and usually have a circular or oval shape. Colors are usually shades of gray or brown. Soft scales produce honeydew as they feed. The protective waxy cover (teste) cannot be detached from the body of soft scales. Common species include black scale, soft brown scale, and hemispherical scale. Armored scales secrete a hard, waxy cover (shield) over their bodies. Armored scales do not produce honeydew. The protective waxy cover (teste) can be separated from the body of armored scales. Examples include Florida red scale and fern scale.

All immature scales, called "crawlers" hatch from eggs. The first nymphal instar of both soft and armored scales has functional legs. Soft scale crawlers crawl out over the leaves and stems to feed on the plant, and may move back again. Armored scale crawlers move a short distance from where they were hatched and find a suitable place to settle down and feed. They do not move again for the remainder of their lives. The crawler stage is the most sensitive to insecticides.

Scale insects are small, sucking insects that remove sap from plants as they feed. This causes spotting or yellowing of leaves, overall poor plant growth, and dieback. Soft scales can produce distorted foliage from their feeding on young tissue causing the leaves to turn yellow. High populations can cause twigs and branches to die back. Soft scales excrete a sugary product called honeydew which can fall onto leaves and cause them to become shiny and sticky. Honeydew can support the growth of unsightly sooty mold. Armored scales can produce either yellow or brown spots or streaks on the leaves. They can cause general yellowing of the foliage, poor growth, and incrustations of both stems and leaves. In very high populations they can cause twig dieback or even kill the plant.

Monitoring: Check foliage and stems for presence of scale covers. The presence of honeydew and sooty mold is a good indication of an infestation.

Treatment: Avoid overfertilization. If releasing beneficial predaceous mites or other natural enemies, do so prior to damaging pest population levels. Time all treatments to the susceptible crawler stage. Systemic insecticides have shown better control levels on soft scales than armored scales.

Table 9.9 Insecticides for Scale Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acephate	1B	Organophosphate	Acephate Pro 75 WSP	24	Ready-to-use insecticide fogger. Apply when foliage is dry and greenhouse is completely closed. Do not apply to chrysanthemums and roses with open blooms. Do not apply to poinsettia in bract.
			Acephate 90 Prill		
			Acephate 97Up		
			Avatar		Do not apply to roses in flower or poinsettia after bract formation. Caution if applying on the following foliage plants due to phytotoxicity concerns: *Bletchum gibbum, Cissus, Ficus, Fittonia, Maranta, Pachystachya, Plectranthus, Polypodium, Polystichum, Pteris,* and *Tolmiea*. Do not treat chrysanthemum in flower; see label for caution on specific chrysanthemum cultivars.
			Orthene TT&O (WSP)		
			(Turf, tree, & Ornamental)		
			Orthene TT&O 97 (WP) (Turf, tree, & ornamental)		
			Precise 4% G		Controlled-release systemic product. For use only on 3” to 12” diameter pots. Do not apply to freshly rooted cuttings.
Acetamiprid	4A	Neonicotinoid	TriStar 70 WSP	12	Do not irrigate overhead for at least 6 hrs after application.

Table 9.9 Insecticides for Scale Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Azadirachtin	18B	Botanical	Aza-Direct (EC)	4	Repellant, anti-feedant, and IGR. Controls larvae and pupae on contact or by ingestion Do not use with Bordeaux mixture, triphenyltin hydroxide, lime, sulfur, or highly alkaline materials. Use within 8 hours. Reduce pH of irrigation water if pH >7.0.
			Azatin XL (EC)		
			Ecozin Plus 1.2% ME		
			Ornazin 3% EC	12	
			Neemix 4.5 (EC)		
			Neemazad 1.0% EC	4	
Bifenthrin	3A	Pyrethroid	Attain TR (fogger)	12	Micro total release insecticide. Apply when foliage is dry.
			Attain Greenhouse (microemulsion)		Do not apply through irrigation system. See label for scale species.
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% F		Restricted use.Wait 30 days between applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any irrigation system or exceed max. label rate.
			Talstar Nursery F		Can make low-volume application. Do not apply through any irrigation system. Spreader sticker is not necessary. Not for edible plants. Can tank mix with plant growth regulators.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through any irrigation system, to wet foliage or during high humidity periods. Do not use on Boston ivy, maidenhair fern, and Virginia creeper.
			Wisdom F		

Table 9.9 Insecticides for Scale Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Buprofezin	16	Buprofezin	Courier 40 SC Talus 40SC	12	IGR; suppresses egg-laying as well as reduces egg viability. Not disruptive to beneficial insects and mites. Make no more than two applications per season. Do not apply this product through any type of irrigation system.
Chlorpyrifos	1B	Organophosphate	DuraGuard ME	24	Restricted use. Do not mix with alkaline materials (e.g. lime). Phytotoxicity noted on some varieties of azalea, camellia, poinsettia, roses and variegated ivy. Do not use on kalanchoe. Treating open blooms may cause petal drop.
Chlorpyrifos and Cyfluthrin	1B 3A	Organophosphate and Pyrethroid	Duraplex TR (WP)	24	Restricted use. Micro total release insecticide. Apply when foliage is dry
Cyfluthrin	3A	Pyrethroid	Decathlon 20WP	12	Do not apply through any irrigation system
Dinotefuran	4A	Neonicotinoid	Safari 20 SG Safari 2G	12	Systemic. Only apply to moist soil media. Do not apply to dry or saturated media.
Fenoxycarb	7B	Fenoxycarbs	Preclude TR	12	Micro-release IGR. Apply to dry foliage.
Fenpropathrin and Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR	24	Must store spray cans at room temperature for 24 hrs before using. Do not use in greenhouses <900 ft^2. Do not apply within 48 hrs of a previous application or to poinsettia in bract. Apply to dry foliage.

Table 9.9 Insecticides for Scale Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Flonicamid	9C	Flonicamid	Aria (WSP)	12	Spray water should be buffered to pH 5–7. Can be used as a dip for flower and foliage cuttings. Do not use through any type of irrigation system
Fluvalinate	3A	Pyrethroid	Mavrik Aquaflow (F)	4	Spray water should be buffered to pH 5–7. Can also be used as a dip for flower and foliage cuttings. Caution on roses and poinsettia.
Imidacloprid	4A	Neonicotinoid	Areca (EC)	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.
			Benefit 60WP		
			Imida E-Pro 2F		
			Lada 2F		
			Majesty		
			Mallet 2F		
			Mantra 1G		
			Mantra 2F		
			Marathon 1% G		
			Marathon II (F)		
			Quali-Pro Imidacloprid 1G Nursery & Greenhouse		
			Quali-Pro Imidichloprid 2F Nursery & Greenhouse Insecticide		

Table 9.9 Insecticides for Scale Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Insecticidal soap	NC	Potassium salts of fatty acids	Bonide Insecticidal Soap Concern DES-X M-Pede Natural Guard Insecticidal Soap	12	Contact insecticide so complete coverage is essential. Protection period is shorter if media has >30–50% bark content. Do not tank mix with products that contain boron or release free chlorine. Use soft water for best results. Do not use on new transplants, unrooted cuttings, plant material stressed by drought under hot, humid, drought conditions or overcast conditions. Caution if using on euphorbias or if final pH of solution is below 8.0. Do not use on bleeding heart, fern, crassula, petunia, jade, lantana, lily, and sweet pea. Do not apply to poinsettia in bract or to chrysanthemum in bloom.
Kinoprene	7A	Juvenile hormone analogues	Enstar II	4	IGR. Apply before bract formation in poinsettia. Some varieties of roses show delayed damage.
Lambda-cyhalothrin	3A	Pyrethroid	Scimitar GC Quali-Pro lambda GC-O	24	Restricted use. A spreader-sticker is recommended. Do not apply through any type of irrigation system.

Table 9.9 Insecticides for Scale Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Neem oil	NC	Botanical	Triact 70	4	Kills immature and adult insects. Do not apply to wilted or stressed plants, or to new transplants prior to root establishment. Caution if applying to flowers of impatiens, fuchsia, hibiscus, or some roses and carnation varieties.
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	Golden Pest Spray Oil (soybean oil) JMS Stylet oil (paraffinic oil) Organic JMS Stylet Oil (Paraffinic oil) PureSpray Green (petroleum oil) Saf-T-Side (petroleum oil) SuffOil-X (paraffinic oil) Superior Miscible Spray Oil (petroleum oil) Ultra-Fine Spray Oil (paraffinic oil) Ultra-Pure Oil (Petroleum oil)	4	Need complete coverage. Do not apply to plants under any kind of stress, during periods of prolonged high temperatures combined with high relative humidity or under overcast conditions. Do not exceed label rates or apply more often than recommended. Effectiveness is reduced below 50 °F. Do not use within 2 weeks of sulfur or 7 days of Captan. Do not apply through any irrigation system.
Pyriproxyfen	7C	Pyriproxyfen	Distance (F)	12	IGR. Apply no more than twice per crop cycle or per 6 months. Do not apply to Boston fern, coral bells, ghost plant, salvia, gardenia, schefflera or poinsettia in bract.
Thiamethoxam	4A	Neonicotinoid	Flagship 25WG	12	For soft scales only. Translaminar absorption for excellent knockdown and long residual control.

Shore Fly Control (Larvae)

Identification and Damage: Shore flies (*Scatella tenuicosta*) feed on algae and are found in areas where algae is growing such as under benches or on shaded, wet substrate. Adult shore flies are small, dark-gray flies (approximately 1/8 in. long) that slightly resemble a *Drosophila* fruit fly, with a robust body and short legs and antennae. They have five distinctive whitish spots on their grey wings. Their single pair of wings lacks the characteristic Y-shaped vein at the tip seen in fungus gnats. In addition, the shore fly adult has short antennae, unlike the long multi-segmented antennae of fungus gnat adults. Larvae of the shore fly are small translucent-white maggots without a distinct head capsule as seen in fungus gnat larvae. Larvae and adults are found in close association with algae. Larvae develop through 3 instars while feeding on the algae. Adult shore flies are considered a nuisance pest by greenhouse workers and consumers. In heavy infestations they also deposit characteristic unsightly black "fly specks" on foliage. Larvae are considered algae feeders and do not feed on crop plant tissue. Adult shore flies are capable of transmitting *Pythium*/damping off disease.

Monitoring: Yellow sticky traps or tape are useful in monitoring adults as well as for mass trapping. Look for fly specks on foliage. Look for pupae that attach themselves (often in groups) to the sides of pots or objects just above the water level. Pay close attention to misted propagation facilities where algal growth and shore flies are common.

Treatment: Reducing algae in the greenhouse—on pots, floors, walls, and potting mix surfaces—is the best way to reduce the populations of these pests. Avoid overwatering.

Table 9.10 Insecticides for Shore Fly (Larva) Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Azadirachtin	18B	Botanical	Azatin XL (EC) Ecozin Plus 1.2% ME	4	Repellant, anti-feedant, and IGR. Controls larvae and pupae on contact or by ingestion Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Use within 8 hours. Reduce pH of irrigation water if the pH exceeds 7.0.
Beauveria bassiana	NC	Microbial	Naturalis L (JW-1 strain) Naturalis H&G	4	Contact insecticide; insect-specific fungus. Do not apply through a thermal pulse fogger. Treat media and under benches with a coarse spray. Some fungicides may kill the spores. Do not apply with insecticides such as Metasystox R, Neemazad or Thiodan EC. Do not apply to poinsettia in bract.
Chlorpyrifos	1B	Organophosphate	DuraGuard ME	24	Restricted use. Do not mix with alkaline materials (e.g. lime). Some varieties of azalea, camellia, poinsettia, rose and variegated ivy have shown phytotoxicity. Do not use on kalanchoe. Treating some open blooms may cause petal drop.
Chlorpyrifos and Cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR (WP)	24	Restricted use. Micro total release insecticide. Apply when foliage is dry.

Table 9.10 Insecticides for Shore Fly (Larva) Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Cyromazine	17	Cyromazine	Citation (WSP)	12	Molting disruptor. Mandatory rotation details on label. Will not kill adults.
Diflubenzuron	15	Benzoylureas	Adept (WSP)	12	IGR. Do not reuse potting media. Do not apply to poinsettia, hibiscus, or Reiger begonia. Do not apply to pots grown on capillary water mats.
Nematodes , beneficial or entomopathogenic (*Steinernema carpocapsae*)			Ecomen (Steinernema carpocapsae) Entonem (Steinernema feltiae) ScanMask (Steinernema feltiae) Millenium	Exempt	Insect-parasitic nematode that releases symbiotic bacteria that kill larvae. Use as a preventive or curative control. Apply as soon as possible after potting or placement in greenhouse. Apply solution to moist soil. Three applications must be made at 7-day intervals. Spray the surfaces of the pots and benches and other areas where insects can breed.
Pyriproxyfen	7C	Pyriproxyfen	Distance (F)	12	IGR. Apply no more than twice per crop cycle or per 6 months. Do not apply to Boston fern, coral bells, gardenia, ghost plant, salvia, or schefflera. Do not apply to poinsettia in bract.
Spinosad	5	Spinosyn	Conserve SC	4	Maximum of two consecutive applications. See label for crops that can be chemo-irrigated. Caution when spraying African violet blooms.

Slug Control

Identification and Damage: Slugs are soft bodied arthropods with beak–like mouthparts. Garden slugs, pear slugs and brown slugs are three common species found in the greenhouse. High moisture levels in the greenhouse create ideal conditions. The slugs lay eggs in cryptic spots. Slugs live for several years, depending on species, and can build up over several years in a greenhouse. Foliage is torn and shredded from slug feeding. Slime trails are often found on foliage.

Monitoring: Look for slime trails on plants. Examine foliage for torn or shredded damage. Slugs hide during sunny weather and during the day. Since slugs are active in overcast weather and at night, monitoring should occur during these times. Rotting wooden benches are favored by slugs and should be inspected.

Treatment: Inspect incoming plants and containers for the presence of slugs. Remove weeds and slug hiding places (debris, boards, empty containers, etc.) in and around the greenhouse. Research shows that fewer slug problems exist in greenhouses where plants are grown on expanded metal benches, vs. wooden benches or on the ground. Handpicking slugs can be helpful in small infestations, and is best done in the early evening, (~two hours after sunset). Copper flashing/strips can act as a slug barrier; wrap copper tape on bench legs, or surround raised beds with flashing to help exclude slugs. Abrasive materials such as dry gravel, or diatomaceous earth may also act as a barrier that slugs may not cross, as long as these materials remain dry. Poison baits must be eaten by slugs. Apply baits in the evening – irrigating prior to placement -- when slugs are active.

Table 9.11 Pesticides for Slug Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Iron phosphate	NC	Inorganic	Bonide Slug Magic	0	Bait granules. Scatter the bait in the plant pots of plants being damaged or around pots on greenhouse benches. Apply when soil is moist but not saturated. Reapply as bait is consumed or every two weeks as needed.
			Earth Tone Slug and Snail Control		
			Escar-Go Slug and Snail Bait		
			Garden Safe Slug and Snail Bait		
			Ortho EcoSense Slug and Snail Killer		
			Sluggo		
			Spectracide Snail & Slug killer Bait		
			Worry Free Lilly Miller Slug & Snail Bait		
Iron phosphate + Spinosad	NC 5	Inorganic Spinosyn	Deadline Bullets Sluggo Plus	12 None	Pellet bait granule. Scatter on the soil around or near plants, and also around the perimeter of the area. Do not apply more than 3 times in any 30 day period.
Metaldehyde	NC	Aldehyde molluscicide	Deadline M-PS	12	Bait granules/pellets. Soil treatment. Apply in early evening preferably after watering. Do not re-water for 48 hours. Do not apply directly to plants. Maximum of 6 treatments per year.
			Hi-Yield® Improved Slug & Snail Bait		
			Ortho Bug- _GETA		
			Metarex 4% Slug & Snail Bait		
			Mesurol Pro		Restricted use. Bait. The bait should be broadcast over plant foliage or applied to soil around plants. Irrigate before applying the bait. Treating areas under greenhouse benches and around building foundations.

Thrips Control

Identification and Damage: Adult thrips are small, about 1/16-inch - 1/32 inch long, with long, narrow bodies and fringed wings. Females are reddish brown and males are light tan to yellow. Most adult thrips seen in a greenhouse are females; reproduction without fertilization is common. Adults are gregarious, large numbers are found feeding in protected areas of the plant such as flowers and terminals. Eggs are inserted into leaf or petal tissue and are thus protected from insecticides. The two wingless larval stages vary in color from light yellow to orange to green. The larvae usually remain protected in flower buds or foliage terminals. While in two pupal stages in the soil, they are protected from insecticides directed at the crop. Currently, no pesticides are labeled as drenches to kill thrips pupae in soil.

The pest's rapid developmental time (egg to adult in 7 to 15 days under fluctuating temperatures), high reproductive rate, and preference for protected areas can make early detection difficult. Adults fly readily and can be carried by wind currents, or on clothing, to greenhouses near an infested field. They can fly from a sprayed to an unsprayed area or move into or out of a greenhouse through doors or greenhouse vents. Some species of thrips such as the western flower thrips (WFT) vector tospoviruses. Feeding marks from the rasping mouthparts of thrips destroy plant cells, and appear as silvery-white streaks on the leaves or flowers. Infested new growth may curl under and leaves are often deformed.

Monitoring: Early detection of a thrips infestation is critical because the symptoms of thrips feeding are often not noticed until after damage or virus transmission has occurred and because an infestation is easier to control when it is small. When the crop is in flower, detect thrips using a white or yellow piece of paper placed under open flowers. Gently tap the flowers and use a 10x magnifier to examine the insects that fall out. Using yellow or blue sticky cards is the easiest way to detect the onset of an infestation. To monitor the movement of thrips, place the cards just above the crop canopy, at about one per 500 square feet, as well as near doors, vents, and over thrips-sensitive cultivars. Recent research shows that light- to medium-blue sticky cards catch more thrips than yellow ones.

To monitor only for adult thrips, use the blue sticky cards. Keep a weekly record of the number of thrips per card and graph the totals to detect trends. This information will help with population estimates and in correctly timing pesticide applications.

Treatment: Remove any weeds and plant debris in and around the greenhouse that may harbor thrips. Locate all trash containers away from the growing area. Screen any building openings (vents, walls with cooling pads) to prevent or exclude thrips from entering the greenhouse.

Sprays must thoroughly cover plants, including flowers. Small spray droplets are recommended in order to penetrate flower buds. Mixing a pyrethroid 'irritant' into the spray mix can compel thrips to leave their hiding places for better spray exposure. Rotate all sprays in order to minimize resistance. If releasing beneficial natural enemies, do so prior to damaging pest population levels.

Table 9.12 Insecticides for Thrips Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Abamectin	6	Avermectin	Abamectin E-Pro 0.15 EC	12	Do not apply through any type of irrigation system. Do not use product for suppression of aphids, whiteflies, and thrips on roses, chrysanthemums, and gerbera. Do not use on ferns or shasta daisies.
			Ardent 0.15 EC		
			Avid 0.15 EC		
			Flora-Mek 0.15 EC		
			Lucid 2F		
			Minx		
			Quali-Pro Abamectin 0.15 EC		
			Timectin 0.15EC T&O		
Acephate	1B	Organophosphate	Acephate Pro 75 WSP	24	Ready-to-use insecticide fogger. Apply when foliage is dry and greenhouse is completely closed. Do not apply to chrysanthemums and roses with open blooms. Do not apply to poinsettia in bract.
			Acephate 90 Prill		
			Acephate 97Up		
			Avatar		Do not apply to roses in flower or poinsettia in bract. Caution if treating the following foliage plants: *Bletchum gibbum, Cissus, Ficus, Fittonia, Maranta, Pachystachya, Pteris, Plectranthus, Polypodium, Polystichum,* and *Tolmiea*. Do not treat chrysanthemum in flower (see label for specific cautions).
			Orthene TT&O (Turf, Tree, and Ornamental) WSP		
			Orthene TT&O 97 (Turf, Tree, and Ornamental) WP		
			Precise 4% G		Controlled-release systemic. For use only on 3” to 12” diameter pots. Do not apply to freshly rooted cuttings. Limited plants listed.

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acetamiprid	4A	Neonicotinoid	TriStar 70 WSP	12	Do not irrigate overhead for at least 6 hrs after application.
Azadirachtin	18B	Botanical	Aza-Direct	4	Repellant, IGR, and anti-feedant. Controls larvae and pupae on contact or by ingestion Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Use within 8 hours. Reduce pH of irrigation water if the pH exceeds 7.0.
			Azatin XL (EC)		
			Ecozin Plus 1.2% ME		
			Ferti-Lome Triple Action Plus		
			Ornazin 3% EC (citrus thrips only)	12	
			Neemix 4.5		
			Neemazad® 1.0% EC	4	
			Triact 70		
Beauveria bassiana GHA stain	NC	Microbial	Botanigard ES	4	Contact insecticide; insect-specific fungus. Do not apply through a thermal pulse fogger. Compatible with some fungicides such as Neemazad or Thiodan EC; other fungicides may kill the spores. Do not apply with insecticides such as Metasystox R, Neemazad or Thiodan EC. Do not apply to poinsettia in bract.
			Botanigard 22 WP		
			Mycotrol O (WP)		
			Naturalis L (JW-1 strain) (WP)		
			Naturalis H&G		

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Bifenthrin	3A	Pyrethroid	Attain TR	12	Micro total release insecticide. Apply when foliage is dry.
			Attain Greenhouse (Citrus thrips only)		Microemulsion. Do not apply through any kind of irrigation system.
			LESCO Crosscheck Plus (Citrus thrips only)		May be used with ULV equipment
			Menace GC 7.9% F (Citrus thrips only)		Restricted use. Wait 30 days between greenhouse applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any kind of irrigation system. Do not exceed the maximum label rate
			Talstar Nursery F		Label permits low-volume application Do not apply through any type of irrigation system. The addition of spreader stickers is not necessary. Do not use on edible plants. Can be tank mixed with plant growth regulators. Can be used as a topical drench or bare root dip for certain pests.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through any irrigation system. Do not apply to wet foliage or during periods of high humidity. Do not use on Boston ivy, Virginia creeper, and maidenhair fern.
			Wisdom F		

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Chlorfenapyr	13	Pyrrole	Pylon (S)	12	Not ovicidal. Controls immature mites. Apply prior to bloom or avoid blooms when possible. Do not apply to some varieties of carnations, dianthus, kalanchoe, poinsettia, roses, salvia and zinnia. Do not add oils, surfactants, and fertilizers or other additives to tank. Translaminar activity. May be applied twice consecutively, but no more than three times within a season. Do NOT apply to consecutive crops.
Chlorpyrifos	1B	Organophosphate	DuraGuard ME	24	Restricted use. Do not mix with alkaline materials (e.g. lime). Do not use on croton, kalanchoe, schefflera, zebra plant, copperleaf, papayas, cissus, weeping fig, Cuban laurel, yellow/ red/Chinese hibiscus, ficus, impatiens, Boston fern, or petunia. Some azalea, camellia, poinsettia, rose and variegated ivy varieties have shown phytotoxicity. Direct spray to open blooms may cause petal drop.
Chlorpyrifos + Cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR	24	Restricted use. Micro total release insecticide. Apply when foliage is dry.
Cyfluthrin	3A	Pyrethroid	Decathlon TR (WP)	12	Do not apply through irrigation systems.

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Dinotefuran	4A	Neonicotinoid	Safari 20 SG Safari 2G	12	Systemic. Only apply to moist soil media - not to dry or saturated media. No more than two foliar or broadcast applications and/or one soil application per crop per year.
Fenoxycarb	7B	Fenoxycarbs	Prescription Treatment Preclude TR	12	Micro-release IGR. Apply to dry foliage.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR	24	Do not use in greenhouses <900 ft^2. Do not apply product within 48 hrs of a previous application. Must store cans at room temp. for 24 hrs before application. Apply to dry foliage. Do not apply to poinsettia in bract.
Flonicamid	9C	Flonicamid	Aria (WDG)	12	Spray water should be buffered to pH 5–7. Can be used as a dip for flower and foliage cuttings. Do not use through any type of irrigation system.
Imidacloprid	4A	Neonicotinoid	Areca (EC) Benefit 60WP Imida E-Pro 2F Lada 2F Majesty Mallet 2F Mantra 1G Mantra 2F Marathon 1% G Marathon II (F) Quali-Pro Imidacloprid (1G Nursery & Greenhouse and 2 F Nursery & Greenhouse)	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Insecticidal soap	NC	Potassium salts of fatty acids	Bonide Insecticidal Soap	12	Contact insecticide. Use soft water for best results. Do not use on new transplants, unrooted cuttings, or plant material stressed by drought or under hot, humid, or overcast conditions. Caution if using on euphorbias or if the pH of the final solution is below 8.0. Do not use on bleeding heart, jade, lantana, lily, and sweet pea. Do not apply to poinsettia in bract or to chrysanthemum after bloom.
			Concern		
			M-Pede		As above; only labeled for exposed thrips and blossom thrips on African violets.
Kinoprene	7A	Juvenile hormone analogues	Enstar II (F)	4	IGR. Apply before bract formation in poinsettia. Some varieties of roses show delayed damage.
Lambda-cyhalo-thrin	3A	Pyrethroid	Quali-Pro lambda GC-O	24	Restricted use. A spreader-sticker is recommended. Do not apply through any type of irrigation system.
			Scimitar GC		
Methiocarb	1A	Carbamate	Mesurol 75WP	24	Restricted use. Do not apply with foliar fertilizers or oils. Do not make more than 2 applications per year. Do not apply with foliar fertilizers or oils. Spray solution should have a pH >7. Applications must be at least 10 days apart.

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Nematodes, beneficial or entomopathogenic	NC		Nemasys, others		Use as a preventive or curative control. Apply to moist growing media as soon as possible after potting. Works best between 50 and 85 °F.
Nicotine	4B		Fulex Nicotine Fumigator	WPS vent. reqs met	Restricted use. Do not use on violets. Do not water on the day of application.
Novaluron	15	Benzoylurea	Pedestal	12	IGR; controls immature (not adults). Do not apply more than twice a year. Do not apply to poinsettia.
Oil, Horticultural (paraffinic hydrocarbon oils; petroleum oil, soybean oil, vegetable oil)	NC	Oil	All Seasons Horticultural Spray Oil concentrate (mineral oil)	4	
			Golden Pest Spray Oil (soybean oil)		
			PureSpray Green (petroleum oil)		
			Saf-T-Side (petroleum oil)		
			SuffOil-X (paraffinic oil)		
			Summit Year Round Superior Horticulture Spray Oil (mineral oil)		
			Ultra-fine Spray Oil (paraffinic oil)		
			Ultra-Pure Oil (Petroleum oil)		

Table 9.12 Insecticides for Thrips Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Permethrin	3	Pyrethroid	Astro 3.2 EC Permethrin E-Pro Perm-Up 3.2EC (restricted use)	12	For use on citrus thrips only. Avoid spraying chrysanthemum blooms since not all cultivars have been tested for phytotoxicity. Marginal leaf burn has been noticed on Salvia, *Dieffenbachia*, pteris fern. Application to blooms may cause petal browning.
Pyrethrins and Piperonyl butoxide	3A 27A	Pyrethrin	Pyrenone Crop Spray Prentox Pyronyl Crop Spray Pyreth-It (Prescription Treatment Brand)	12	A botanical insecticide plus a synergist to to flush insects out of hiding and into contact with spray residues. Apply when foliage is dry. Do not use on cyclamen or nasturtium.
Pyridalyl	NC	Pyridalyl	Overture 35WP	12	Strong translaminar activity. Do not apply through any type of irrigation system.
Spinosad	5	Spinosyn	Conserve SC	4	Minimum impact upon beneficials. Maximum of two consecutive applications. See label for crops that can be chemoirrigated. Caution when spraying African violet blooms.

Whitefly Control

Identification and Damage: Whiteflies are small flying insects (0.06 in. or 1-2 mm) that feed on many greenhouse crops, particularly poinsettias and bedding plants. Both the adults and immature stages are found on the underside of the leaves where they suck plant fluids.

Adults of greenhouse whitefly (*Trialeurodes vaporariorum*) have powdery-white wings that are held flat over their bodies. *Bemesia tabaci* whitefly adults are slightly smaller than the greenhouse whitefly adults and yellowish in color. They hold their wings roof-like, at a 45-degree angle close to their body. The adults bandedwinged (*Trialeurodes abutilonea*) have two grayish bands that form a zigzag pattern across each front wing. Eggs are white when first laid and turn dark grey (greenhouse whitefly) or amber brown (*B. tabaci* whitefly) with time. The insect hatches from the egg as a crawler, which is an active, mobile stage and moves about on the plant looking for a feeding site on which to settle. The crawler and other nymphal stages of the most common species are oval, greatly flattened, and somewhat translucent with a white, light-green or light-yellow cast.

On floricultural crops, even a few whiteflies can reduce the retail value for several reasons. Flying adults can result in consumer complaints. High populations of whiteflies can weaken plants, causing chlorotic foliage and reduced vigor. Whiteflies are phloem feeders and can weaken plants by directly consuming carbohydrates and other nutrients carried within a plant's vascular system. Heavy populations can cause defoliation.

Whiteflies also produce "honeydew" excretions, which cause leaves to become sticky and shiny, as well as the resulting sooty mold fungus. Furthermore, *Bemesia tabaci* (B strain or Q strain) can cause tomato fruit to become mottled (uneven ripening), the leaves of squash to turn silver green, and hibiscus foliage to have yellow speckles. In severe infestations, the insect can cause stems and bracts of red poinsettia cultivars to turn whitish yellow. *B. tabaci* whiteflies are found to be capable of transmitting plant viruses.

Monitoring: Sampling for whiteflies is critical to establishing whether a treatment threshold has been reached and to determining whether a treatment is effective. Use a combination of yellow sticky traps and foliage inspection. Monitor the location and relative numbers of adults with yellow sticky traps; nymphs must be monitored by frequent foliage inspection. Observing adult activity on foliage to become aware of egg laying and potential population build-up on "hotspot" plants in a greenhouse. The older life stages are often found on older foliage; eggs and younger life stages are usually found on younger leaves.

Sticky cards are best used at 1 to 2 cards per 1,000 square feet of growing area; check the cards weekly at a minimum. The threshold of adults found on a card per day and numbers of nymphs per leaf often changes according to the maturity of the crop. Early in a crop cycle a grower may tolerate 0.5 whitefly per day on cards. At the time near the sale of the crop the grower may have an increased tolerance of adults, allowing 2 whiteflies per card per day.

Treatment: Proper species identification is important in order to choose the most effective management option. Insecticides are applied as either foliar sprays (targeting nymphs and adults), systemic drenches (targeting nymphs), or smoke fumigation (targeting adults).

Rotate all sprays in order to minimize resistance. If releasing beneficial natural enemies, do so prior to damaging pest population levels.

Table 9.13 Insecticides for Whitefly Control

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Abamectin	6	Avermectin	Abamectin E-Pro 0.15 EC	12	Do not apply through any type of irrigation system. Not for the suppression of aphids, whiteflies, and thrips on roses, chrysanthemums, and gerbera. Do not use on ferns or shasta daisies. QualiPro is the only abamectin product labeled for eggs. Do not use on adults.
			Ardent 0.15 EC		
			Avid 0.15 EC		
			Flora-Mek 0.15 EC		
			Lucid 2F		
			Minx		
			Quali-Pro Abamectin 0.15 EC		
			Timectin 0.15EC T&O		
Acephate	1B	Organophosphate	Acephate Pro 75 WSP	24	Ready-to-use insecticide fogger. Apply when foliage is dry and greenhouse is completely closed. Do not apply to chrysanthemums and roses with open blooms. Do not apply to poinsettia in bract.
			Acephate 90 Prill		
			Acephate 97Up		
			Avatar		Do not apply to poinsettia in bract or roses in flower. Caution treating the following due to phytotoxicity concerns: *Bletchum gibbum, Cissus, Ficus, Fittonia, Maranta, Pachystachya, Plectranthus, Pteris, Polypodium, Polystichum,* and *Tolmiea*. Do not treat chrysanthemum in flower (see label).
			Orthene TT&O (Turf, tree, and Ornamental) WSP		
			Orthene TT&O 97 WP		
			Precise 4% G		Controlled-release systemic. For use only on 3” to 12” diameter pots. Do not apply to freshly rooted cuttings. Limited plants listed.

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Acetamiprid	4A	Neonicotinoid	TriStar 70 WSP	12	Do not irrigate overhead for at least 6 hrs after application. See label for specifics.
Azadirachtin	18B	Botanical	Azatin XL	4	Repellant, anti-feedant, and insect growth regulator. Controls larvae and pupae on contact or by ingestion Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron or other highly alkaline materials. Use within 8 hours. Reduce pH of irrigation water if it exceeds 7.0. Kills immature and adult insects. Do not apply to wilted or stressed plants or to new transplants prior to root establishment. Caution if applying to flowers of impatiens, fuchsia, hibiscus, or some roses and carnations.
			Aza-Direct		
			Ecozin Plus 1.2% ME		
			Ferti-Lome Triple Action Plus		
			Ornazin 3% EC	12	
			Neemix 4.5		
			Neemazad 1.0% EC	4	
			Triact 70 (only neem product labeled for adults)		
Beauveria bassiana GHA stain	NC	Microbial	Botanigard ES	4	Contact insecticide; insect-specific fungus. Do not apply through a thermal pulse fogger. Compatible with some fungicides such as Neemazad or Thiodan EC; other fungicides may kill the spores. Do not apply with insecticides such as Metasystox R, Neemazad or Thiodan EC. Do not apply to poinsettia in bract.
			Botanigard 22 WP		
			Mycotrol O (WP)		
			Naturalis L		
			(JW-1 strain)		
			Naturalis H&G		

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Bifenthrin	3A	Pyrethroid	Attain TR	12	Micro total release insecticide. Apply when foliage is dry.
			Attain Greenhouse		Microemulsion. Do not apply through any kind of irrigation system.
			LESCO Crosscheck Plus		May be used with ULV equipment.
			Menace GC 7.9% F		Restricted use. Wait 30 days between greenhouse applications.
			QualiPro Bifenthrin Golf & Nursery 7.9		Restricted use. Do not apply through any kind of irrigation system or exceed the maximum label rate.
			Talstar Nursery F		Label permits low-volume application Do not apply through any irrigation systems. Spreader sticker is not necessary. Can tank mix with plant growth regulators.
			Talstar P (Professional) (F)		
			Talstar Select (FC)		
			Up-Star SC		Restricted use. Do not apply through any irrigation system. Do not apply to wet foliage or during periods of high humidity. Do not use on Boston ivy, Virginia creeper, and maidenhair fern.
			Wisdom F		
Buprofezin	16	Buprofezin	Courier 40 SC	12	IGR; suppresses adult egg-laying and reduces egg viability. Not disruptive to beneficial insects and mites. Make no more than two applications per season. Do not apply through any type of irrigation system.
			Talus 40SC		

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Chlorpyrifos + Cyfluthrin	1B 3A	Organophosphate Pyrethroid	Duraplex TR	24	Restricted use. Micro total release insecticide. Apply when foliage is dry.
Cyfluthrin	3A	Pyrethroid	Decathlon	12	Do not apply through any type of irrigation system.
Dichlorvos	1B	Organophosphate	DDVP	Meet WPS Ventilation require-ments	Total release fumigant smoke. Do not apply when foliage or blossoms are wet as injury may result.
Diflubenzuron	15	Benzoylurea	Adept (WSP) Dimilin SC (F)	12	Labeled for control of immature nymphs only. Little to no effect on beneficial insects. Insect growth regulator. Do not reuse potting media. Do not apply to poinsettia, hibiscus, or Reiger begonia. Do not apply to pots grown on capillary water mats.
Dinotefuran	4A	Neonicotinoid	Safari 20 SG Safari 2G	12	Systemic; only apply to moist soil media. Do not apply to dry or saturated media. No more than two foliar or broadcast applications and/or one soil application should be made per crop per year.
Endosulfan	2A	Cyclodiene organochlorine	Thiodan 50WP	24	Do not use >6 lbs per year. Do not use through irrigation systems. Do not use on 'Bernafon Deluxe', 'Fred Shoesmith' or 'White Knight' chrysanthemums; On chrysanthemums, apply before plants flower.

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Fenoxycarb	7B	Fenoxycarb	Preclude (Micro Total Release)	12	Micro-release insect growth regulator. Apply when foliage is dry.
Fenpropathrin	3A	Pyrethroid	Tame 2.4 EC	24	Restricted use. Apply when foliage is dry. Do not apply to chrysanthemums and roses with open flowers, or to poinsettia in bract. Do not exceed 0.37 fl. oz. per 1000 ft^2 per application.
Fenpropathrin + Acephate	3A 1B	Pyrethroid Organophosphate	Tame/Orthene TR (Prescription Treatment Brand)	24	Do not use in greenhouses <900 ft^2. Do not apply product within 48 hrs of a previous application. Cans must be stored at room temperature for 24 hrs before application. Apply when foliage is dry. Do not apply to poinsettia in bract.
Flonicamid	9C	Flonicamid	Aria (WSP)	12	Spray water should be buffered to pH 5–7. Can be used as a dip for flower and foliage cuttings. Do not use through any type of irrigation system.
Fluvalinate	3A	Pyrethroid	Mavrik Aquaflow (F)	4	Spray water should be buffered to pH 5–7. Can also be used as a dip for flower and foliage cuttings. Caution on roses and poinsettias.

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Imidacloprid	4A	Neonicotinoid	Areca (EC)	12	Systemic. Protection period is shorter if media has >30–50% bark content. Do not use in a tank mix with products that contain boron or release free chlorine. Do not apply to ferns, crassula, petunias, and lantana.
			Benefit 60WP		
			Imida E-Pro 2F		
			Lada 2F		
			Majesty		
			Mallet 2F		
			Mantra 1G		
			Mantra 2F		
			Marathon 1% G		
			Marathon II (F)		
			Quali-Pro Imidacloprid 1G Nursery & Greenhouse		
			Quali-Pro Imidichloprid 2F Nursery & Greenhouse Insecticide		
Insecticidal soap	NC	Potassium salts of fatty acids	Bonide Insecticidal Soap	12	Contact insecticide; complete coverage is essential. Do not use on new transplants, unrooted cuttings or plant material stressed by drought or under hot, humid, dry or overcast conditions. Caution if pH of final solution is <8.0 or if using on euphorbias. Do not apply to jade, bleeding heart, lantana, lily, sweet pea, poinsettia in bract or to chrysanthemum after bloom.
			Concern Insect Killing Soap		
			DES-X		
			M-Pede		
			Natural Guard Insecticidal Soap		
Kinoprene	7A	Juvenile hormone analogues	Enstar II (F)	4	IGR. Apply before bract formation in poinsettia. Some varieties of roses show delayed damage.

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Lambda-cyhalothrin	3A	Pyrethroid	Scimitar GC	24	Restricted use. A spreader-sticker is recommended. Do not apply through any type of irrigation system.
			Quali-Pro lambda GC-O		
Naled	1B	Organophosphate	Dibrom 8E	WPS Ventilation Req's met	For adult whitefly only. May be applied to steam pipes or in open pans on hot plates, but can be corrosive. May injure certain rose and chrysanthemum varieties, wandering Jew, poinsettia, and Dutchman's Pipe. Do not apply when air temperature is above 90 °F due to phytotoxicity issues.
Novaluron	15	Benzoylurea	Pedestal	12	IGR; controls immature (not adults). Do not apply more than twice a year or to poinsettias.
Oil (horticultural: Parrafinic, petroleum, soybean)	NC	Oil	All Seasons Horticultural Spray Oil concentrate, Summit Year Round Superior Horticulture Spray Oil (mineral oils)	4	Liquid/oil. Desiccation of membrane disrupters. Thorough application is necessary for control. Effectiveness at temperatures below 50 °F is reduced due to reduced respiration of organisms. Do not apply in excessively hot or in humid conditions. Use once a week until insect population is controlled, then reduce applications to every 2–3 weeks. Can tank mix with other pesticides.
			Golden Pest Spray Oil (soybean oil)		
			Organic JMS Stylet Oil (paraffinic/ mineral oil)		
			PureSpray Green, Saf-T-Side, Ultra-Pure Oil (petroleum oils)		
			SuffOil-X, Ultrafine Spray Oil (paraffinic oils)		

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Paecilomyces fumosoroseus	NC	Microbial	PFR-97 20% WDG	4	Do not tank mix with fungicides. High level of control in greenhouses where humidity levels are relatively high. Apply in late morning or early evening (cloudy, overcast days are optimal).
Permethrin	3A	Pyrethroid	Astro 3.2 EC Permethrin E-Pro Perm-Up 3.2EC (restricted use)	12	Treating blooms may cause petal browning. Avoid spraying chrysanthemum blooms; not all cultivars have been tested for phytotoxicity. Marginal leaf burn has been noted on salvia, *Dieffenbachia*, pteris fern.
Pymetrozine	9B	Pyridine	Endeavor (WDG)	12	Insects remain on plant for 2–4 days after application. Label restrictions on application amounts. Do not apply to poinsettia in bract. Selective feeding blocker. Available in 2.5 oz. packets. Do not apply more than 100 oz. per year.
Pyrethrins + Piperonyl butoxide	3A 27A	Pyrethrin Synergist	Pyrenone Crop Spray Prentox Pyronyl Crop Spray Pyreth-It (Prescription Treatment Brand)	12	A botanical insecticide plus a synergist to to flush insects out of hiding and into contact with spray residues. Apply when foliage is dry. Do not use on cyclamen or nasturtium.

Table 9.13 Insecticides for Whitefly Control (continued)

Chemical Name	IRAC Code	Class	Trade Name (Formulation)	Re-entry Interval (hours)	Comments
Pyridaben	21A	METI-acaricides	Sanmite WP	12	May be fatal if inhaled. Do not use in successive miticide applications. Do not use fertilizers containing boron. Do not apply this product through any type of irrigation system.
Pyriproxyfen	7C	Pyriproxyfen	Distance (F)	12	IGR. Apply no more than two times per cropping cycle or no more than two times per six months. Do not apply to Boston fern, coral bells, gardenia, ghost plant, salvia, or schefflera. Do not apply to poinsettia in bract.
Spiromesifen	23	Tetronic acid derivative	Judo (F)	12	Provides knockdown and residual control of all lifestages, including eggs and pupae. Thorough coverage recommended. Do not apply this product through any type of irrigation system. See label for restrictions on use on specific plants or cultivars.
Thiamethoxam	4A	Neonicotinoid	Flagship 0.22G Flagship 25WG	12	Foliar and soil applications. Soil applications take at least one week to translocate to foliage for control.

Part 3
Disease, Algae, Weed and Cultural Management

Chapter 10
Managing Plant Diseases

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Introduction

An IPM program helps to prevent and manage plant diseases using, environmental, cultural and chemical practices. Ideally, the crop should be monitored regularly for disease symptoms while keeping in mind the three primary factors for disease development: a susceptible host plant, a pathogen present, and favorable environmental conditions. Reducing one or more of these factors will reduce the level of disease. Greenhouse sanitation is extremely important, as is reducing condensation and keeping foliage dry. Eliminating weeds and managing insect pests in the greenhouse also helps to reduce disease problems. Relying on fungicide applications alone without first implementing these cultural practices to reduce disease pressure will result in disease management failures. Refer to other sections of this manual for detailed information on these topics.

Diagnosis

Before treating any disease, it is important to make an accurate diagnosis of the cause of the symptoms. It is very important to identify the pathogen, its host range, and the optimum conditions for disease development. Often the reason that diseases are not controlled well with chemical applications is because the problem was misidentified and therefore treated with an ineffective product applied at the improper time. Most plant diseases are caused by fungi, but bacteria and viruses can also cause significant losses in greenhouse crops. Noninfectious disorders, such as nutritional deficiencies and environmental damage, can mimic the symptoms of infectious diseases. It may be necessary to submit plants to a diagnostic laboratory for specialized tests to confirm the presence of plant pathogenic microorganisms (see Appendix A).

General Guidelines For Fungicides

When used in conjunction with greenhouse sanitation and optimum nutrition and environmental conditions for plant health, fungicides can be an excellent tool to help manage certain plant diseases. Applications for control of root diseases are generally used preventively. For most foliage diseases, fungicides are applied when symptoms are first observed, but for highly susceptible crops, or when conditions are known to be favorable for disease, fungicides may be used preventively. Make sure spray coverage is thorough; for soil drench applications, additional irrigation water may be necessary to move the product deeply into the medium. Always follow label directions regarding rates, crops and application method allowed.

Fungicide Resistance Management

Fungicides are grouped by their mode of action or chemical structure, and the groups are given a code number (called a FRAC code) by the Fungicide Resistance Action Committee. Products having the same FRAC code will attack plant pathogens in a similar manner, even if they have different generic chemical names. In addition, fungicides are classified as systemic (the active ingredient is absorbed into plant tissues) or protectant (the active ingredient does not penetrate plant tissues, but provides a barrier on the plant surface that prevents fungal infection). A third classification system focuses on the specific biochemical processes , or target sites, that a product disrupts in the biology of the fungus. Site-specific fungicides attack one specific biochemical process in fungus physiology, while multi-site fungicides affect a number of different biochemical processes at the same time. Protectant fungicides generally have multiple modes of

action (multi-site), and are designated with an "M" in the FRAC code. Most systemic fungicides have a site-specific mode of action.

True fungicide resistance occurs when a genetic mutation occurs in a fungus that allows the biochemical process targeted by the fungicide to continue, making the fungus insensitive to the effects of the fungicide. Fungal pathogens are more likely to develop resistance to products with single target sites because this involves a single genetic mutation. If the same single-site fungicide is used repeatedly and exclusively, over time only the portion of the population with the mutation will survive and multiply, rendering the fungicide ineffective. Site-specific fungicide groups known to have a high risk of resistance development include benzimidasoles (FRAC 1), phenylamides (4), and strobilurins (11). Resistance is much less likely to develop with multi-site products, because a number of simultaneous mutations would be necessary to overcome multiple modes of action. Groups with low risk of resistance development include aromatic hydrocarbons (14), inorganics (M1), dithiocarbamates (M3), and chloronitriles (M5).

Several tactics are necessary to avoid fungicide resistance. First, use good cultural practices to improve plant health and reduce diseases, thereby reducing the need for fungicide applications. Apply fungicides only when necessary, and always follow label instructions regarding rates and application intervals. Products with high potential for resistance development in the fungal population will provide specific instructions to minimize resistance risk. Use a diversity of products with different modes of action in rotation to provide broad-spectrum disease control. Products with the same FRAC code will have the same general mode of action, so rotate with products with different codes. Plant pathogens are less likely to develop resistance to commercially available combination products, which include two fungicides from different FRAC groups. Tank mixes of products with different modes of action are also effective in reducing fungicide resistance, but always check product labels for guidelines on compatible tank-mix options.

Biological Control of Plant Diseases

In recent years, scientists have discovered naturally-occurring microorganisms that are able to out-compete plant pathogenic microorganisms, resulting in less plant disease. Some of these biological control agents have been developed into commercial products called biofungicides, and they are becoming common weapons in the greenhouse grower's arsenal for plant disease defense.

Biological control microorganisms can reduce plant disease by one or more of four basic methods. Some beneficial fungi or bacteria can "outgrow" plant pathogenic microorganisms, and successfully compete for the nutrients and space available on plant surfaces. Some biocontrol agents produce toxins or antibiotics that inhibit or kill the pathogenic organisms. A third method is parasitism, where the biocontrol agent directly attacks the pathogenic microorganism, using it as a food source. The fourth method is called "induced resistance". In this case, the biocontrol agent induces specific biochemical changes in the plant without causing any visible symptoms. These changes make the plant more resistant to infection from plant pathogens, while not directly affecting the pathogen itself. Often, a single biocontrol agent will utilize more than one of these mechanisms for disease control.

There are benefits to using biological control microorganisms in a disease management program. In general, these products are safer for workers to use, have shorter re-entry intervals than traditional fungicides and are less phytotoxic. Plant pathogens are less likely to develop resistance to biofungicides, because of varied mechanisms these microorganisms use to control plant pathogens. They can reduce the amount of traditional chemical fungicides needed to finish a crop, thus saving money, and they are among the few disease control options available to organic growers.

Biofungicides must be used with standard cultural control practices to be successful. Biocontrol microorganisms are protectants, and are not effective in eradicating a pathogen or in "curing" infected

plants. To be effective, biological control agents must be applied before infection takes place. Some of the commercially available biofungicides have a narrower range of target plant pathogens than traditional fungicides, and they may be more expensive. There may also be compatibility problems between biofungcides and some traditional fungicides, and biofungicides require specific storage conditions to remain active. Nevertheless, biofungicides can be used efficiently and effectively when keeping these factors in mind.

Biofungicides labelled for use in greenhouse ornamentals include:

Rootshield and PlantShield: These products are formulations of *Trichoderma harzianum* strain T-22, which is labelled for control of soil-borne pathogens such as *Pythium, Fusarium, Rhizoctonia* and *Sclerotinia* as well as several foliar pathogens.

SoilGard 12G: This is a granular formulation of the soil fungus *Gliocladium virens* strain GL-21. It is labelled for control of damping-off and root rot due to *Pythium, Fusarium* and *Rhizoctonia*.

Mycostop: The active ingredient of this product is the soil fungus *Streptomyces griseoviridis* strain K-16. It is labelled for control of *Fusarium* diseases, among others.

Cease: This formulation of *Bacillus subtilis* strain QST 713, is labelled for several fungal and bacterial diseases of ornamentals.

Actinovate: This product, containing *Streptomyces lydicus* WYEC108, is labeled for control of *Rhizoctonia, Pythium* and *Fusarium* root rots, as well as for suppression of some foliar diseases.

DISCLAIMER

The following tables serve as guidelines only. The fungicides listed are recommended only if they are registered with the Environmental Protection Agency and your state department of agriculture. If a registration is changed or cancelled, any products listed here are no longer recommended. Before you apply any pesticide, fungicide or herbicide, check with your Extension agent for the latest information. The USER is responsible for using products that are registered for use on specific crops in their own state, and for using products according to label instructions.

If any information presented here is inconsistent with the product label, follow the label instructions. Always consult the product label for rates and crops listed. Presence of a product in these tables is not an endorsement, and absence of a labeled product from this list does not imply ineffectiveness.

Bacterial Diseases

Bacteria are tiny, single-celled microorganisms that can multiply at a very rapid rate. Bacterial pathogens require films of water to enter plant tissues, and can be spread through splashing water or handling. Symptoms of bacterial diseases on ornamentals include leaf spots, stem rot, vascular wilt and galls.

Leaf spots caused by bacteria are initially watersoaked or greasy in appearance, then turn dry and dark to light brown. In some cases, yellow "haloes" develop near the edges of the brown lesions. Cool, wet conditions favor leaf spots caused by *Pseudomonas* species. Bacterial leaf spot diseases are becoming more common, particularly in plug production where mist irrigation is often used. Bacterial soft rot of stems is usually associated with wounds caused by handling or insect feeding. Fungus gnat larvae can spread soft rot bacteria. Bacterial soft rot is a common problem with poinsettia cuttings, often causing significant losses. Bacterial leaf spot diseases are common on zinnia and chrysanthemum. Bacterial blight (caused by *Xanthomonas pelargonii*) is a serious disease of zonal and ivy geranium (*Pelargonium* x *hortorum*, *P. peltatum*) that causes leaf spots, blight, vascular wilt and plant death.

Management Strategies:

Promote leaf drying by managing irrigation and air circulation. Destroy infected plants, being careful to avoid contact with other plants. Remove all plant debris, and keep tools and benches free of unsterilized soil which may harbor soft rot bacteria. The products listed in the following table may help reduce the spread of bacterial leaf spot diseases, but they must be used along with a strict sanitation program for effective control.

Table 10.1 Products for Managing Bacterial Leaf Spot Diseases

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Bacillus subtilis QST 713 strain	NC	Biopesticide	Cease Rhapsody	0	Apply when environment favors disease development.
Copper salts of fatty/rosin acids	M1	Inorganic	Camelot	12	Do not apply to plants just before/during flowering. Possible phytotoxicity when applied in a spray solution with pH < 6.5.
Copper hydroxide	M1	Inorganic	Champ	24	Possible phytotoxicity when applied in a spray solution with pH < 6.0. Do not apply to hibiscus plants in flower. Do not apply to plants just before selling season.
			CuPro 2005 T/N/O		Possible phytotoxicity when applied in a spray solution with pH < 6.5. See label for specific crop restrictions.
			Nu-Cop 50DF		
Copper hydroxide + mancozeb	M1 M3	Inorganic Dithiocarbamate	Junction	24	Possible phytotoxicity when applied in a spray solution with pH < 6.5. May injure flowers of certain chrysanthemum varieties.
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For plants not listed on label, test a small group and observe for 5-7 days for phytotoxicity.

Botrytis Blight

Botrytis blight is an ever-present threat to ornamental plants in the greenhouse. The fungus causes a range of symptoms, including spots and blights on leaves or petals, stem cankers, crown rot, wilting and damping-off. *Botrytis* infections may also cause discoloration and death of flower buds and premature loss of flowers. The fungus is spread primarily by the movement of spores in air currents and in splashing water. The fungus commonly invades wounded or senescent tissue, such as fallen flower petals or other fresh plant residues. It can also invade healthy tissue in contact with infected residues. Masses of fuzzy, grayish-brown spores on thin black stalks develop on infected plant tissues under cool, moist, humid, and cloudy conditions. The presence of these spores is diagnostic for confirming *Botrytis* infections.

Management Strategies:

Sanitation is critical to *Botrytis* blight management. Even a small piece of infected debris can generate huge numbers of spores when environmental conditions are favorable to development, and these spores are easily dispersed in air currents during normal greenhouse operations such as watering or spacing plants. Rogue out infected plants and clean up any plant debris on the benches or greenhouse floors. Use plastic bags to collect this material and carry it out of the greenhouse for disposal. If trash containers are used, make sure they have tight-fitting lids, and empty the containers frequently.

Botrytis spores require free moisture on plant surfaces to germinate and cause infection. Reduce leaf wetness periods, films of moisture and relative humidity in the greenhouse to make conditions unfavorable for *Botrytis* blight development. Heating and venting the greenhouse for a short time before sunset will help to reduce humidity and condensation (dew formation) on plant surfaces that commonly occurs at nightfall when warm humid air cools down. Use horizontal air flow systems or fans to circulate the air, which will help reduce humidity as well. If overhead irrigation is used, make sure watering occurs early enough in the day to allow plant surfaces to dry off before evening. Proper plant spacing will reduce the humidity within the plant canopy by allowing increased air circulation around the plants.

The fungicides listed are effective in managing *Botrytis* blight, but they must be used in conjunction with cultural practices to obtain maximum disease control. Resistance management is an important consideration when choosing a fungicide for *Botrytis* control. Resistance to the benzimidazole fungicides is common in *Botrytis* populations, so these compounds are often ineffective in managing the disease. To minimize the chances of fungicide resistance, it is important to rotate applications of products from different fungicide groups.

Table 10.2 Fungicides for Managing Botrytis Blight

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not apply more than 2 times in sequence, and alternate with a non-strobilurin product to avoid resistance development. Do not apply to leatherleaf fern.
Bacillus subtilis QST 713 strain	NC	Biopesticide	Cease	0	Apply when environmental conditions favor disease development.
			Rhapsody		
Chlorothalonil	M5	Chloronitrile	Daconil Ultrex	12	Do not combine with horticultural oil. See label for other tank mix restrictions. Applications during bloom may damage flowers. For plants not specified on label, apply to a small group to ensure plant safety.
			Daconil Weather Stik 54F		
			Echo 720 T+O		
			Echo Ultimate		
			Echo Zn T+O		
			Pegasus L		
			PrimeraOne Chloro-thalonil 720 SFT		
			Quali-Pro Chloro-thalonil 720 SFT		
			Quali-Pro Chloro-thalonil 500 Zn		
			Quali-Pro Chloro-thalonil DF		
			Exotherm Termil		Use only when plants are dry and when temperature is below 75 °F. Do not apply to blooms if flower injury is unacceptable.
Chlorothalonil + Thiophanate methyl	M5 1	Chloronitrile Benzimidazole	Spectro 90 WDG	12	Do not mix with copper compounds. See label for additional tank mix restrictions. Do not use on Swedish ivy, Boston fern or Easter cactus.

Table 10.2 Fungicides for Managing Botrytis Blight (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Copper hydroxide	M1	Inorganic	Champ	24	Possible phytotoxicity when applied in a spray solution with pH < 6.0. Do not apply to hibiscus plants in flower. Do not apply to plants just before selling season.
			CuPro 2005 T/N/O		Possible phytotoxicity when applied in a spray solution with pH < 6.5. See label for specific crop restrictions.
			Nu-Cop 50 DF		
Copper hydroxide + mancozeb	M1 M3	Inorganic Dithiocarbamate	Junction	24	Possible phytotoxicity when applied in a spray solution with pH < 6.5.
Copper salts of fatty/ rosin acids	M1	Inorganic	Camelot	12	Do not apply to plants just before/during flowering. Possible phytotoxicity when applied in a spray solution with pH < 6.5.
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For plants not listed on label, test a small group and observe for 5-7 days for phytotoxicity.
Dicloran	14	Aromatic hydrocarbon	Botran 75 W	12	Labeled for use on rose, geranium and chrysanthemum. May cause plant injury when combined with miscible oil formulations of insecticides.
Fenhexamid	17	Hydroxyanilide	Decree	4	
Fludioxonil	12	Phenylpyrrole	Medallion	12	May cause stunting and/ or chlorosis in impatiens, New Guinea impatiens and geranium. Do not use on leatherleaf fern.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.

Table 10.2 Fungicides for Managing Botrytis Blight (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Iprodione	2	Dicarboxamide	Iprodione Pro OHP Chipco 26 GT-O OHP Chipco 26019 N/G Sextant	12	For plants not specified on label, test on a small number of plants to evaluate for phytotoxicity before large-scale use. Do not use as a soil drench on impatiens or pothos. Do not use on spathiphyllum.
Iprodione + Thiophanate methyl	2 1	Dicarboximide Benzimidazole	26/36 Fungicide	12	Do not use as a soil drench on impatiens or pothos. Do not use on spathiphyllum.
Mancozeb	M3	Dithiocarbamate	Dithane 75 DF Rainshield T+O Fore 80 WP Rainshield T+O Pentathlon DF Protect DF	24	Addition of spreader sticker may improve performance. For plants not specified on label, trial applications are recommended.
Polyoxin D Zinc Salt	19	Polyoxin	Affirm WDG Veranda O	4	For resistance management, alternate with products having different mode of action. Do not apply through any type of irrigation system.
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.

Table 10.2 Fungicides for Managing Botrytis Blight (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Thiophanate methyl + Mancozeb	1 M3	Dithiocarbamate Benzimidazole	Zyban	12	Do not use on French marigold or gloxinia.
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	For resistance management, after each application make 2 applications of a non-strobilurin fungicide. Do not apply to pansy or leatherleaf fern.

Downy Mildew

Symptoms of downy mildew include blotchy yellow or brown lesions on leaves, a general yellowing, leaf distortion and stunting. These symptoms can be mistaken for other infectious or noninfectious problems. Check the undersides of symptomatic leaves to look for the gray, brown or white fungal growth typical of downy mildew infections. Common hosts for downy mildew include snapdragon, rose, coleus, sunflower, impatiens, and basil.

Management Strategies:

Early detection is key for minimizing spread of downy mildew. Remove infected plants promptly, and use protectant fungicides on the rest of the crop.

Table 10.3 Fungicides for Managing Downy Mildew

Refer to disclaimer statement on page 137.

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not treat leatherleaf fern. To avoid resistance development, do not make more than 3 applications before rotating with a non-strobilurin fungicide.
Copper hydroxide	M1	Inorganic	Champ	24	Possible phytotoxicity when applied in a spray solution with pH < 6.0. Do not apply to hibiscus plants in flower. Do not apply to plants just before selling season.
			CuPro 2005 T/N/O		Possible phytotoxicity when applied in a spray solution with pH < 6.5. See label for specific crop restrictions.
			Nu-Cop 3L		
Copper hydroxide + Mancozeb	M1 M3	Inorganic Dithiocarbamate	Junction	24	Possible phytotoxicity when applied in a spray solution with pH < 6.5.
Copper salts of fatty/ rosin acids	M1	Inorganic	Camelot	12	Possible phytotoxicity if spray solution pH is < 6.5. Do not apply to plants in bud or flower.
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For plants not listed on label, test a small group and observe for 5-7 days for phytotoxicity.

Table 10.3 Fungicides for Managing Downy Mildew (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Fixed copper tannate	M1	Inorganic	Nu-Cop HB	24	Possible phytotoxicity when applied in a spray solution with pH < 6.5.
Cyazofamid	21	Cyanoimidazole	Segway 34.5 EC	12	See label for resistance management guidelines. Do not make more than 4 applications per crop cycle.
Dimethomorph	40	Cinnamic acid	Stature DM 50%	12	Make no more than 2 consecutive applications. See label for additional resistance management guidelines.
Fenamidone	11	Imidazolinone	Fenstop	12	For foliar spray, do not make more than 2 applications of maximum rate per crop per season.
Fludioxonil + Mefenoxam	12 4	Phenylpyrrole Phenylamide	Hurricane	48	Applications to impatiens, New Guinea impatiens, pothos, geranium and Easter lily may cause stunting and/or chlorosis.
Fluopicolide	43	Acylpicolide	Adorn	12	Only one application per poinsettia crop.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.
Fosetyl-Al	33	Phosphonate	Aliette 80 WDG	12	May not be compatible with foliar fertilizers or copper products. Do not apply within 7 days of copper product application to avoid possible phytotoxicity.
Kresoxim methyl	11	Strobilurin (QoI)	Cygnus	12	To avoid resistance development, make no more than 2 applications before rotating with a non-strobilurin fungicide.

Table 10.3 Fungicides for Managing Downy Mildew (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Mancozeb	M3	Dithiocarbamate	Dithane 75 DF Rainshield T+O Fore 80 WP Rainshield T+O Lesco Mancozeb DG Pentathlon DF Pentathlon LF Protect DF	24	Addition of spreader sticker may improve performance. For plants not specified on label, trial applications are recommended.
Phosphorous acid-potassium salts	33	Phosphonate	KPhite Alude 45.8%	4	Mixing with some foliar fertilizers and copper products may cause phytotoxicity. Test for crop safety before use.
Polyoxin D Zinc Salt	19	Polyoxin	Affirm WDG Veranda O	4	For resistance management, alternate with products having different mode of action. Do not apply through any type of irrigation system.
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Thiophanate methyl + Mancozeb	1 M3	Benzimidazole Dithiocarbamate	Zyban	12	Do not use on French marigold or gloxinia.

Table 10.3 Fungicides for Managing Downy Mildew (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	For resistance management, make no more than 2 consecutive applications before making 2 applications of a non-strobilurin fungicide. Do not apply to pansy or leatherleaf fern.

Fungal Leaf Spots

Some plants, such as dusty miller, ageratum, pansy and marigold, are occasionally affected by fungal leaf spot diseases. Symptoms range from tiny discolored specks to larger blotches. The lesions may have red or purple margins depending on the host plant and pathogen involved. Most of these diseases affect only one or a few plant species. Fungal leaf spot pathogens survive on infected plant debris, and are spread by spores carried in air currents or splashing water. Prolonged leaf wetness usually favors fungal leaf spot disease development.

Management Strategies:

Inspect plants on a regular basis for fungal leaf spot symptoms. Discard symptomatic plants. Reduce humidity in the greenhouse. Use protectant fungicide sprays if disease continues to spread. Specific fungicides may not control all leaf spot fungi – check the label carefully for list of fungal pathogens.

Table 10.4 Fungicides for Managing Fungal Leaf Spots

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not treat leatherleaf fern. To avoid resistance development, do not make more than 3 applications before rotating with a non-strobilurin fungicide.
Bacillus subtilis QST 713 strain	NC	Biopesticide	Cease	0	Apply when environmental conditions favor disease development.
			Rhapsody		
Chlorothalonil	M5	Chloronitrile	Daconil 2787	48	May damage flowers.
			Daconil Ultrex	12	Do not combine with horticultural oil. See label for other tank mix restrictions. Applications during bloom may damage flowers. For plants not specified on label, apply to a small group to ensure plant safety.
			Daconil Weather Stik 54F		
			Echo 720 T+O		
			Echo Ultimate		
			Echo Zn T+O		
			Pegasus L		
			Quali-Pro Chlorothalonil 500 Zn		
			Quali-Pro Chlorothalonil 720 SFT		
			Quali-Pro Chlorothalonil DF		

Table 10.4 Fungicides for Managing Fungal Leaf Spots (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Chlorothalonil + Thiophanate methyl	M5 1	Chloronitrile Benzimidazole	Spectro 90 WDG	12	Do not mix with copper compounds. See label for additional tank mix restrictions. Do not use on Swedish ivy, Boston fern or Easter cactus.
Copper hydroxide	M1	Inorganic	Champ	24	Possible phytotoxicity when applied in a spray solution with pH < 6.0. Do not apply to hibiscus plants in flower. Do not apply to plants just before selling season.
			CuPro 2005 T/N/O		Possible phytotoxicity when applied in a spray solution with pH < 6.5. See label for specific crop restrictions.
			NuCop 50DF		
Copper hydroxide + Mancozeb	M1 M3	Inorganic Dithiocarbamate	Junction	24	Possible phytotoxicity when applied in a spray solution w/ pH < 6.5.
Copper salts of fatty/ rosin acids	M1	Inorganic	Camelot	12	Do not apply to plants just before/during flowering. Possible phytotoxicity when applied in a spray solution with pH < 6.5.
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For plants not listed on label, test a small group and observe for 5-7 days for phytotoxicity.
Fludioxonil	12	Phenylpyrrole	Medallion	12	May cause stunting and/ or chlorosis in impatiens, New Guinea impatiens and geranium. Do not use on leatherleaf fern.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.

Table 10.4 Fungicides for Managing Fungal Leaf Spots (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Iprodione	2	Dicarboxamide	Iprodione Pro OHP Chipco 26 GT-O OHP Chipco 26019 N/G Sextant	12	Effective for Alternaria. For plants not specified on label, test on a small number of plants to evaluate for phytotoxicity before large-scale use. Do not use as a soil drench on impatiens or pothos. Do not use on spathiphyllum.
Iprodione + Thiophanate methyl	1 2	Benzimidazole Dicarboximide	26/36 Fungicide	12	Do not use on Spathiphyllum. Do not use as soil drench on impatiens or pothos. For plants not listed on label, test on a small number for phytotoxicity before large scale use.
Kresoxim methyl	11	Strobilurin (QoI)	Cygnus	12	To avoid resistance development, make no more than 2 applications before rotating with a non-strobilurin fungicide.
Mancozeb	M3	Dithiocarbamate	Dithane 75 DF Rainshield T+O Fore 80 WP Rainshield T+O Pentathlon DF Pentathlon LF Protect DF	24	Addition of spreader sticker may improve performance. For plants not specified on label, trial applications are recommended.
Myclobutanil	3	Dimethylation inhibitor	Eagle 20 EW Hoist	24	Test on plants not listed on label before large scale use. See label for cautions regarding use of plant growth regulators.
Polyoxin D Zinc Salt	19	Polyoxin	Affirm WDG Veranda O	4	For resistance management, alternate with products having different mode of action. Do not apply through any type of irrigation system.

Table 10.4 Fungicides for Managing Fungal Leaf Spots (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Thiophanate methyl	1	Benzimidazole	Allban Flo 46.2% F Cleary's 3336 50% WP Fungo Flo 50 OHP-6672 50W Quali-Pro TM 4.5 F Quali-Pro TM 85 WDG T-Bird 85 T-Storm 50 WSB	12	Do not tank mix with copper compounds. For plants not specifically listed on label, trial applications are recommended. For resistance management, rotate with products having different mode of action. Do not apply to Swedish ivy, Boston fern, or Easter cactus.
Thiophanate methyl + Mancozeb	1 M3	Benzimidazole Dithiocarbamate	Zyban	12	Do not use on French marigold or gloxinia.
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	For resistance management, make no more than 2 consecutive applications before making 2 applications of a non-strobilurin fungicide. Do not apply to pansy or leatherleaf fern.

Fusarium Root and Stem Rot; Fusarium Wilt

Although less common than other root rot pathogens, *Fusarium* can cause root rot in greenhouse crops, particularly in plants that are under stress from other environmental or cultural factors. Symptoms of *Fusarium* root rot are similar to other root rot diseases. *Fusarium* species are common inhabitants of untreated field soil. Certain *Fusarium* subspecies cause vascular wilt of specific crops, such as cyclamen, basil and chrysanthemum. The water-conducting tissue (xylem) of plants infected with *Fusarium* wilt will often show a reddish or brown discoloration. The vascular wilt subspecies are host specific, while the root rot *Fusarium* species can infect numerous plant species.

Management Strategies: As with other root rot diseases, good sanitation practices help to avoid introduction of *Fusarium* into a greenhouse. Maintain the vigor of the crop using optimum cultural practices to help plants resist Fusarium root rot infection. While protectant fungicides can help manage *Fusarium* root rot, fungicides have little effect on *Fusarium* vascular wilts. Discard plants with vascular wilt symptoms, or with severe root rot.

Table 10.5 Fungicides for Managing Fusarium Root Rot

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not make more than 3 drench applications before rotating with a non-strobilurin fungicide. Possible phytotoxicity on small plants in seedling/ plug stage – test on a small number of plants before large scale use.
Etridiazole + Thiophanate methyl	14 1	Aromatic hydrocarbon Benzimidazole	Banrot 8G Banrot 40W	12 12	Irrigate immediately after application. See label for crop list.
Fludioxonil	12	Phenylpyrrole	Medallion	12	May cause stunting and/ or chlorosis in impatiens, New Guinea impatiens and geranium. Do not use on leatherleaf fern.
Fludioxonil + Mefenoxam	12 4	Phenylpyrrole Phenylamide	Hurricane	48	Applications to impatiens, New Guinea impatiens, pothos, geranium and Ester lily may cause stunting and/or chlorosis.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.

Table 10.5 Fungicides for Managing Fusarium Root Rot (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Iprodione	2	Dicarboxamide	Iprodione Pro	12	For plants not specified on label, test on a small number of plants to evaluate for phytotoxicity before large-scale use. Do not use as a soil drench on impatiens or pothos. Do not use on spathiphyllum.
			OHP Chipco 26 GT-O		
			OHP Chipco 26019 N/G		
			Sextant		
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Thiophanate methyl	1	Benzimidazole	Allban 50 WSB	12	Do not tank mix with copper compounds. For plants not specifically listed on label, trial applications are recommended. For resistance management, rotate with products having different mode of action. Do not apply to Swedish ivy, Boston fern, or Easter cactus.
			Allban Flo 46.2% F		
			Cleary's 3336 F		
			Cleary's 3336-WP 50%		
			Cleary's 3336-G 2%		
			Fungo Flo 50		
			OHP-6672 50W		
			Quali-Pro TM 4.5 F		
			Quali-Pro TM 85 WDG		
			T-Bird 85		
			TM 4.5 T&O		
			T-Storm 50 WSB		
			T-Storm Flowable		

Table 10.5 Fungicides for Managing Fusarium Root Rot (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Trichoderma harzianum KRL-AG2	NC	Biopesticide	Plant Shield HC 1.15%	0	Check label for information on compatibility with certain fungicides.
			RootShield WP		
			RootShield granules		
Triflumazole	3	Dimethylation inhibitor	Terraguard 50W	12	Do not use on impatiens plugs.
			Terraguard SC		

Powdery Mildew

Powdery mildew is characterized by the presence of whitish fungal growth on the surfaces of leaves and stems. Infection of young, expanding leaves or shoots can result in severe distortion. There are many different fungi in the powdery mildew group; some are quite host specific while others can infect a wide range of plants. The fungi obtain nutrients from host plants by penetrating the outermost layer of plant cells. Powdery mildew spores are easily detached from the hyphae on which they develop and are carried by air currents to surrounding plants. Unlike most fungal diseases, leaf wetness is not required for powdery mildew infection. Disease development is favored by high humidity resulting from dry, sunny days followed by cool, moist nights.

Management Strategies: Reduce humidity by increasing plant spacing and air circulation and irrigating carefully. Scout plants regularly for the first signs of powdery mildew, as this disease can spread very quickly throughout the crop. Fungicides may be necessary when conditions are favorable for disease. Avoid repeated use of fungicides with the same mode of action to minimize the development of resistance.

Table 10.6 Fungicides for Managing Powdery Mildew

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not apply to leatherleaf fern.
Bacillus subtilis QST 713 strain	NC	Biopesticide	Cease	0	
			Rhapsody		
Chlorothalonil	M5	Chloronitrile	Daconil 2787	48	May damage flowers.
			Daconil Ultrex	12	Do not combine with horticultural oil. See label for other tank mix restrictions. Applications during bloom may damage flowers. For plants not specified on label, apply to a small group to ensure plant safety.
			Daconil Weather Stik 54F		
			Echo 720 T+O		
			Echo Ultimate		
			Echo Zn T+O		
			Manicure 6FL		
			Pegasus L		
			Quali-Pro Chlorothalonil 720 SFT		
			Quali-Pro Chlorothalonil 500 Zn		
			Quali-Pro Chlorothalonil DF	48	
			Thalonil 6L	12	
Chlorothalonil + Thiophanate methyl	M5 1	Inorganic Benzimidazole	Spectro 90 WDG	12	Do not mix with copper compounds. See label for additional tank mix restrictions. Do not use on Swedish ivy, Boston fern or Easter cactus..

Table 10.6 Fungicides for Managing Powdery Mildew (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Copper hydroxide	M1	Inorganic	Champ	24	Possible phytotoxicity when applied in a spray solution with pH < 6.0. Do not apply to hibiscus plants in flower. Do not apply to plants just before selling season.
			CuPro 2005 T/N/O		Possible phytotoxicity when applied in a spray solution with pH < 6.5. See label for specific crop restrictions.
			Nu-Cop 50 DF		
Copper hydroxide + Mancozeb	M1 M3	Inorganic Dithiocarbamate	Junction	24	Possible phytotoxicity when applied in a spray solution with pH < 6.5. Do not spray plants just before selling season.
Copper salts of fatty/ rosin acids	M1	Inorganic	Camelot	12	Possible phytotoxicity when applied in a spray solution w/ pH < 6.5. Do not apply to plants just before/during flowering.
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For plants not listed on label, test a small group and observe for 5-7 days for phytotoxicity.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.
Hydrogen dioxide	NC		ZeroTol	0	Test for phytotoxicity on a small number of plants before large scale use – see label.
Kresoxim methyl	11	Strobilurin (QoI)	Cygnus	12	
Myclobutanil	3	Dimethylation inhibitor	Eagle 20 EW	24	Test on plants not listed on label before large scale use. See label for cautions regarding use of plant growth regulators.
			Hoist		
Neem oil	NC		Triact 70	4	Do not apply to impatiens in bloom.
Piperalin	5	Amine	Pipron 84.4%L	12	Do not use on hydrangeas in flower.

Table 10.6 Fungicides for Managing Powdery Mildew (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Polyoxin D Zinc Salt	19	Polyoxin	Affirm WDG	4	For resistance management, alternate with products having different mode of action. Do not apply through any type of irrigation system.
			Veranda O		
Potassium bicarbonate	NC		Armicarb O	4	
			Kaligreen		
			MilStop	1	Do not use on young pansies.
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Sulfur	M2	Inorganic	Microthiol Disperss	24	
Thiophanate methyl	1	Benzimidazole	Allban 50 WSB	12	Do not tank mix with copper compounds. For plants not specifically listed on label, trial applications are recommended. For resistance management, rotate with products having different mode of action. Do not apply to Swedish ivy, Boston fern, or Easter cactus.
			Allban Flo 46.2% F		
			Cleary's 3336 F		
			Cleary's 3336 WP 50%		
			Fungo Flo 50		
			OHP-6672 50W		
			Quali-Pro TM 4.5 F		
			Quali-Pro TM 85 WDG		
			T-Bird 85		

Table 10.6 Fungicides for Managing Powdery Mildew (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Thiophanate methyl + Mancozeb	1 M3	Benzimidazole Dithiocarbamate	Zyban	12	Do not use on French marigold or gloxinia.
Triadimefon	3	Dimethylation inhibitor	Strike 50 WDG	12	Labeled for use on calendula, carnation chrysanthemum, cineraria, crassula, daisy, geranium, gerbera, grape ivy, hydrangea, kalanchoe, poinsettia, rose, snapdragon.
Trichoderma harzianum KRL-AG2	NC	Biopesticide	Plant Shield HC 1.15%	0	
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	For resistance management, after each application make 2 applications of a non-strobilurin fungicide. Do not apply to pansy or leatherleaf fern.
Triflumizole	3	Dimethylation inhibitor	Terraguard 50W Terraguard SC	12	Do not use on impatiens plugs.

Pythium and Phytophthora Root Rot and Blight

Pythium and *Phytophthora* are in the group of microorganisms called water molds. Both pathogens are soil inhabitants and produce spores that swim in films of water. Both pathogens are favored by poorly drained growing media and excessive moisture. Roots infected with water molds often show a dark, soft, wet rot. In some hosts, the pathogens can invade the lower stem as well, causing a black stem discoloration or crown rot. Symptoms can range from slight stunting and/or chlorosis of infected plants to wilting and plant death. *Pythium* is more commonly found in greenhouse production, but *Phytophthora* is usually more aggressive in killing infected plants. *Phytophthora* can also cause blighting of foliage and stems above the soil line. *Pythium* root rot is favored by high soluble salts in the growing medium. Both pathogens can survive in surface water sources, such as ponds, and can be distributed through irrigation. Fungus gnats and shore flies can spread *Pythium* by carrying spores on their bodies or through their feeding activities.

Management Strategies: As with all root rot diseases, sanitation is important for keeping the pathogen out of the greenhouse. Field soil in a potting mix should be sterilized before use. Clean pots, tools and benches with a greenhouse disinfectant. Use a well-drained growing medium, and monitor irrigation practices to avoid saturated conditions. Do not over fertilize and avoid high soluble salts levels in growing mix. If using pond water for irrigation, treat the pond water to reduce *Phytophthora* and *Pythium* prior to irrigation. Remove and discard plants with root rot symptoms. Fungicide drenches can help protect uninfected plants. Most fungicides effective against *Pythium* root rots will also control *Phytophthora* root and crown rots. Products labeled for *Phytophthora* foliar blight may not be effective against *Pythium* root rot. Many *Pythium* isolates and some *Phytophthora* isolates are insensitive to metalaxyl and mefenoxam (Subdue and Subdue MAXX), so always rotate with products having different modes of action for the best control of these diseases.

Table 10.7 Fungicides for Managing Phytophthora Foliar Blight

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not apply to leatherleaf fern.
Chlorothalonil	M5	Chloronitrile	Daconil Ultrex Daconil Weather Stik 54F	12	Do not combine with horticultural oil. See label for other tank mix restrictions. Applications during bloom may damage flowers. For plants not specified on label, apply to a small group to ensure plant safety.
Chlorothalonil + Thiophanate methyl	M5 1	Chloronitrile Benzimidazole	Spectro 90 WDG	12	Do not mix with copper compounds. See label for additional tank mix restrictions. Do not use on Swedish ivy, Boston fern or Easter cactus.

Table 10.7 Fungicides for Managing Phytophthora Foliar Blight (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Copper hydroxide	M1	Inorganic	Champ	24	Possible phytotoxicity when applied in a spray solution with pH < 6.0. Do not apply to hibiscus plants in flower. Do not apply to plants just before selling season.
			CuPro 2005 T/N/O		Possible phytotoxicity when applied in a spray solution with pH < 6.5. See label for specific crop restrictions.
			Nu-Cop 50 DF		
Copper salts of fatty/ rosin acids	M1	Inorganic	Camelot	12	Do not apply to plants just before/during flowering. Possible phytotoxicity when applied in a spray solution w/ pH < 6.5.
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For plants not listed on label, test a small group and observe for 5-7 days for phytotoxicity.
Cyazofamid	21	Cyanoimidazole	Segway 34.5 EC	12	See label for resistance management guidelines. Do not make more than 4 applications per crop cycle.
Dimethomorph	40	Cinnamic acid	Stature DM 50%	12	Make no more than 2 consecutive applications. See label for additional resistance management guidelines.
Fenamidone	11	Imidazolinone	Fenstop	12	For foliar spray, do not make more than 2 applications of maximum rate per crop per season.
Fludioxonil + Mefenoxam	12 4	Phenylpyrrole Phenylamide	Hurricane	48	Applications to impatiens, New Guinea impatiens, pothos, geranium and Ester lily may cause stunting and/or chlorosis.

Table 10.7 Fungicides for Managing Phytophthora Foliar Blight (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Fluopicolide	43	Acylpicolide	Adorn	12	Make only one application per poinsettia crop.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.
Fosetyl-Al	33	Phosphonate	Aliette 80 WDG	12	May not be compatible with foliar fertilizers or copper products. Do not apply within 7 days of copper product application to avoid possible phytotoxicity.
Mancozeb	M3	Dithiocarbamate	Protect DF	24	Addition of spreader sticker may improve performance. For plants not specified on label, trial applications are recommended.
Mefenoxam	4	Phenylamide	Subdue MAXX	48	Foliar application. Apply only 1 foliar application before alternating with a non-Group 4 fungicide for sequential foliar applications. Some *Phytophthora* isolates are insensitive to mefenoxam.
Phosphorous acid - postassium salts	33	Phosphonate	KPhite Alude 45.8%	4	Mixing with some foliar fertilizers and copper products may cause phytotoxicity. Test for crop safety before use.

Table 10.7 Fungicides for Managing Phytophthora Foliar Blight (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI)	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	Do not apply to pansy or leatherleaf fern.

Table 10.8 Fungicides for Managing Pythium and Phytophthora Root and Crown Rots

Refer to disclaimer statement on page 137.

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Cyazofamid	21	Cyanoimidazole	Segway 34.5 EC	12	Do not use more than 2 applications per crop cycle for Pythium and Phytophthora soilborne diseases.
Dimethomorph	40	Cinnamic acid	Stature DM 50%	12	Not effective against *Pythium*.
Etridiazole	14	Aromatic hydrocarbon	Terrazole 35 WP Terrazole L	12	Test for crop safety before large-scale use. Irrigate immediately after soil drench for improved penetration of fungicide.
			Truban 25 EC Truban 30 W	12	See label for specific crop list. Irrigate immediately after soil drench for improved penetration of fungicide.
Etridiazole + Thiophanate methyl	14 1	Aromatic hydrocarbon Benzimidazole	Banrot 8G Banrot 40W	12	Irrigate immediately after application. See label for crop list.
Fenamidone	11	Imidazolinone	Fenstop	12	See label for resistance management guidelines. Do not make more than 4 drench applications at maximum rate per crop per season.
Fludioxonil + Mefenoxam	12 4	Phenylpyrrole Phenylamide	Hurricane	48	Applications to impatiens, New Guinea impatiens, pothos, geranium and Easter lily may cause stunting and/or chlorosis.
Fluopicolide	43	Acylpicolide	Adorn	12	Make only 1 application to poinsettia. Test for possible phytotoxicity on a small number of plants before large scale use – see label.
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.

Table 10.8 Fungicides for Managing Pythium and Phytophthora Root and Crown Rots (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Fosetyl-Al	33	Phosphonate	Aliette 80 WDG	12	May not be compatible with foliar fertilizers or copper products. Do not apply within 7 days of copper product application to avoid possible phytotoxicity.
Mefenoxam	4	Phenylamide	Mefenoxam 2 AQ Subdue MAXX	48	Soil drench or soil surface spray. For plants not specified on label, test on a small number to check for phytotoxicity before large scale use. See label for resistance management comments. Some *Pythium* and *Phytophthora* isolates are insensitive to mefenoxam.
Phosphorous acid	33	Phosphonate	KPhite Alude 45.8%	4	Mixing with some foliar fertilizers and copper products may cause phytotoxicity. Test for crop safety before use.
Propanocarb	28	Carbamate	Banol	24	For plants not listed on label, test on a small number before large scale use.
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.

Table 10.8 Fungicides for Managing Pythium and Phytophthora Root and Crown Rots (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Trichoderma harzianum KRL-AG2		Biopesticide	Plant Shield HC 1.15% RootShield WP RootShield granules	0	For suppression of Pythium root rot.

Rhizoctonia Root and Crown Rot

Rhizoctonia root rot is common under a range of environmental conditions. Symptoms of *Rhizoctonia* root rot are similar to those caused by other root pathogens, but *Rhizoctonia* lesions on lower stems and roots are often drier and lighter in color than other root rots. The fungus tends to be most active in upper soil layers where the medium is drier. *Rhizoctonia* can also cause foliar blight when plants are crowded and humidity is high. *Rhizoctonia* is a common soil inhabitant, and can produce small sclerotia that can persist for several years in the soil. The primary means of introduction and spread in greenhouse production is the introduction of contaminated soil on greenhouse floors, pots, tools and plants.

Management Strategies: As with other root rot diseases, management is focused on sanitation to keep the pathogen out of the greenhouse. Field soil in a potting mix should be sterilized before use. Clean pots, tools and benches with a greenhouse disinfectant. Remove and discard plants with root rot symptoms. Fungicide drenches can help protect uninfected plants.

Table 10.9 Fungicides for Managing Rhizoctonia Root and Crown Rot

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not apply more than 2 times in sequence, and alternate with a non-strobilurin product to avoid resistance development. Do not apply to leatherleaf fern.
Chlorothalonil	M5	Chloronitrile	Daconil Ultrex	12	Do not combine with horticultural oil. See label for other tank mix restrictions. Applications during bloom may damage flowers. For plants not specified on label, apply to a small group to ensure plant safety.
			Daconil Weather Stik 54F		
			Echo 720 T+O		
			Echo Ultimate		
			Echo Zn T+O		
			Pegasus L		
			Quali-Pro Chlorothalonil 720 SFT		
			Quali-Pro Chlorothalonil 500 Zn		
			Quali-Pro Chlorothalonil DF		
Chlorothalonil + Thiophanate methyl	M5 1	Chloronitrile Benzimidazole	Spectro 90 WDG	12	Do not mix with copper compounds. See label for additional tank mix restrictions. Do not use on Swedish ivy, Boston fern or Easter cactus.

Table 10.9 Fungicides for Managing Rhizoctonia Root and Crown Rot (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Etridiazole + Thiophanate methyl	14 1	Aromatic hydrocarbon Benzimidazole	Banrot 8 G Banrot 40 W	12	Irrigate immediately after application. See label for crop list.
Fludioxonil	12	Phenylpyrrole	Medallion	12	May cause stunting and/or chlorosis in impatiens, New Guinea impatiens and geranium. Do not use on leatherleaf fern.
Fludioxonil + Mefenoxam	12 4	Phenylpyrrole Phenylamide	Hurricane	48	Applications to impatiens, New Guinea impatiens, pothos, geranium and Ester lily may cause stunting and/or chlorosis.
Flutalonil	7	Carboxamide	Contrast 70 WSP ProStar 70 WDG	12	Trial applications recommended for plants not specified on label – see label for details.
Fluxastrobin	11	Strobilurin (QoI)	DisarmO	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.
Iprodione	2	Dicarboxamide	Iprodione Pro OHP Chipco 26 GT-O OHP Chipco 26019 N/G Sextant	12	For plants not specified on label, test on a small number of plants to evaluate for phytotoxicity before large-scale use. Do not use as a soil drench on impatiens or pothos. Do not use on spathiphyllum.
Iprodione + Thiophanate methyl	2 1	Dicarboximide Benzimidazole	26/36 Fungicide	12	Do not use as a soil drench on impatiens or pothos. Do not use on spathiphyllum.
Pentachloro-nitrobenzene	14	Aromatic hydrocarbon	Terraclor 75 WP Terraclor 400	12	Soil drench or pre-plant bulb soak. See label.
Polyoxin D Zinc Salt	19	Polyoxin	Affirm WDG Veranda O	4	For resistance management, alternate with products having different mode of action. Do not apply through any type of irrigation system.

Table 10.9 Fungicides for Managing Rhizoctonia Root and Crown Rot (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Thiophanate methyl	1	Benzimidazole	Allban Flo 46.2% F Cleary's 3336 F Cleary's 3336 G 2% Cleary's 3336 WP 50% Fungo Flo 50 OHP-6672 50W Quali-Pro TM 4.5 F	12	Do not tank mix with copper compounds. For plants not specifically listed on label, trial applications are recommended. For resistance management, rotate with products having different mode of action. Do not apply to Swedish ivy, Boston fern, or Easter cactus.
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	For resistance management, do not use more than 2 consecutive applications before rotating with a non-strobilurin fungicide. Do not apply to pansy or leatherleaf fern.
Triflumizole	3	Dimethylation inhibitor	Terraguard 50W Terraguard SC	12	Do not use on impatiens plugs.

Rusts

Rust diseases are caused by a group of highly specialized fungi with complex life cycles. They are obligate parasites, and must infect living plant tissue to grow and survive. Some rusts need two different host plants to complete their development, while others require only one host. The disease gets its name from the orange or brown spores produced by most of these fungi in at least one part of their life cycle. Spores develop in erupent structures called pustules, which often develop in concentric rings on the foliage. Rust diseases can be spread through the air via wind-blown spores or through the introduction of infected plants in the greenhouse. Rust spores can also spread plant to plant through splashing water. High humidity and long leaf wetness periods favor rust disease development. Snapdragon, geranium and fuchsia are among greenhouse ornamentals that can be infected. **Chrysanthemum white rust**, caused by *Puccinia horiana* is a **federally regulated plant pathogen**, and subject to quarantine restrictions. Incidents of suspected Chrysanthemum white rust must be reported to state horticulture officials.

Management Strategies: Management of rust diseases starts with inspecting plants when they arrive. Careful scouting and rouging out of any symptomatic plants is a great way to avoid plant disease problems. Rust fungi can produce large quantities of spores in a relatively short period of time, so even a small number of infected plants can cause an epidemic. There are several effective fungicides for controlling rust diseases, but these are preventative, not curative. Fungicide treatment is no substitute for sanitation.

Table 10.10 Fungicides for Managing Rusts

Refer to disclaimer statement on page 137.

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Azoxystrobin	11	Strobilurin (QoI)	Heritage	4	Do not make more than 3 applications before rotating with a non-strobilurin fungicide.
Chlorothalonil	M5	Chloronitrile	Daconil Ultrex	12	Do not combine with horticultural oil. See label for other tank mix restrictions. Applications during bloom may damage flowers. For plants not specified on label, apply to a small group to ensure plant safety.
			Daconil Weather Stik 54F		
			Echo 720 T+O		
			Echo Ultimate		
			Echo Zn T+O		
			Pegasus L		
			Quali-Pro Chlorothalonil 720 SFT		
			Quali-Pro Chloro-thalonil 500 Zn		
			Quali-Pro Chlorothalonil DF		
Chlorothalonil + Thiophanate methyl	M5 1	Chloronitrile Benzimidazole	Spectro 90 WDG	12	Do not mix with copper compounds. See label for additional tank mix restrictions. Do not use on Swedish ivy, Boston fern or Easter cactus.

Table 10.10 Fungicides for Managing Rusts (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Copper sulfate pentahydrate	M1	Inorganic	Phyton 27	24	For rust on geranium, hollyhock, snapdragon.
Flutalonil	7	Carboximide	Contrast 70 WSP	12	Trial applications recommended for plants not specified on label – see label for details.
			ProStar WDG		
Fluxastrobin	11	Strobilurin (QoI)	Disarm O	12	Rotate with non-strobilurin fungicide. See label for resistance management guidelines.
Kresoxim methyl	11	Strobilurin (QoI)	Cygnus	12	To avoid resistance development, make no more than 2 applications before rotating with a non-strobilurin fungicide.
Mancozeb	M3	Dithiocarbamate	Dithane DF	24	Addition of spreader sticker may improve performance. For plants not specified on label, trial applications are recommended.
			Dithane 75 DF Rainshield T+O		
			Fore 80 WP Rainshield T+O		
			Pentathlon DF		
			Pentathlon LF		
			Protect DF		
Myclobutanil	3	Dimethylation inhibitor	Eagle 20 EW	24	Test on plants not listed on label before large scale use. See label for cautions regarding use of plant growth regulators.
			Hoist	24	
Neem Oil	NC		Triact 70		Do not apply to impatiens in bloom.
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.

Table 10.10 Fungicides for Managing Rusts (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.
Triadimefon	3	Dimethylation inhibitor	Strike 50 WDG		Labeled for use on Boston fern, calendula, carnation, chrysanthemum, daisy, geranium, snapdragon.
Trifloxystrobin	11	Strobilurin (QoI)	Compass O 50 WDG	12	For resistance management, do not use more than 2 consecutive applications before rotating with a non-strobilurin fungicide. Do not apply to pansy or leatherleaf fern.
Triflumizole	3	Dimethylation inhibitor	Terraguard 50W Terraguard SC	12	Do not use on impatiens plugs.

Sclerotinia Blight and Crown Rot

Sclerotinia blight, also called white mold, can occur on a wide variety of herbaceous ornamentals as well as vegetables, field crops and weeds. Symptoms include crown rot, stem rot, and flower blight. The pathogen produces hard, black structures called sclerotia that are irregular in shape and about 1/8 to 1/4 inch in size. Sclerotia may appear on the plant or soil surface, or inside the stem of infected plants. Under conditions of high humidity, fluffy white fungal growth develops on infected plant parts as well, giving the disease the name "white mold". Sclerotia are very resistant to environmental extremes, and can survive in soil and plant debris for several years. The disease is primarily spread through movement of sclerotia in soil or infected plants. Under certain environmental conditions, sclerotia can produce cup-like structures that release airborne spores.

Management Strategies: Sanitation is critical for managing *Sclerotinia* blight. Do not use unsterilized field soil in potting mixes. Avoid introducing untreated field soil to the greenhouse on tools or equipment, and keep weeds under control. Discard infected plants promptly. Fungicide drenches can help protect plants from infection.

Table 10.11 Fungicides for Managing Sclerotinia Blight and Crown Rot

*Refer to disclaimer statement on page 137.

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Pentachloro-nitrobenzene	14	Aromatic hydrocarbon	Terraclor 75 WP Terraclor 400	12	
Pyraclostrobin	11	Strobilurin (QoI)	Insignia	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not apply to impatiens or petunias in flower. Do not use organosilicone-based adjuvants. For plants not specified on label, test on a small group to check for phytotoxicity.
Pyraclostrobin + Boscalid	11 7	Strobilurin (QoI) Anilide	Pageant	12	Make no more than 2 sequential applications before rotating with a non-strobilurin product. Do not use organosilicone-based adjuvants. Injury may occur to flowers of impatiens and petunia.

Table 10.11 Fungicides for Managing Sclerotinia Blight and Crown Rot (continued)

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Thiophanate methyl	1	Benzimidazole	Allban 50 WSB	12	Do not tank mix with copper compounds. For plants not specifically listed on label, trial applications are recommended. For resistance management, rotate with products having different mode of action. Do not apply to Swedish ivy, Boston fern, or Easter cactus.
			Allban Flo 46.2% F		
			Cleary's 3336 F		
			Cleary's 3336-WP 50%		
			Cleary's 3336-G 2%		
			Fungo Flo 50		
			OHP-6672 50W		
			Quali-Pro TM 4.5 F		
			Quali-Pro TM 85 WDG		
			T-Bird 85		
			TM 4.5 T&O		
			T-Storm 50 WSB		
			T-Storm Flowable		

Thielaviopsis Root Rot

Thielaviopsis root rot disease is also called black root rot, due to the discrete black lesions present in infected roots. In severe cases, the root system is almost entirely black. The dark color is due to numerous dark, thick-walled spores produced by *Thielaviopsis* in infected plant tissues. Plants with *Thielaviopsis* root rot are often stunted and have chlorotic (yellowing) foliage. The pathogen has a wide host range, but the most common greenhouse ornamentals affected include pansy, vinca, calibrachoa, and fuchsia. *Thielaviopsis* root rot is favored by high soil pH (6.5 and higher) and poor drainage.

Management Strategies: Keep the growing medium pH at 6 or below to reduce *Thielaviopsis* problems. As with all root rot diseases, sanitation is key to keeping the fungus out of the greenhouse. Discard diseased plants. Fungicides applied as a soil drench can help protect roots from *Thielaviopsis* infection.

Table 10.12 Fungicides for Managing Thielaviopsis Root Rot

**Refer to disclaimer statement on page 137.*

Chemical Name	Code	Class	Trade Name	REI (hour)	Comments
Etridiazole + Thiophanate methyl	14 1	Aromatic hydrocarbon Benzimidazole	Banrot 8 G Banrot 40 W	12	Irrigate immediately after application. See label for crop list.
Fludioxonil	12	Phenylpyrrole	Medallion	12	May cause stunting and/or chlorosis in impatiens, New Guinea impatiens and geranium. Do not use on leatherleaf fern.
Fludioxonil + Mefenoxam	12 4	Phenylpyrrole Phenylpyrrole	Hurricane	48	Applications to impatiens, New Guinea impatiens, pothos, geranium and Ester lily may cause stunting and/or chlorosis.
Thiophanate methyl	1	Benzimidazole	Allban Flo 46.2% F Cleary's 3336 50 WP Cleary's 3336 F Cleary's 3336 G 2% Fungo Flo 50 OHP-6672 50W Quali-Pro TM 4.5 F Quali-Pro TM 85 WDG T-Bird 85	12	Do not tank mix with copper compounds. For plants not specifically listed on label, trial applications are recommended. For resistance management, rotate with products having different mode of action. Do not apply to Swedish ivy, Boston fern, or Easter cactus.
Triflumizole	3	Dimethylation inhibitor	Terraguard 50W Terraguard SC	12	Do not use on impatiens plugs.

Virus Diseases

Virus symptoms are often quite striking and distinctive. Chlorotic mottling, ringspots and line patterns on the foliage or stems may occur. Stunting is commonly observed. The single most important virus in ornamental plant production is Impatiens Necrotic Spot Virus (INSV). New Guinea and common impatiens are often affected, although the virus can infect a wide range of bedding plants, pot crops and weed hosts. Symptoms of INSV on impatiens include dark black or purple lesions on the stems and leaf veins and dark ringspots or blotches on leaves. Infected plants are stunted, and young leaves may be small and misshapen. INSV causes bleached white spots and rings on leaves and stems of snapdragons. INSV is spread by western flower thrips feeding. In recent years, viruses have been associated with new crops that are propagated vegetatively through cuttings. Tobacco mosaic virus (TMV), calibrachoa mottle virus (CbMV), tobacco rattle virus (TRV), and cucumber mosaic virus (CMV) have been found in various bedding plants and pot crops. TMV is a very stable virus with a wide host range, and any practices that move infected plant sap (handling plants, taking cuttings, potting) can spread the virus easily throughout a crop.

Management Strategies: Inspect plants regularly for virus symptoms. Test symptomatic plants for virus diseases to have a definitive diagnosis of specific virus problems. Samples may be sent to a diagnostic laboratory or commercial virus-testing company, or may be tested in-house using commercially available virus test kits. Maintain strict weed control inside the greenhouse as well as around the outside walls. Destroy plants showing virus symptoms. Manage thrips to minimize the spread of INSV (refer to Thrips section for more information). Place plants that are most susceptible to the virus in the center of the greenhouse, away from doors, vents and sidewalls.

Chapter 11
Weed and Algae Control in Commercial Greenhouses

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Weed Control

Controlling weeds in the greenhouse is important for several reasons. First, weeds serve as a hiding place for several insect and arthropod species, including whiteflies, thrips, aphids, mites, slugs, and snails. Second, weeds can serve as reservoirs for impatiens necrotic spot virus (INSV), tomato spotted wilt virus (TSWV), and several other viruses. Third, weed seeds can end up in pots and containers.

Because most growers use sterile soil substrates, weeds are usually not a major problem. Weeds are a major problem on greenhouse floor areas and areas just outside the greenhouse, especially near intake vents. Growers need to check labels for herbicides, since several specifically limit the use when crops are growing in the greenhouse and must be applied to empty growing space.

There are not many herbicides available that can be used safely and legally to control weeds in greenhouses. Herbicides are commonly classified by their mechanism of action and use pattern. Preemergence herbicides are applied before weeds emerge and generally provide residual control of weed seedlings for several weeks. There are no preemergence herbicides currently labeled for use in greenhouses.

Cultivation and hand pulling are often the few available options. There are two important facts to remember about mechanical cultivation. Hoeing and tilling will control small annual weeds fairly well. However, successive flushes of germinating weeds, stimulated by the cultivation itself, need to be controlled on a two- to three-week cycle. Once residual herbicides are applied and activated with water, they need to be in contact with the germinating weed seedlings to work well. Mechanical cultivation will often destroy this contact.

Hand pulling is often an important, if backbreaking, component of a weed management program. It should be considered when no other cultural or herbicide options are available and when weeds are present that will disperse their seed by wind to weed-free areas.

Never apply preemergence herbicides in heated or unheated covered houses or greenhouses. Several herbicides that are otherwise safe can volatilize under these conditions and cause injury.

Scouting for Weeds in the Greenhouse

Scout the outside perimeter of the greenhouse and note if weeds are present near vents or doorways entering the greenhouse. Examine this area during the spring and fall months before a crop is moved into the greenhouse. The easiest nonchemical method to control weeds near the greenhouse is to put a weed barrier fabric in place. Although weeds may germinate through the weed barrier, you can easily hand pull the weed from the barrier.

Make sure that substrate used for growing plants is stored in an area protected against weed seeds that may be windblown or washed in by rainfall. Before placing a crop in a substrate, take a representative sample of substrate and fill in a greenhouse flat. Water the substrate and place the flat in the greenhouse for at least a week. If no weeds germinate, then you can probably assume that the substrate is free of weeds.

Inspect under the greenhouse benches. If weeds are present, hand pulling is the safest and most effective way to eliminate them. Try to pull weeds when they are still growing vegetatively and before seeds mature; this prevents weed seeds from blowing through the greenhouse. Sometimes bedding plants produce seeds that escape and establish themselves under benches. The plants that result are considered weeds; eliminate them because they can harbor insects, mites, and diseases. Scout under the greenhouse bench on a weekly or bi-weekly basis and eliminate weeds while they're still small.

Placing weed barrier cloth under the benches helps prevent weeds from getting established. Remove all "pet" plants from the greenhouse. Like weeds, these plants can serve as a source of diseases, mites, and insects that can spread to the new greenhouse plants.

Weed Control – Use Chemicals as a Last Resort

Greenhouse growers should be extremely cautious if using herbicides in the greenhouse. Greenhouse and air circulation fans must be off during herbicide application. When applying herbicides, use large droplet, low pressure type nozzles.

Table 11.1 Herbicides Labeled for Use in Controlling Weeds in Greenhouses

(Only for emerged weeds; i.e. postemergence activity)

Chemical Name	Brand Name (*restricted use product)	Re-entry Interval (hours)	Selectivity/ Mode of Action	Notes on Use
Clethodim	Arrow Envoy* Envoy Plus* Select Max	24	Selective postemergent; Contact	Controls annual and perennial grasses only. Does not control broadleaf weeds or sedges. Do not use in soil beds/benches. No residual activity. Consult label for recommended spray adjuvants. NOTE: Envoy Plus is labeled for ornamentals only. May cause significant injury to flowers of greenhouse grown plants. Select Max and Arrow are labeled for numerous food crops.
Clove oil plus citric acid	BurnOut II	Not specified	Non-selective; contact	For ornamental plants only. Controls small annual and perennial broadleaf weeds; poor control of grassy weeds. Thorough coverage is necessary. Rainfall within one hour of application will reduce degree of control. Older, hardier plants may require retreatment. Avoid application to aluminum, tin, iron, or items such as fencing or lawn furniture in order to prevent staining, mottling, or otherwise interfering with finished metal surfaces.

Table 11.1 Herbicides Labeled for Use in Controlling Weeds in Greenhouses (continued)

Chemical Name	Brand Name (*restricted use product)	Re-entry Interval (hours)	Selectivity/ Mode of Action	Notes on Use
D-limonene citrus oil extract	GreenMatch	4	Non-selective; contact	OMRI-approved for vegetable and fruit crops. Controls small broadleaf weeds; poor control of grassy weeds. Label does not require adjuvant, but manufacturer recommends use of an adjuvant.
Diquat (dibromide)	Reward	24	Non-selective postemergent; Contact	Good control of small annual and grassy weeds; large weeds will be injured but may not be killed. Highly toxic – do not use on food crops. Use of a nonionic surfactant is recommended. Do not allow contact of spray or drift on desirable foliage.
Fenoxaprop	Acclaim Extra	24	Postemergent; Contact	For use on herbaceous perennials only. Controls annual and perennial grassy weeds. Does not control annual bluegrass, broadleaf weeds, sedges, or most perennial grasses. Apply to young (seedling to 3-tiller) actively growing grasses. Flat fan nozzles are recommended. May be tank mixed with other pre- and postemergence herbicides. Thorough spray coverage is essential. Growth inhibition occurs within 48 hours; death within about 14 days. Addition of a surfactant is generally not recommended. Do not use on *Salvia*, *Philodendron*, or *Pittosporum*.
Fluazifop-P-butyl	Fusilade II*	12	Selective; postemergent; Systemic	Controls annual and most perennial grasses. Does not control broadleaf weeds, sedges, rushes, lilies, and other nongrasses. May be applied over the top or as directed spray in woody and herbaceous ornamentals in containers. Mix with nonionic surfactant (some ready-to-use formulations are available). Thorough coverage is essential; spray to cover but not to runoff. Do not tank mix with other pesticides or fertilizers except as instructed on the label. Growth inhibition occurs within 48 hours; weeds are killed within 2 weeks.

Table 11.1 Herbicides Labeled for Use in Controlling Weeds in Greenhouses (continued)

Chemical Name	Brand Name (*restricted use product)	Re-entry Interval (hours)	Selectivity/ Mode of Action	Notes on Use
Glyphosate	Glyphosate Pro II Round-up Pro® Round-up Pro Concentrate ® Round-up Pro Dry ® Touchdown*	Variable, depending on product		For use in empty greenhouses only (between crop cycles). Controls broadleaf weeds and small grassy weeds by translocation, killing roots. Field horsetail is not well controlled. See label for recommended spray adjuvants. Do not apply if overhead irrigation will occur within 6 hours. Works in 7-10 days. No residual soil activity. Do not apply to runoff. Turn off fans during application. Treat perennials when in flower and soil moisture level maintains active weed growth. Do not use more than 10.6 quarts of product per acre per year. Keep people and pets off treated areas until dry to prevent transfer to desirable foliage. Maximum application rates up to 2 gal/100 gal water for Roundup Pro and up to 5 qt/100 gal for Touchdown. Apply lower rates to young weeds.
Glufosinate ammonium	Finale	12	Nonselective postemergent; Systemic	For ornamental crops only; not for greenhouses with food-producing crops. Controls broadleaf weeds and small grassy weeds. Air circulation fans must be turned off during application. Use low pressure nozzles that produce larger droplets. Do not use in soil beds/benches. Weed dieback symptoms often noticed within 48 hours. Use of ammonium sulfate may improve control.
Pelargonic acid	Scythe	12	Nonselective postemergent; Contact	Controls small broadleaf weeds; poor control of grassy weeds. Older annual and perennial weeds will only be suppressed with top kill. Works best when air temperatures are >80 ˚F. Use low pressure nozzles with larger droplets. Apply in a ventilated area. Do not apply using hose-end sprayers. Possible odor issues.
Sethoxydim	Sethoxydim G-Pro (1 EC)	12	Postemergent	Foliar-applied; controls annual and perennial grasses in ornamentals, ground covers, and bedding plants. Does not control annual/ perennial sedges, annual bluegrass, or broadleaf weeds. Spray small, actively growing grasses to wet but not to the point of runoff. Thorough coverage is essential. Do not apply when irrigation will occur within one hour. Caution when using on azalea, potentilla, Japanese privet, and red and white oak.

Algae Control

Algae are common in greenhouses with high moisture levels. They grow on walkways and under benches and can form an impenetrable layer on the surface of pots. Eliminating puddles in the greenhouse will help eliminate algae on the floor and under the bench. Control of algae can also help to reduce shore flies, fungus gnats and moth flies. Manage algae by watering only as needed, avoiding excess puddling on the greenhouse floor, and avoiding watering late in the day. Avoid overwatering to reduce algae growth on pot surfaces. Surfaces with algae can be scrubbed with a stiff-bristle brush. Use chemicals as a last resort to control algae.

Table 11.2 Algae Control With Chemicals

Common Name	Brand Name	Formulation/REI	Amount to use	Registered Use
Bromochloro-dimethylimidazolidinedione	Agribrom	Soluble granule	Initial application: 10 to 35 ppm maintenance applications: 5 to 10 ppm	Can be used on cooling pads, subirrigation mats, floors, and ebb and flow benches and injected into irrigation water. Treat clean surfaces. Not phytotoxic. Caution when using on lipstick vine, ficus, hibiscus, and English ivy.
Clorine dioxide	Selectrocide 12G	Soluble granule	To control: 5 ppm To inhibit, use 0.25 ppm in continuous treatment.	Injects chlorine dioxide into irrigation lines. Ultra low rates irrigate while inhibiting algae; higher rates is a shock treatment to clear lines.
Hydrogen dioxide	Zero Tolerance	Liquid 0	1:50 for surface applications	Sanitizer for tools, floors, pots, benches, greenhouse structures, watering systems, and cooling pads. Wet all surfaces before treating. Do not mix with pesticides/fertilizers. Can use in chemigation.

Table 11.2 Algae Control With Chemicals (continued)

Chemical Name	Brand Name (*restricted use product)	Re-entry Interval (hours)	Selectivity/Mode of Action	Notes on Use
Quaternary ammonium chloride salt	Green-Shield Physan 20 Triathlon	Liquid 12	1 teaspoon per gallon of water for greenhouse glass; 1 tablespoon per gallon for walkways.	Labeled for use on greenhouse glass and walkways. Shock treatment; can be injected into irrigation lines. Surfaces should remain wet for at least 10 minutes.
Sodium carbonate peroxyhydrate	GreenClean Pro Granular algicide	Granular 1	Initial curative application: 10 to 15 lb. per 1000 sf. For prevention/ follow up (weekly or biweekly applications): 5 lb. per 1000 sf	For ornamental crops only. Water activated. Apply over thoroughly watered soil surface. Thoroughly rinse granules off foliage. Use may increase soil pH by 0.5 pH units (makes the soil more alkaline). Incompatible with metal-based fungicides and fertilizers. Do not apply within three days of metal-based applications.
	TerraCyte (34 G)*	Granular 4		

Chapter 12
Plant Growth Regulators for Floricultural Crops

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Introduction

Plant growth regulators (PGRs) are chemicals that are designed to affect plant growth and/or development. They are applied for specific purposes to elicit specific plant responses. Although there is much scientific information on using PGRs in the greenhouse, it is not an exact science. Achieving the best results with PGRs is a combination of art and science – science tempered with a lot of trial and error and a good understanding of plant growth and development.

For best results, PGRs should be handled as production tools like water and fertilizer. PGRs should be an integrated part of your crop production cycle. They should not be used as crutches for poor management of other cultural practices. However, PGRs should be used in conjunction with a number of non-chemical control options to manipulate plant growth so well-proportioned, compact plants are produced.

Cultivar Selection for Plant Height Control

Selecting shorter growing cultivars is often the first step available to growers for reducing the occurrence of overgrown plants. While this works well in theory, it may not be commercially practical. Customer demand for specific color or growth form characteristics may limit plant choices. However, response to PGRs depends on species and cultivar selection. In general, slow growing or dwarf cultivars will require less PGR than more vigorous cultivars. Some plant species or cultivars are responsive to specific PGRs but not all PGRs. Research the crop, including its responsiveness to PGRs.

Environmental and Cultural Control for Plant Growth Management

Knowing how the growing environment and cultural practices can affect plant growth will help in managing a crop's growth. There are a number of factors that can be manipulated in the greenhouse or nursery to reduce plant growth: container size, timing of transplant or seeding, irrigation practices, nutrient management, mechanical conditioning, light quality and quantity, pinching, and temperature. How these factors are manipulated will affect whether chemical control is necessary and the amount of PGR required for optimum growth control.

Container Size

Root restriction can be used to control plant growth by utilizing a small container or by increasing the number of plants per pot. This method works especially well when other production parameters such as ample light, i.e., wide spacing, and proper nutrition are provided. Plants grown in small pots at close spacing will require more chemical growth regulation for adequate growth control than those receiving ample light.

Timing

One of the most effective methods of controlling excessive plant growth is by crop timing. The simple method of staggering the finish time of a crop at 2 to 3 week intervals is very effective with many crops like bedding plants. This ensures that a new supply of plants will be available; thus avoiding the need to hold a crop beyond its market window where it generally becomes "leggy."

Irrigation Practices
A traditional method of controlling plant growth is to withhold water. Drought stress can be used on a number of crops, including impatiens and tomatoes. Allow the plants to wilt slightly between irrigations, but do not allow them to reach the permanent wilting point. Drought stress will lead to shorter plants, but excessive stress or drought stress of sensitive crops may have the undesirable effects of reduced plant quality and delayed flowering. Drought stress also may cause premature bolting of some crops such as ornamental cabbage and kale. Growers who tend to "run their plants dry" will use less PGRs than growers who run their plants wet. The method of irrigation can affect the plant response to PGRs. Plants grown on sub-irrigation trays or water collectors should be treated with lower rates of soil-active PGRs since the overspray from the treatment will be available to the roots during subsequent irrigation events.

Nutrient Management
Reducing or withholding fertilizer tends to slow overall plant growth. Limiting the amount of nitrogen to 50 to 100 ppm N will help control growth of many crops like bedding plants. The type of nitrogen supplied can also impact plant growth. Relying on nitrate-nitrogen instead of ammoniacal-nitrogen or urea-nitrogen forms (which encourage lush growth) will also help. Phosphorus also promotes plant growth. Plug producers commonly use low phosphorus fertilizers like 13-2-13 Cal-Mag® or 15-0-15 which does not contain phosphorus to help limit stem elongation. As with "dry" plants, nutrient-deficient plants require less growth regulator for growth control than lush plants.

Mechanical Conditioning
Brushing plants is a very effective way of controlling plant height (30% to 50% reductions) of many vegetable transplants or herbs. Currently only one PGR (Sumagic, Valent USA) is labeled for chemical growth control of fruiting vegetable transplants. Brushing is the movement of a PVC pipe, wooden dowel rod, or burlap "bags" over the top third of a plant. Research at the University of Georgia suggests that plants should be brushed daily for about 40 strokes to obtain the greatest effect. The foliage should be dry to avoid damage to the leaves. This method is not effective on plants such as cabbage or broccoli and should not be used if foliar diseases, or, in many cases, flowers, are present. Evaluate the degree of growth regulation provided by brushing before adding a PGR treatment. Also, be aware that the effects of brushing on plant growth dissipate within three to four days after you stop applying the treatment. You may want to apply a low rate of a PGR to provide continued growth control during the shipping, handling and retail phases.

Pinching
Pinching can be used to improve the shape of the plant, increase branching, and control excessive stretch. However, the labor costs of pinching and the subsequent delay in plant development may not make it an economically feasible option of controlling growth of many crops.

Light Quality and Quantity
Higher light quality tends to limit plant elongation, thus resulting in shorter plants. Low light quality caused by late spacing or crowding of the crop or too many hanging baskets overhead can lead to leggy plants and should be avoided. Photoperiod also can be used to control growth of many plants. This practice is widely used with pot chrysanthemums by providing taller cultivars with only one week of long days (LD) to limit vegetative growth when compared to shorter cultivars which receive three weeks of LD to promote growth. Light quantity also affects plant growth. Higher light levels improve plant growth and quality as well as branching. Spacing will often determine the need for, and amount of, additional chemical control necessary for optimum height control under high light levels.

Temperatures
Temperature manipulation can be used very effectively to control plant growth. Lower temperatures reduce plant growth. Remember to account for the effects of lower temperatures on the developmental processes

of the plant, i.e., lower temperatures may delay flowering so you may need to adjust your crop schedules to hit your market window. Lower rates of PGRs are required for plants grown under lower temperatures. Conversely, higher temperatures enhance plant growth and higher rates of PGRs are necessary for adequate growth regulation. Some growers use differential day/night temperatures (DIF) to control growth. In the South and Mid-Atlantic regions, we are typically limited to a DIP in temperatures, where we reduce the pre-dawn temperatures to 5 to 10 °F below the night temperature setting and hold it for up to 4 hours. This treatment reduces growth at the time of day that cell elongation is greatest and therefore controls plant height. Obviously, do not use drop the temperature low enough to injure cold sensitive crops.

Optimizing plant growth control requires an understanding of the effects of environmental and cultural conditions on plant growth. Experience and in-greenhouse trials will allow you to combine PGRs with a number of non-chemical control options to manipulate plant growth to produce high quality, compact plants.

Choosing The Correct PGR

The selection of PGRs and their application rates will be affected by the vigor of the cultivars selected and how your crop is grown. Especially with very vigorous plants, higher fertility and irrigation levels will increase the amounts of growth regulator required to prevent excessive growth. Shading, lower light levels or tight plant spacing, especially under higher growing temperatures, will also increase plant stretch and reduce lateral branching. For the highest quality plants, the use of PGRs must be integrated into your production plan.

PGRs are most effective when applied at the appropriate times to regulate plant growth or development. In other words, growth retardants cannot "shrink" an overgrown plant. They must be applied before the plant is overgrown to avoid plant stretch. When planning PGRs in your production schedule, consider what you want to accomplish with the treatment.

- Do you want to regulate shoot growth of the plant, resulting in a sturdier, more compact plant with improved color? If so, you probably want a growth retardant.(A)

- Do you want to increase plant branching for enhanced cutting production, or for a more bushy potted plant or hanging basket? If so, you probably want to use a branching agent or "chemical pincher."(B)

- Do you want to enhance flower initiation or synchronize flowering? If so, you probably want to use chlormequat chloride or gibberellic acid.(C)

- Do you want to remove flowers from stock plants to increase the number of vegetative cuttings? If so, you probably want to use an ethylene-generating compound.(D)

Answering these questions will indicate which type of PGR you need to use to accomplish your goal and the most appropriate timing of the application. Then you will need to select a specific PGR in that class, determine the appropriate dosage and the appropriate application method to attain the desired response.

A. Regulating Shoot Growth

Most of the PGRs used in the greenhouse or nursery are used to regulate shoot growth of containerized crops and are referred to as "growth retardants." Typical growth retardants are daminozide (B-Nine or Dazide), chlormequat chloride (Cycocel, Citadel or Chlormequat E-Pro), ancymidol (A-Rest or Abide), flurprimidol (Topflor), paclobutrazol (Bonzi, Piccolo, Paczol, or Downsize) and uniconazole (Sumagic or Concise). Now that most of the PGR chemistries are off patent, there are several options available (Table 12.3) that reduce plant height by inhibiting the production of gibberellins, the primary plant hormones responsible for cell elongation. Therefore, these growth retardant effects are primarily seen in stem, petiole

and flower stalk tissues. Lesser effects are seen in reductions of leaf expansion, resulting in thicker leaves with darker green color. Other benefits include improved plant appearance by maintaining plant size and shape in proportion with the pot, and increased shipping capacity with the smaller plants. Plant growth retardants also increase the tolerance of plants to the stresses of shipping and handling as well as retail marketing, thereby improving shelf-life and extending plant marketability.

Remember growth retardants do not reduce plant size. They reduce the plant's growth rate. You must apply the growth retardant prior to the "stretch." Look for recommendations on the PGR label for time of application. These recommendations will be given in terms of plant development or plant size as opposed to production time. For example, the uniconazole (Sumagic or Concise) labels specify that pansies should have attained a minimum height of four inches prior to application. The paclobutrazol (Bonzi, Paczol, or Piccolo) labels state that bedding plant plugs should be treated at the one to two true leaf stage and bedding plants (after transplanting) at two inches of new growth or when the plants reach marketable size.

Generally, growth retarding PGRs should be applied just prior to rapid shoot growth. This is generally one to two weeks after transplanting a plug, after the roots are established and as the plant resumes active growth; on pinched plants, it is after the new shoots are visible and starting to elongate. This is where the art of plant growth regulation is most important. You must learn how your crop grows and when to intervene to obtain the desired results. Remember to note details of crop development in your records of PGR treatments. For example, due to the weather conditions, next year you may need to treat at seven days after transplanting instead of at the ten days after transplanting that you used this year. You must gauge when rapid elongation will likely occur and treat to counter it.

Many growers use multiple applications of growth retardants to better control plant growth. A single application at a high rate early in the plant production cycle may be excessive if growing conditions are not as good as expected. An early application at a lower rate provides more flexibility, but the tradeoff is the additional labor involved with a second application if it becomes necessary. Some growers improve crop uniformity by using multiple applications of lower rates to effect small corrections in plant growth. Be aware that excessive rates of many of these PGRs can cause persistent growth reductions in the flat or even in the landscape. It is always a good idea to evaluate the long-term effects of your treatments by growing some out for yourself and talking with your customers. Be careful to avoid late applications, especially of paclobutrazol or uniconazole as they may delay flower opening on bedding plants. However, drench applications of paclobutrazol have provided excellent control of poinsettia height very late in the production cycle without causing the reduction in bract size accompanying late spray applications. Learn the art of using PGRs for plant growth regulation.

Daminozide (B-Nine or Dazide; Re-entry Interval (REI) = 24 hrs.) was one of the first PGRs labeled for use in the floriculture industry and is still widely used. In general, it is not phytotoxic and has a short-term effect that seldom results in over-stunting of treated plants. The low activity of daminozide and its lack of soil activity make it easier to get consistent, predictable responses than with the newer, more potent PGR chemistries. Plants should be well-irrigated prior to treatment but foliage should be dry at the time of treatment. Do not irrigate overhead for 18 to 24 hours after treatment. The low activity also means that daminozide must be applied more frequently to maintain control over vigorous crops. Generally, foliar sprays of 2500 to 5000 ppm are applied every 10 to 14 days as necessary. Daminozide is labeled for use on containerized or bed-grown crops in the greenhouse and on containerized plants grown outdoors under nursery conditions. Frequency of application may need to be increased to weekly for more vigorous cultivars grown outdoors.

Chlormequat chloride (Cycocel, Citadel or Chlormequat E-Pro; REI = 12 hrs.) is another PGR with a long history in floriculture. Note that the product use labels for these three chlormequat chloride products

vary in application limits. See the label for your product for the specific rates and sites of application. Chlormequat chloride is generally applied as a foliar spray at 200 to 3000 ppm with a maximum of three to six applications per crop cycle depending on which product you use. Rates above 1500 ppm often cause chlorosis on young treated leaves of floricultural crops. Chlormequat chloride also promotes earlier flowering and greater flower numbers on hibiscus and geranium (*Pelargonium*). Chlormequat chloride is also labeled for drench applications at rates of 2000 to 4000 ppm when applied inside a greenhouse depending on the specific product label (Table 12.1).

Of these three chlormequat chloride products, only Cycocel is labeled for use on containerized plants in the outdoor nursery where it may be applied at a maximum spray rate of 3000 ppm up to three times in any crop production cycle. This limit includes any applications of Cycocel combined with daminozide. Drench applications of Cycocel are not permitted in the outdoor nursery, even on containerized plants. Read the pesticide label for your product. It is the law for application sites and rates. Chlormequat chloride is not labeled for application through the irrigation system.

A **daminozide/chloremquat chloride Tank Mix** has more PGR activity than either daminozide or chloremequat chloride alone and generally causes less phytotoxicity than chlormequat chloride applied by itself. Both the daminozide and chlormequat chloride labels have approved tank mix instructions. This combination provides activity that ranges from low (800 ppm daminozide plus 1000 ppm chlormequat chloride) to very high (5000 ppm daminozide plus 1500 ppm chlormequat chloride). This tank mix has been tested on a wide variety of perennials. For example, three-lobed coneflower (*Rudbeckia triloba*) was very responsive to B-Nine applied twice at 5000 ppm, but not responsive to Cycocel at rates up to 4000 ppm. However, a tank mix of 5000 ppm B-Nine with increasing rates of Cycocel resulted in height control similar to the B-Nine treatments with a single application. Although the rate of daminozide is usually adjusted to increase or decrease activity, changing the chlormequat chloride rate also affects activity. Single applications of the tank mix are frequently more effective than multiple applications of daminozide alone. However, multiple applications of the tank mix may be required for the more vigorous crops.

Ancymidol (A-Rest or Abide; REI = 12 hrs.) is a more active compound than daminozide or chlormequat chloride. Ancymidol is active as a spray or a drench so application volume affects plant response. In addition, ancymidol is labeled for chemigation, i.e., distribution through the irrigation system via flood, sprinkler or drip systems. Follow all label directions. A-Rest is labeled for use as a spray or drench on containerized plants in greenhouses, nurseries, shadehouses and interiorscapes. Abide is not labeled for spray applications in shadehouses or nurseries but drench applications can be made indoors and outdoors. Ancymidol is widely used for treatment of plants in the plug stage. It's relatively high activity and toning ability produces excellent plugs. Ancymidol is more economical applied as a drench rather than a foliar application on finished plants. However, many growers consider ancymidol to be the product of choice for pansy production. Rates vary with cultivar or series. For example, the Delta series is more responsive to PGRs than the Sky/Skyline series.

Flurprimidol (Topflor; REI = 12 hrs.) is similar in chemistry to ancymidol but much more potent. Its activity is similar to that of the triazoles. Many floricultural crops are responsive to flurprimidol. With spray applications, Topflor rates are similar to those used with paclobutrazol. However, in soil applications, its activity is more similar to that of uniconazole. It is labeled for use as a spray, drench, or chemigation on containerized ornamental plants grown in nurseries, greenhouses, and shadehouses. Topflor is only recommended for a few bedding plant plugs and should never be used on the plugs of sensitive crops like begonia, pansy, salvia or vinca. Topflor is very active on most bulb crops like tulips, Oriental lilies, callas, caladiums, and hyacinths, where it is applied as a drench when the new growth is about one-inch tall.

The triazole class of PGRs includes **paclobutrazol** (Bonzi, Piccolo, Paczol, or Downsize; REI = 12 hrs.) and **uniconazole** (Sumagic or Concise; REI = 12). These compounds are much more active than most of the previous compounds. Uniconazole is more potent than paclobutrazol. As mentioned above, the activity of flurprimidol (Topflor) is between these two triazoles depending on application method. These PGRs are rapidly absorbed by plant stems and petioles or through the roots. Excess spray dripping off treated plants acts as a drench to the substrate, increasing the activity of the treatment. For foliar sprays of triazoles, uniform application of a consistent volume per unit area is critical to uniform and consistent crop response. Both compounds (Table 12.2) are labeled for application to the media surface prior to planting plugs. In this case, the PGR is applied as a spray to the surface of the medium in filled pots. The PGR moves into the medium with subsequent irrigations and effectively behaves as a drench.

Take care with applications to sensitive plants. In some cases, excessive stunting can be persistent. Growth of velvet sage (*Salvia leucantha*) was excessively reduced by 45 or 60 ppm Sumagic in the greenhouse. Furthermore, 60 ppm Sumagic caused in a significant delay in landscape growth of the salvia. These compounds must be used carefully and appropriately. Especially when working with the triazoles, thoroughly test your application methods and rates on a small number of plants before treating your entire crop. Avoid late applications of the triazoles. They should be applied prior to flower initiation when possible.

Paclobutrazol has a broad label for ornamentals that includes use on greenhouse or outdoor-grown containerized crops. See Table 12.2 for label restrictions for the different products. All of the paclobutrazol products are labeled for application through the irrigation system, including ebb/flow or flooded floor systems. Do not use paclobutrazol on annual vinca (periwinkle) as it causes spotting or on fibrous begonias which exhibit severe stunting with exposure to paclobutrazol. To establish rates for plants not listed on the product label, treat a small number of plants with 30 ppm as a foliar spray or 1 ppm as a drench. In many cases, multiple treatments with lower rates have been more effective, with less chance of over-stunting, than a single application at a higher rate.

Uniconazole also has a broad label for ornamentals, but its use is limited to containerized plants grown in greenhouses, overwintering structures, shadehouses, or lathhouses. It is not labeled for outdoor nursery use. Uniconazole also is not labeled for application through any irrigation system. Uniconazole has been very effective on a large number of floricultural crops. As with paclobutrazol, avoid using on fibrous begonias. Since it is very potent, pay special attention to proper mixing, uniform application and proper volumes. Use caution in the higher rates or on more sensitive species since uniconazole effects can be persistent in the landscape. NOTE: Ancymidol, flurprimidol, paclobutrazol and uniconazole are persistent on plastic surfaces and in soil. Do not reuse flats, pots or soil from treated plants, especially for plug production of sensitive crops.

B. Enhancing Lateral Branching

Another group of PGRs used in floricultural crops are those that enhance branching, including ethephon (Florel), BA (benzyladenine, Configure), dikegulac sodium (Atrimmec or Augeo), and methyl esters (Off-Shoot-O) (Table 12.3). These PGRs are frequently called “chemical pinchers” because they generally inhibit the growth of the terminal shoots or enhance the growth of lateral buds, thereby increasing the development of lateral branches. They can be used to replace mechanical pinching of many crops like vinca vine, verbena, lantana, and English ivy (*Hedera*).

Ethephon (Florel Brand Pistill (Florel); REI = 48 hrs.) is a compound that breaks down in plant tissue after application to release ethylene, a natural plant hormone. As with ethylene, its effects can vary depending upon the species and the stage of growth at time of application. It has a broad use label (EPA Reg. No. 54705-8) for increasing lateral branching of floricultural crops. Florel is commonly used on zonal and ivy geraniums and poinsettia to increase branching. Florel also inhibits internode elongation

of many plants. Florel controlled runner elongation of clump verbena (*Verbena* 'Homestead Purple') and increased inflorescence numbers of sage (*Salvia* 'May Night') and yarrow (*Achillea* 'Coronation Gold'). You may need to consider combinations of PGRs. For example, if you apply Florel to enhance the branch development of 'Wave' petunias in a hanging basket, you may still need to follow up with a treatment of a plant growth retardant to control the elongation of those new laterals.

Florel should be applied to actively growing plants prior to flower development. If flowers are present at the time of application, they are likely to abort. Florel may delay flowering about one to two weeks, particularly if applied close to the time of flower initiation. Florel should not be applied to plants that are heat or drought stressed. The pH of the water used for the spray solution can be important. If the pH is too high, the ethephon will convert to ethylene before it gets to the plant and activity will be reduced. Florel contains sufficient acidifiers and buffers to maintain a pH of 5.0 or lower when mixed with most greenhouse water supplies. In general, water that has sufficient quality for irrigation of greenhouse crops (moderate pH and alkalinity) is suitable for mixing Florel. However, if you are acidifying your water prior to irrigation, use the acidified water for mixing the Florel as well. The solution should be applied within 4 hours of mixing.

Benzyladenine (6-BA, Configure; REI = 12 hrs.). Configure is a synthetic cytokinin (6-benzyladenine) which is a plant hormone that stimulates lateral branching. It is a relatively inexpensive PGR and enhances branching of a wide variety of floricultural crops. Configure stimulates, but does not cause, an increase in branching. Therefore, timing of the application is critical to a good branching response. Again, read the label for details of when to apply for optimum response. BA has a short period of activity and has no residual in the plant. So, multiple applications may be useful with many crops. Furthermore, it is not well translocated in the plant so thorough coverage is required.

Depending on the timing of the Configure application, BA increases branching of the phyllocades or, when applied during floral initiation, increases the number of flower buds breaking on Christmas cactus. Configure at 500 to 3000 ppm increased basal branching of hosta and at lower rates, 300 to 600 ppm, increased basal branching of *Echinacea*. Further screening trials with other annuals and herbaceous perennials have identified a large number of crops with increased basal or lateral branching in response to Configure. We have found few incidences of phytotoxicity on herbaceous perennials with Configure application at 600 ppm. However, pansy and *Exacum* are very sensitive to spray applications of Configure with long-lasting leaf yellowing even at low rates, 50 to 100 ppm. So, consider multiple applications at low rates. Several growers report successful use of Configure to increase the number of shoots on plugs/liners.

Although the primary objective with Configure is to increase branching, it has resulted in growth reduction in some crops. However, if additional growth control is necessary, we have found that growth retardants may be used immediately following the Configure treatment without reducing the branching response.

Dikegulac sodium (Atrimmec, Augeo; REI = 12 hrs.) is a compound that interferes with terminal growth by inhibiting deoxyribonucleic acid (DNA) synthesis which is required for new growth. By primarily inhibiting terminals, apical dominance is reduced which enhances the production of lateral branches. Note that this mode of action tends to cause a delay in the resumption of plant growth and may add 2 to 4 weeks to production time. Take care not to overwater or over-fertilize during this period. Atrimmec is labeled for use on containerized and landscape woody ornamentals, but also is labeled for use on begonia, bougainvilla, kalanchoe, ivy geranium, lantana, buddleia, and ivies. The EPA label for Augeo was submitted in October 2009 with an REI of 4 hrs. and a broad use label on greenhouse ornamentals as well as container-grown and landscape ornamentals and trees.

Dikegulac sodium should be applied to actively growing plants with at least two nodes to provide sufficient lateral development. In addition to creating a fuller plant, enhancing the number of laterals in a pot generally

reduces the overall height of the plant due to the greater distribution of resources. Responses are very species-specific so test several rates under your growing conditions. Dikegulac sodium usually causes leaf chlorosis which can be very persistent at higher rates (above 1500 ppm). Other phytotoxic responses, including malformed flowers, have been noted at higher rates on perennials such as gayfeather (*Liatris spicata*).

C. Enhancing Plant Flowering

Plant growth regulators can be used to enhance flowering. To improve flowering, Florgib, ProGibb or GA3 4%, which contain the growth promoter gibberellic acid (GA3), can be used to substitute for all or part of the chilling requirement of some woody and herbaceous ornamentals typically forced in the greenhouse, including azalea for florist crops and asters for cut flowers. These compounds also can improve flowering and/or bloom size of camellia and baby's breath (*Gypsophila*), promote earlier flowering and increased yield of statice (*Limonium*) and induce of flowering of *Spathiphyllum*. Gibberellic acid also is used to promote growth and increase stem length of other cut flowers like stock (*Matthiola*), delphinium, and sweet william (*Dianthus*). See product labels for specific uses and recommended rates. Again, timing is critical since late applications, or excessive rates, may cause excessive plant stretching resulting in weak, spindly stems. Chlormequat chloride (a plant growth retardant) used to control stem height of hibiscus and geranium also improves early flowering of these crops.

D. Removal of Flowers

Flower removal is especially desirable for stock plants maintained for cuttings of vegetatively propagated ornamentals, like verbena or lantana. Florel (ethephon) is the primary compound used for flower removal. Once ethephon is absorbed by the plant it is converted to gaseous ethylene, a natural plant hormone effective in many plant processes. Ethylene is the primary hormone responsible for flower senescence and fruit ripening. It is the "postharvest" hormone. With proper rates and timing, it will remove unwanted flowers from stock plants, cuttings, or plugs. Flower removal diverts more energy into vegetative growth and increases the number of laterals available for cuttings on stock plants. It also promotes increased branching of plugs and finished plants which increases fullness in the container. Since initiation and development of flowers requires time, Florel should not be used on crops within six to eight weeks of marketing.

C. Other PGR Uses

Another specific application of the gibberellin and cytokinin products (Fascination or Fresco) is the reduction of lower leaf yellowing on Easter, Oriental, and LA hybrid lilies. See the label for detailed instructions. These products also may be used to increase bract expansion in poinsettias. Fascination, ProGibb and GA3 4% are labeled to promote the growth of plants that have been over-regulated by plant growth retardants. These PGRs are very potent growth promoters. Start with low rates, 1 to 3 ppm, and apply at 5 day intervals as necessary.

Read the Label!

Plant growth regulators are classified as pesticides. Therefore, they are subject to all of the same USDA recordkeeping and Worker Protection Standard (WPS) rules as all of your other pesticides. Their use is governed by the manufacturer's label as with other pesticides. The label not only contains information on restrictions, but also much information on how to use the product effectively. Before going to the time and expense of applying PGRs to your crop, answer these questions:

- Is the chemical labeled for the crop you wish to treat? Most PGR labels have undergone revisions that apply to a broad range of similar crops not specifically listed on the label, with the user taking responsibility for determining appropriate rates. This provides label permission to use the compound on these crops without the manufacturer accepting the responsibility for the rate selection.

- Is the chemical labeled for the area you wish to treat? Many of the PGRs are only labeled for use inside a greenhouse or other growing structure.
- Are there any potential side effects such as phytotoxicity? Note that you may need to look elsewhere for this information for your specific crop.
- Are there label warnings regarding the PGR's effect on plant flowering? For example, many branching enhancers delay flowering. Florel causes flower bud abscission prior to enhancing branching, and is not recommended within six to eight weeks of marketing. Side effects are frequently affected by the timing of the application; e.g., late applications of growth retardants may delay flowering.

Always follow the label for mixing and application instructions. Many of these products require a thorough shaking before dispensing. For best results use only clean equipment that is dedicated to PGRs. Do not use sprayers that may contain other pesticide residues. In general, PGR labels restrict the addition of wetting agents and tank mixing with other pesticides or fertilizers. See the label for specific applications that recommend additional adjuvants. Follow label directions exactly in mixing PGR solutions and apply them on the same day as they are prepared. Store PGRs tightly sealed in their original containers in a cool, dry, dark place.

Application Guidelines

Spray Applications
Plants to be treated with PGRs should be healthy, turgid and unstressed – never wilted. The label will identify the target tissue for that PGR. For example, daminozide is only effective as a foliar spray whereas paclobutrazol and uniconazole sprays must reach the stems. When making spray applications, look at the growth and development of the plant to see that there is sufficient development to make the treatment effective and to accomplish your goal. Generally, there should be sufficient foliage or stems to absorb the PGR.

Uptake and effectiveness of a PGR also depend on selecting the application technique that will ensure proper coverage of the target tissue. Daminozide is not soil active and is fairly immobile in the plant. Therefore, a foliar spray application, wetting most of the foliage, is necessary to provide a uniform reduction in growth. Leaf surfaces should be dry for foliar applications and the best uptake of PGRs from spray applications will occur under low stress, low drying conditions. This is more critical for daminozide and ethephon than for some of the newer chemistries like the triazoles. Overhead irrigation after treatment with daminozide or ethephon should be delayed for 18 to 24 hours to avoid washing the material off of the leaves.

The triazoles, paclobutrazol and uniconazole, are absorbed primarily by stem tissue and then translocated upwards in the plant. Therefore, consistent and complete coverage of the stems is necessary for uniform effects. In other words, if the stem of one lateral receives an inadequate amount of spray, it will grow faster than the others, resulting in a poorly shaped plant, most noticeable in potted crops like poinsettia or chrysanthemum. Ancymidol and flurprimidol are taken up by both foliage and stems. In addition, all four of these compounds are very "soil active" which means they may be adsorbed to particles in the media and become available to the plant through root uptake. Therefore, drenching is a very effective application method for these chemicals in crops where it is economically feasible.

The label will provide a recommended application volume for sprays, especially for chemicals that are soil active. All foliar applications of PGRs should be applied on an area basis, i.e., uniformly spray the area where the plants are located with the recommended volume of solution. Do NOT spray individual plants or spray to reach a subjective target like "spray to glistening." Since every applicator will have a slightly

different definition of these goals, there will be no way of recommending appropriate rates or obtaining predictable results. For soil active PGRs, dosage is dependant on both concentration of the solution and the volume of that solution applied in the treated area. Therefore, to improve predictability, the label-recommended spray application rates are generally set at 2 quarts of finished spray per 100 square feet, which is sufficient to cover the plant and permit a small amount of runoff onto the medium. It also is considered to be a comfortable walking pace for applicators with hand-held sprayers. This is the same application volume recommended for daminozide which is not soil-active.

With the soil active PGRs, precautions should be taken to avoid over-application with sprays. Spray applications require more attention to detail because overspray material lands or drips onto the medium. The overspray from a 2 quarts per 100 square feet application is a part of the recommended dosage. However, if your application volume exceeds that recommendation, then your application dosage also exceeds the recommendation. Recognizing that stem coverage is necessary for the triazoles, you may need to apply a higher than recommended volume to large or dense plants to obtain adequate coverage. In fact, the paclobutrazol label recommends a spray volume of 3 quarts per 100 square feet for "larger plants with a well developed canopy." Adjust the concentration you apply accordingly. This suggests the importance of record-keeping (see below). Always consider the rates presented in Table 12.4, on PGR product labels, or from any other resource, to be a **guideline** to assist you in developing your own rates based on your growing conditions and application methods.

The relationship of rate and volume can be exploited when treating multiple crops with different PGR needs. With a single solution of PGR in the spray tank, you can apply the label recommended volume to attain your basic application dosage or you can apply additional volume to crops that need additional growth regulation to attain a higher dosage. Application volume is another tool that you can use to maximize your efforts and reduce time mixing or reloading higher concentrations of PGR solutions.

Spray Equipment

To assure proper spray volumes, your compressed air sprayer should be equipped with a pressure gauge and regulator and you should consistently use the same nozzle for all PGR applications. Your sprayer should be calibrated by determining the output of the chemical with the selected nozzle at the selected pressure within a specified time period. Using this information, you can apply a known amount of material to a known area. Spray droplet size also affects response with smaller droplet sizes providing better coverage, but only up to a point. Mist or fog type applicators do not provide adequate volume for coverage of plant stems and the medium, and have not been effective when used with compounds like paclobutrazol and uniconazole. PGR applicators should be trained to uniformly apply a given amount of clear water in the greenhouse before they make PGR applications. Uniformity of the application is critical to the uniformity of the crop response.

Applying Drenches

Although drench applications have several advantages over sprays, traditional drenches are seldom used on perennials due to the higher application costs of handling individual pots. Drenches generally have less effect on flowering or flower size, and tend to provide longer lasting growth regulation than sprays. Drenches are easier to apply uniformly than sprays because the drench volume is easily measured, and when applied to moist media, it is easy to obtain good distribution of the PGR in the media. Therefore, the resulting growth

Pot diameter (inches)	Drench volume (fl. oz. per pot)	Drench volume (ml per pot)
4"	2	60
5"	3	90
6"	4	120
8"	10	300
10"	25	750
12"	40	1200

Table 12.1 Volume recommendations for drench applications.

regulation is frequently more uniform. The product label specifies the recommended volumes for drench applications to different size pots or types of media. In general, 4 fluid ounces of drench solution is applied to a six-inch "azalea" pot, and that volume is adjusted up or down with pot size to obtain a volume where about 10% of the solution runs out the bottom of the pot when the media is moist. Remember that the amount of active ingredient applied to plants depends on both the concentration (ppm) of the solution and the volume applied. **Read the label.**

Alternative methods of applying PGRs directly to the media have been developed and are described on the label. For example, ancymidol, flurprimidol, and paclobutrazol are labeled for application through the irrigation system ("chemigation"). These are generally labeled for flood (sub-irrigation), drip irrigation and overhead sprinkler systems. Again, rates vary with the volumes used and method of application. Paclobutrazol applied once by sub-irrigation requires 50% to 75% of the amount of paclobutrazol that is applied in a typical drench application. Pressure compensated drippers are recommended for use with PGRs to more accurately regulate the volume of solution applied to each pot. Read and exactly follow the label for chemigation applications, especially with regard to safety of municipal water supplies.

Three other methods of providing a drench type application of soil-active PGRs on a more economical scale are being used by growers. One is **media surface application** sprays. These are spray applications made to the surface of the media of filled flats or pots. The treatment is applied at normal to high spray volumes, but since it is applied to the media surface it is activated by irrigation and is available to the plant in the root zone. Both paclobutrazol and uniconazole are labeled for this method of application. Rates are lower than used for sprays, but higher than used for drench applications. A second method is called **"sprenches"** which is a high volume foliar spray that results in additional runoff into the media, providing a drench effect. Rates are lower than what is recommended for spray rates. A third technique is called **"watering in"** is a type of chemigation where the PGR is injected into the irrigation water and applied at each irrigation at very low rates of active ingredient. Only PGRs labeled for chemigation can be used for watering-in. All of these application methods use the relationship between rate and volume to provide the desired control. Again, you must develop techniques that fit your production methods and your growth management preferences.

Liner dips or drenches are another specialized way to use soil active growth retardants. Although many of the soil active PGRs have been tested, only Paczol (paclobutrazol) is labeled for this application (Table 12.2). The root system of rooted liners or plugs is dipped into a solution of the PGR (or they may be thoroughly drenched in the plug tray). Extensive work has been conducted at the University of Florida on this application method:

- Liners should be "dry" (root ball being ready for irrigation), but not under drought stress.
- Time in the solution is not critical; 30 sec to 2 minutes is sufficient for saturation of the rootball.
- Liners may be planted immediately or held up to 10 days without loss of PGR effect.
- There is no loss of effectiveness of the dip solution during treatment.

Advantages of the liner dip include early control of very vigorous crops and flexibility of the treatment with respect to not having to handle plants during the restricted entry interval (REI). The liner dip is especially useful in combination plantings where the more vigorous plants can be treated prior to planting without reducing the growth of the slower plants in the group. The liner dip rates should be selected to provide early control of plant growth. Additional applications can be made as necessary for longer term crops.

Be Aware of Bark. For many years, the adage in PGR drenches has been "Bark ties up soil-active PGRs." However, new research shows that this is not necessarily true. As long as the bark is properly aged before the media is mixed, it has little effect on the availability of these soil active PGRs to the plant roots. Again, you must identify PGRs and rates that work with your production system.

Growing Conditions. Look for label recommendations on time of day or condition of the plant for optimum treatment response. Generally, a healthy, unstressed plant growing under low evaporative conditions, e.g., early in the morning or late in the afternoon, is most responsive to treatment. To maximize uptake, the chemical must remain in contact with the leaf long enough to be absorbed. This time varies for the different PGRs, but generally foliar uptake is enhanced with slower drying conditions which in turn increases the effectiveness of the treatment. This is especially important with foliar uptake of PGRs like daminozide, chlromequat chloride, Configure or Florel. Plants treated with daminozide or Florel should not be overhead irrigated for at least 18 to 24 hours after treatment, but plants treated with flurprimidol, paclobutrazol or uniconazole may be irrigated one hour after treatment. Read the label for any warnings on how irrigation or environmental conditions will affect plant response to the PGR treatment.

Recordkeeping

Keeping notes on your application methods and the results of your PGR treatments will allow you to improve the consistency of your own application methods and establish rates and volumes appropriate your production system. Note the concentration and the volume applied, the stage of development of the crop (number of leaves, approximate height, presence of flowers), and the environmental conditions under which the PGR was applied. It is always recommended to keep a few untreated plants for comparison, especially if you are new to using PGRs.

Summary

The degree of growth regulation caused by PGRs is impacted by all other phases of plant culture. Remember that you have to fit PGRs into your own production program. Plan ahead to achieve the best results from PGRs; do not use them as an afterthought when the plants are out of control. You cannot "shrink" an overgrown plant!

The multitude of variations possible in application methods, cultivar and species grown, and growing conditions make it impossible to recommend specific rates for all operations. Use the product labels and Table 12.4 as a resource for the use of PGRs on a variety of crops. In the Mid-Atlantic and South, use the lower of suggested effective rates for starting your own trials.

There are a couple of general rules for using rate recommendations from other sources:

1) Southern growers use higher rates and more frequent applications than Northern growers. Rates for Virginia/Maryland tend be closer to the Southern rates.
2) Outdoor applications usually require higher rates or more frequent applications than for plants grown under cover.

Always consider any rate recommendation as a starting point for your own trials and keep records of your successes and failures with PGRs. Whenever you treat your crop, hold back a few untreated plants so that you can judge the effectiveness of your treatment. Remember that application methods have significant effects on results. Develop, test and refine your own program. Watch for new PGR compounds and for expanded labeling of current products as we develop more guidelines for their use on perennials.

Recommended Resource

PGR Calculator: A resource on preparing PGR solutions developed by specialists at North Carolina State University and the University of New Hampshire: http://www.nhfloriculture.com. Microsoft Excel spreadsheet to enter your own PGR costs and calculate solutions based on the rate desired and the amount of area to be treated. The spreadsheet includes information on both spray and drench applications, giving the amount of PGR to mix per gallon or liter of water, and the cost of the application based on the area or number of containers treated.

Table 12.1 Plant Growth Regulators Used To Reduce Plant Height

Common Name/Trade Name(s)	Application Methods	Comments	Concerns
Ancymidol **A-Rest** (SePRO Corp.) **Abide** (Fine Americas, Inc.)	Foliar spray Bulb dip Drench Chemigation Injection	Broad spectrum label. Very safe. Very active on many bedding plants (except geraniums and impatiens); commonly used on plugs. **A-Rest** labeled for use as spray or drench on containerized ornamentals grown in nurseries, greenhouses, shadehouses and interiorscapes. **Abide** label prohibits spray applications in shadehouses or nurseries. Drench applications can be made indoors or outdoors.	Relatively expensive for many crops, but used extensively on plugs. Maximum spray rate is 132 ppm. Do not add wetting agent. Follow all label directions for all chemigation uses. Do not reuse pots, trays or media previously treated with ancymidol.
Chlormequat chloride **Cycocel** (OHP) **Citadel** (Fine Americas, Inc.) **Chlormequat E-Pro** (Etigra LLC)	Foliar spray Drench	Standard for geraniums, poinsettias, and hibiscus; enhances flowering of geranium and hibiscus. Label allows use on a broad spectrum of crops in the greenhouse. Activity is low; multiple applications generally required. Increased activity when tank mixed with daminozide. Only Cycocel is labeled for use as a spray on containerized plants in the outdoor nursery (max 3000 ppm three times in any crop production cycle).	Causes discoloration of leaves especially with rates above 1500 ppm; phytotoxicity reduced in tank mix with daminozide. Less effective under high temperature conditions.
Daminozide **B-Nine 85WSG** (OHP, Inc.) **Dazide 85WSG** (Fine Americas, Inc.)	Foliar spray Cutting dip	Apply uniformly to all foliage. No soil activity. Effective on a broad list of species, but low level activity and short residual; multiple applications generally required. Increased activity when tank mixed with chlormequat chloride. Labeled for use on beds and containers in greenhouses, shadehouses and nurseries. Limited to containerized plants in uncovered production areas.	Safe. Few incidences of phytotoxicity or overstunting. Do not overhead irrigate within 24 hrs. after treatment.

Table 12.1 Plant Growth Regulators Used To Reduce Plant Height (continued)

Common Name/Trade Name(s)	Application Methods	Comments	Concerns
Flurprimidol **Topflor** (SePRO Corp.)	Spray Drench Chemigation Subirrigation	Labeled for use as spray or drench on containerized ornamental plants grown in nurseries, greenhouses, and shadehouses (greenhouses only in New York).	Do not use on plugs of begonia, pansy, salvia or vinca. Do not use wetting agents or reuse pots, trays or media previously treated with flurprimidol.
Paclobutrazol **Bonzi** (Syngenta Crop Protection) **Piccolo** (Fine Americas, Inc.) **Paczol** (OHP, Inc.) will also be available in 2010 as a 10x concentrate (4% a.i.). Fine Americas is also developing a granule formulation. **Downsize** (Greenleaf Chemical, LLC) is labeled only for drench applications indoors or outdoors, manually or through chemigation.	Spray Media spray (Paczol only) Drench Bulb dip Liner dip (Piccolo only) Chemigation Subirrigation	Labeled for use as spray or drench on containerized ornamental plants grown in nurseries, greenhouses, shadehouses and interiorscapes. Apply uniformly to cover stems (not absorbed by leaves). Much more active than above PGRs; measure accurately. Spray procedure and uniformity greatly affects results. Sprays are limited to enclosed areas (greenhouses) to eliminate drift. Very soil active as a drench.	Spray volume critical to establishing rates due to drench effect of runoff. Use higher rates under high temperature conditions. Late applications can reduce flowering. Phytotoxicity includes overstunting and may cause black spots on vinca. Avoid drift onto non-target plants. Agitate spray solution often for uniform concentration. Do not reuse pots, trays or media previously treated with paclobutrazol.
Uniconazole **Sumagic** (Valent USA Corp.) **Concise** (Fine Americas, Inc.)	Spray Media spray Drench Bulb dip Liner dip (mums)	Labeled for use as spray or drench on containerized ornamental plants grown in greenhouses, lathhouses, and shadehouses. Not labeled for chemigation. Apply uniformly to cover stems (not absorbed by leaves). Spray procedure and uniformity greatly affects results. Very soil active as a drench. **Sumagic** also is labeled for greenhouse grown fruiting vegetable transplants (see Supplemental Label). Fine Americas is also developing a granule formulation of **Concise.**	Spray volume critical to establishing rates due to drench effect of runoff. Use higher rates under high temperature conditions. Do not add wetting agents. Late applications can reduce flowering. Phytotoxicity includes overstunting. Avoid drift onto non-target plants. High leaching potential. Do not apply to pots on dirt floors. Do not reuse pots, trays or media previously treated with uniconazole.

Table 12.2 Other Plant Growth Regulators Used In The Production of Floricultural Crops

Common Name/Trade Name(s)	Application Methods	Comments	Concerns
Ethephon **Florel® Brand Pistill** (Monterey Chemical Co.)	Foliar spray	Promotes lateral branching, thereby reducing stem elongation. Also aborts flowers; improves stock plant branching and cutting yield. Use early in crop cycle to increase branching and remove early flowers (6-8 wks before flowering). Reduces height and stem topple of potted daffodils and hyacinths.	The pH of spray solution should be below 5.0. Has no drench activity. Use within 4 hours of mixing. Results less predictable under high temperature conditions. Do not treat plants under environmental stress conditions.
Benzyladenine **Configure** (Fine Americas, Inc.)	Foliar spray	Enhances lateral branching of greenhouse grown containerized ornamentals. Not labeled for chemigation.	May need to add wetting agent for waxy crops. Not translocated in plant so thorough coverage required. Short residual. Multiple applications may improve response.
Benzyladenine/ GA4+7 **Fascination** (Valent USA) **Fresco** (Fine Americas, Inc) **Gibberellic acid** (GA3) **ProGibb T&O** (Valent USA) **Florgib 4L** (Fine Americas, Inc.) **GA3 4%** (Greenleaf Chemical, LLC)	Foliar Spray	Growth promoter and labeled for prevention of leaf yellowing and to delay flower senescence of Easter, Oriental, and *Lilium longiflorum* x LA hybrid lilies. Fascination, ProGibb, and GA3 4% are labeled for growth promotion to overcome growth retardant effects on containerized and field grown ornamentals. Labeled for: substitution of cold to force flowering azaleas; to inhibit flower buds on vegetative azaleas; peduncle elongation of pompom mums; earlier flowering and increased yield of statice; induction of flowering of *Spathiphyllum*.	Effective dose strongly affected by volume (soil active). Thorough coverage required. Over application or incorrect timing can cause weak stems and excessive stem elongation. Very potent growth promoter. Start with 1 ppm on most crops. Avoid application to plants under conditions of environmental stress. To overcome stunting, start with low rates, 1 to 3 ppm. Repeat in five days if necessary.

Table 12.2 Other Plant Growth Regulators Used In The Production of Floricultural Crops (continued)

Common Name/Trade Name(s)	Application Methods	Comments	Concerns
Dikegulac sodium **Atrimmec** (PBI Gordon) **Augeo** (OHP, Inc. – label submitted Oct. 2009)	Foliar spray	Broad label lists greenhouse, nursery and field sites. Inhibits terminal growth, thereby promoting lateral development. Apply to actively growing plants with at least two nodes to provide sufficient lateral development. Atrimmec labeled for several floricultural crops including begonia, bougainvilla, kalanchoe, ivy geranium, lantana, buddleia, ivies. Augeo has proposed a broad use label for greenhouse crops.	May significantly delay plant development, especially at higher rates. Adjust water and fertilizer according to growth. Causes leaf chlorosis which may be persistent at high rates. Do not pinch or prune soon after treatment. Do not add wetting agents.
Methyl esters of fatty acids **Off-Shoot-O** (Cochran Corp.)	Foliar spray	Labeled for chemical pinching of actively growing azalea, cotoneaster, juniper, ligustrum, *Rhamnus*, and *Taxus*.	Ensure coverage of growing points. Do not spray more than once.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses

This table lists labeled rates of plant growth regulators (PGRs) for greenhouse crops, as well as recommendations based on research at North Carolina State University and recommendations by suppliers. Read the label for a complete listing of precautions. The degree of control can vary depending on a number of factors, including plant type, cultivar, stage of development, fertilization program, growing temperatures and crop spacing. When using a PGR for the first time, it is good to test the rate on a few plants prior to spraying the entire crop. Keep accurate records and adjust rates for your location. **General recommendations:** Plug culture and flat culture have different recommended rates. The rates in this table include recommendations for both plug (lower rates) and flat culture (higher rates). Apply ALL foliar sprays of plant growth regulators using 0.5 gallon per 100 square feet of bench area.

Chemical Name	Trade Name	Rate	Precautions and Remarks
BEDDING PLANTS (GENERAL)			
To control plant height			
Ancymidol	Abide / A-Rest	6 to 66 ppm spray (2.9 to 32 fl oz/gal)	Spray to the point of runoff when treating individual plants.
		0.06. to 0.12 mg a.i. drench for a 4-in. pot (0.5 to 1 fl oz/gal of drench solution; apply 2 fl oz/4-in. pot)	Drench volumes and mg a.i. vary with pot size.
Daminozide + Chlormequat chloride	B-Nine/ Dazide + Chlormequat E-Pro/ Citadel/ Cycocel	800 to 5,000 ppm daminozide (0.13 to 0.79 oz/gal) + 1,000 to 1,500 ppm chlormequat chloride (1.08 to1.63 fl oz/gal) applied as a tank-mix spray	Use the highest rate of chlormequat chloride that doesn't cause excessive leaf yellowing, and then adjust the daminozide rate up and down within the labeled range to attain the desired level of height control.
Paclobutrazol	Bonzi/ Paczol/ Piccolo	5 to 90 ppm spray (0.16 to 2.88 fl oz/gal). Use230 ppm spray (0.96 fl oz/gal) as a base rate and adjust as needed.	Conduct trials on a small number of plants, adjusting the rates as needed for desired final plant height and duration of height control. Not recommended for use on fibrous begonia or vinca.
Paclobutrazol	Bonzi/ Downsize/ Paczol/ Piccolo	0.118 mg a.i. drench for a 6-in. pot (0.032 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Drench applications are recommended only for bedding plants in 6-in. or larger containers. Not recommended for use on fibrous begonia or vinca.
Chlormequat chloride	Chlormequat E-Pro/ Citadel/ Cycocel	800 to 1,500 ppm spray (0.87 to 1.63 fl oz/gal)	Conduct trials on a small number of plants, adjusting the rates as needed for desired final plant height and duration of height control.
Uniconazole	Concise/ Sumagic	1 to 50 ppm spray (0.23 to 11.64 fl oz/gal)	Conduct trials on a small number of plants, adjusting the rates as needed for desired final plant height and duration of height control. Apply spray as elongation begins (plant height about 2 to 4 in.).
		0.1 to 2 ppm drench (0.03 to 0.51 fl oz/gal)	

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
BEDDING PLANTS (GENERAL)			
To promote plant growth and overcome over- application of gibberellin- inhibiting PGRs			
Gibberellic acid	GA3 4%/ ProGibb T&O	1 to 25 ppm spray (0.003 to 0.09 fl oz/gal)	Conduct trials on a few plants initially using 1 ppm unless previous experience warrants higher use rates. Following plant response assessment, reapplication or an increase in rate may be warranted. Consult label for other precautions.
6-benzyladenine + gibberellins A4A7	Fascination	1 to 25 ppm spray (0.02 to 0.18 fl oz/gal)	Conduct trials on a small number of plants initially using 1 ppm unless previous experience warrants higher rates. Following plant response assessment, reapplication or an increase in rate may be warranted. The most common rates for use are 3 to 5 ppm. See label for additional precautions.
To induce lateral or basal branching			
6-benzyladenine	Configure	50 to 500 ppm spray (0.3 to 3 fl oz/gal)	The supplemental label allows legal use on greenhouse grown plants not specifically listed on the original label. See label for trialing suggestions and precautions.
CHRYSANTHEMUM (POTTED)			
To control plant height			
Ancymidol	Abide/A-Rest	25 to 50 ppm spray (12.1 to 24.2 fl oz/gal)	
		0.25 to 0.5 mg a.i. drench for a 6-in. pot (1 to 2 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Apply when plants are 2 to 6 in. in height (about 2 weeks after pinch). Drench rates and application volumes vary with pot size.
Daminozide	B-Nine/ Dazide	1,000 ppm preplant foliar dip (0.16 oz/gal)	Dip rooted cuttings in solution to thoroughly wet leaves and stems before potting. Let foliage dry before watering. Dip unrooted stems in solution, remove to flat, cover to prevent dehydration and hold overnight under cool conditions. Stick the next day.
		2,500 to 5,000 ppm spray (0.39 to 0.79 oz/gal)	Spray when new growth from pinch is 1 to 2 in. long. Some varieties may require another application 3 weeks later.
Paclobutrazol	Bonzi/ Baczol/ Piccolo	50 to 200 ppm spray (1.6 to 6.4 fl oz/gal)	Applications should begin when axillary shoots are 2 to 3 in. long. Sprays can be applied earlier to vigorous cultivars if additional control is desired. Sequential applications of lower rates generally provide more uniformly shaped plant, than single-spray applications.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
Paclobutrazol	Bonzi/ Downsize/ Paczol/ Piccolo	0.118 to 0.473 mg a.i. (1 to 4 ppm) drench for a 6-in. pot (0.032 to 0.128 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Drench volumes and mg a.i. vary with pot size. Begin when the axillary shoots are to 2 to 3 in. long. Uniform application is required.
Uniconazole	Concise	5 to 10 ppm dip treatment on cuttings (1.16 to 2.33 fl oz/gal)	Apply when lateral shoots are 1.5 to 2.0 in. tall (7 to 14 days after pinching). Test for cv. sensitivity. Multiple lower rate applications may elicit a more satisfactory response and/ or increasing spray volume from 2 qts/100 ft^2 to 3 qts/100 ft^2. For medium to tall cultivars, increase spray volume to 3 qts/100 ft^2.
		2.5 to 10 ppm spray (0.58 to 2.33 fl oz/gal)	Apply as a dip treatment on unrooted cuttings followed by a foliar spray in the low rate range. On rooted cuttings, use a solution of 2.5 ppm or less, followed by a foliar spray in the low rate range.
Uniconazole	Sumagic	2.5 to 10 ppm spray (0.58 to 2.33 fl oz/gal)	
Fluprimidol	Topflor	7.5 to 25 ppm spray (0.25 to 0.84 fl oz/gal)	Based on NC State Univ. trials. Adjust rates for other locations. Use lower rates for less vigorous cultivars.
COLEUS (VEGETATIVE)			
To control plant growth			
Daminozide + Chlormequat chloride	B-Nine/ Dazide + Chlormequat E-Pro/ Cycocel	2,500 to 4,000 ppm (0.39 to 0.63 oz/gal) + 1,000 to 1,500 ppm chlormequat chloride (1.08 to 1.63 fl oz/gal) applied as a tank-mix spray	See General Recommendations. Scheduling the crop to avoid excessive stretch is an effective means of controlling growth.
Paclobutrazol	Bonzi/ Paczol/ Piccolo	5 to 30 ppm spray (0.16 to 0.96 fl oz/gal)	
Paclobutrazol	Piccolo	6 to 10 ppm liner root soak (0.192 to 0.32 fl oz/ gal)	Irrigating liners within 24 hrs. prior to application results in a moderately dry substrate (the stage the plants would be watered, but not wilted). Soak for a minimum of 30 to 60 seconds. Transplant after 3 hours. Rate based on Mich. State Univ. trials.
Chlormequat chloride	Chlormequat E-Pro / Cycocel	800 to 1,500 ppm spray (0.87 to 1.63 fl oz/gal)	
Uniconazole	Concise/ Sumagic	10 to 20 ppm spray (2.33 to 4.65 fl oz/gal)	

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
GERANIUM			
To control plant height			
Ancymidol	Abide/ A-Rest	26 to 66 ppm spray (12.6 to 32 fl oz/gal	
Paclobutrazol	Bonzi/ Paczol/ Piccolo	5 to 30 ppm spray (0.16 to 0.96 fl oz/gal)	Apply to zonal geraniums when new growth is 1.5 to 2 in. long and to seed geraniums about 2 to 4 weeks after transplanting.
Uniconazole	Concise	3 to 8 ppm spray (0.7 to 1.86 fl oz/gal)	Use lower rates for less vigorous plants and higher rates for more vigorous plants. Flower delay on some cultivars can occur when using rates >6 ppm.
Chlormequat chloride	Chlormequat E-Pro/ Citadel/ Cycocel	800 to 1,500 ppm spray (0.87 to 1.63 fl oz/gal)	Make first application 2 to 4 weeks after planting plugs or rooted cuttings (after stems have started elongating). Multiple applications may be needed.
Uniconazole	Sumagic	3 to 6 ppm spray (0.07 to 1.4 fl oz/gal) for cutting geraniums and 2 to 4 ppm spray (0.47 to 0.93 fl oz/ gal) for seed geraniums	
Fluprimidol	Topflor	15 to 25 ppm spray (0.5 to 0.83 fl oz/gal)	Apply to zonal geraniums when new growth is 1.5 to 2 in. long.
To promote earlier flowering in seed geraniums			
Chlormequat chloride	Chlormequat E-Pro/ Citadel/ Cycocel	1,500 ppm spray (1.63 fl oz/gal)	Make two applications at 35 and 42 days after seeding. Treated plants should flower earlier and be more compact and more well-branched than untreated plants.
Gibberellic acid	GA3 4%/ ProGibb T&O	5 to 15 ppm spray (0.02 to 0.06 fl oz/gal)	Make a single foliar application when first flower bud set is noted. Spray the entire plant until runoff. See label for precautions.
To increase flower number and size in cutting geranium			
Gibberellic acid	GA3 4%/ ProGibb T&O	1 to 5 ppm spray (0.003 to 0.02 fl oz/gal)	Make a single foliar application when first flower bud set is noted. Spray the entire plant until runoff. See label for precautions.
To increase lateral branching			
Dikegulac sodium	Atrimmec	1,562 ppm spray (1 fl oz/ gal)	Labeled for ivy geraniums only.
Ethephon	Florel	300 to 500 ppm spray (1.0 to 1.62 fl oz/gal)	Use lower concentration for ivy geranium. Will also provide some growth retardant effect and delay flowering. Read label for restrictions on timing of applications.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
LILY (EASTER)			
To control plant height			
Ancymidol	Abide/ A-Rest	30 to 132 ppm spray (14.5 to 64 fl oz/gal). Use 50 ppm spray (24.2 fl oz/gal) as a base rate and adjust as needed.	Apply when newly developing shoots are 2 to 3 in. long; a second application when shoots average 6 in. long may be needed.
		0.25 to 0.5 mg a.i. (2 to 4 ppm) drench for a 6-in. pot (1 to 2 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Single drench should be applied when shoots average 3 to 5 in. long. Drench volumes and mg a.i. vary with pot size.
Uniconazole	Concise	3 to 15 ppm spray (0.70 to 3.49 fl oz/gal)	Apply when shoots average 3 in. tall. It's best to make only one foliar application per crop.
		0.03 to 0.06 mg a.i. (0.25 to 0.5 ppm) drench for a 6-in. pot (0.059 to 0.118 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Apply when shoots average 3 in. tall. Use lower rates on cultivars such as 'Nellie White' and higher rates for 'Ace'. For Florida Only: use a solution concentration of between 0.05 to 0.12 mg a.i. (0.4 to 1.0 ppm) drench for a 6-in. pot (0.11 to 0.26 fl oz/gal of drench solution, apply 4 fl oz/6-in. pot).
Uniconazole	Sumagic	3 to 15 ppm spray (0.70 to 3.49 fl oz/gal)	Apply when shoots average 3 in. tall.
		0.03 to 0.06 mg a.i. (0.25 to 0.5 ppm) drench for a 6-in. pot (0.059 to 0.118 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Drench volumes and mg a.i. vary with pot size.
To prevent leaf yellowing			
6-benzyladenine + gibberellins A4A7	Fascination/ Fresco	5 to 10 ppm spray (0.04 to 0.07 fl oz/gal)	
To prevent leaf yellowing and prolong flowers			
6-benzyladenine + gibberellins A4A7	Fascination/ Fresco	100 ppm spray (0.71 fl oz/ gal)	Apply late season (when first bud reaches at least 3 in. in length) and no more than 14 days prior to placement in a cooler or shipping. Apply to foliar and flower buds.
LILY (HYBRID)			
To control plant height			
Paclobutrazol	Bonzi/ Paczol/ Piccolo	200 to 500 ppm spray (6.4 to 16.0 fl oz/gal)	Make first spray application when plants are 2 to 4 in. tall.
		5 to 30 ppm bulb soak (0.16 to 0.96 fl oz/gal)	Soak bulbs in the solution for 15 min. prior to planting.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
Paclobutrazol	Bonzi/ Downsize/ Paczol/ Piccolo	0.25 to 0.5 mg a.i. (4 to 30 ppm) drench for a 6-in. pot (0.14 to 0.96 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Single drench should be applied when shoots average 3 to 5 in. long. Drench volumes and mg a.i. vary with pot size and cultivar.
Uniconazole	Concise	2.5 to 20 ppm spray (0.64 to 4.65 fl oz/gal)	Test to determine optimal rates for each cultivar and adjust as needed. Spray shoots when about 3 in. tall. If a second application is needed or a split application is made, apply when the shoots average 6 in. tall. Usually 2 foliar applications at a lower rate are more effective than 1 application at a higher rate. Do not apply after visible bud stage.
		1 to 3 ppm drench (0.23 to 0.70 fl oz/gal)	Drench volume varies with pot size. Apply newly emerged shoots when 1 to 2 in. tall.
		1 to 10 ppm bulb soak (0.23 to 2.33 fl oz/gal)	Treatment soak time should range from 1 to 5 minutes and will vary depending on bulb size, cultivar, and final desired height. Lower rates may require longer soak times (5 to 10 minutes) than higher rates (1 minute).
Uniconazole	Sumagic	3 to 15 ppm spray (0.7 to 3.49 fl oz/gal)	Apply when shoots average 3 in. tall.
		0.03 to 0.06 mg a.i. (0.25 to 0.5 ppm) drench for a 6-in. pot (0.059 to 0.118 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Drench volumes and mg a.i. vary with pot size.
Fluprimidol	Topflor	0.25 to 0.5 mg a.i. (2.1 to 4.2 ppm) drench for a 6-in. pot	Based on NC State Univ. trials. Adjust rates for other locations.
LILY (Oriental)			
To control plant height			
Paclobutrazol	Bonzi/ Paczol/ Piccolo	100 to 200 ppm bulb soak (3.2 to 6.4 fl oz/gal)	Ten minute soaks provided excellent results in NC State Univ. trials. Cultivar response varied.
Uniconazole	Concise	2.5 to 10 ppm spray (0.58 to 2.33 fl oz/gal)	See Concise label comments for hybrid lilies.
Uniconazole	Concise/ Sumagic	1 to 10 ppm bulb soak (0.23 to 2.33 fl oz/gal)	See Concise label comments for hybrid lilies. Ten minute preplant soaks of 5 ppm (1.16 oz/ gal) provided excellent results in NC State Univ. trials. Cultivar response varied.
Fluprimidol	Topflor	0.5 mg a.i. drench (4.2 ppm); (0.14 fl oz/gal; apply 4 fl oz/6-in. pot)	Optimal rate base on NC State Univ. trials. Adjust rate for plant vigor. Drench volumes and mg a.i. vary with pot size.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
		25 ppm bulb soak (0.84 fl oz/gal)	Ten minute preplant soaks provided excellent results in NC State Univ. trials. Cultivar response varied.
To prevent leaf yellowing			
6-benzyladenine + gibberellins A4A7	Fascination/ Fresco	100 ppm spray (0.71 fl oz/ gal)	Apply early season (7 to 10 days PRIOR or AFTER visible bud stage). Apply spray only to lower leaves to minimize stem elongation.
To prevent leaf yellowing and prolong flowering			
6-benzyladenine + gibberellins A4A7	Fascination/ Fresco	100 ppm spray (0.71 fl oz/ gal)	Apply late season (no more than 14 days prior to placement in a cooler or shipping). Apply to foliar and flower buds.
LINER DIPS			
To control plant height			
Paclobutrazol	Piccolo	0.5 to 8 ppm preplant liner dip (0.02 to 0.51 fl oz/gal)	See label for detailed recommendations for chemical application techniques, adjusting rates for northern or southern locations, and the specific rates for achieving the desired level of activity.
NEW GUINEA IMPATIENS			
To control plant growth			
Paclobutrazol	Bonzi/ Paczol/ Piccolo	0.25 to 15 ppm spray (0.01 to 0.48 fl oz/gal)	Apply 2 to 4 weeks after transplanting. Cultivars' responses to PGRs varies greatly. Test a few plants to determine rate for optimal control.
		0.25 to 2 ppm drench (0.03 to 0.236 mg a.i.)	Drench volumes vary with pot size. See label for recommendations. Cultivars' response to PGRs varies greatly. Test a few plants to determine rate for optimal control.
Ethephon	Florel	100 to 300 ppm spray (0.33 to 1 fl oz/gal)	To increase lateral branching and reduce premature flowering. Don't apply within 8 weeks of desired flower date.
Fluprimidol	Topflor	5 to 15 ppm spray (0.167 to 0.5 fl oz/Gal)	Apply 2 to 4 weeks after transplanting. Cultivars' response to PGRs varies greatly. Test a few plants to determine rate for optimal control.
To control plant growth			
Daminozide + Chlormequat chloride	B-Nine/ Dazide + Cycocel	1,500 to 3,000 ppm (0.24 to 0.47 oz/gal) + 1,000 to 1,500 ppm Cycocel (1.08 to 1.63 fl oz/gal) applied as a tank-mix spray	Multiple sprays required. Stop applications after visible bud to avoid flower delay and smaller flowers. Not effective in NC State Univ. trials.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
Paclobutrazol	Bonzi/ Paczol/ Piccolo	27 to 54 ppm drench (8 to 16 mg a.i.) during production	Drench volumes vary with pot size. See label for recommended volumes. Rates based on NC State Univ. trials.
		2 to 3 ppm drench (0.236 to 0.35 mg a.i.)	For holding plants.
Chlormequat chloride	Cycocel	750 to 1,500 ppm spray (0.82 to 1.64 fl oz/gal)	Two 1500 ppm applications may be required. One applied at the start and the second at end of the vernalization period provided excellent results in NC State Univ. trials.
		1,500 to 3,000 ppm drench (1.63 to 3.26 fl oz/gal)	Drench volumes vary with pot size . See label for recommended volumes. 1,500 ppm worked well in NC State Univ. trials.
Uniconazole	Concise/ Sumagic	3 ppm spray (1.86 fl oz/ gal)	Recommendation based on European trials on a cultivar with prostrate growth. Rates less than 24 ppm were not effective in NC State Univ. trials.
		0.25 to 2 ppm drench (0.06 to 0.47 fl oz/gal; apply 3 fl oz/5-in pot)	One application of 1 to 2 ppm (at start of vernalization) or two applications of 1 ppm (at start of vernalization) and 0.5 ppm (at end of the vernalizatioin period) provided excellent results in NC State Univ. trials for 5-inch production.
Paclobutrazol	Piccolo	4 to 8 ppm liner root soak (0.128 to 0.256 fl oz./gal)	Irrigation of liners that was done within 24 hrs. before application resulted in moderately dry substrate (stage plants are watered but not wilted). Soak for minimum of 30 to 60 seconds. Transplant after 3-hr waiting period. Based on Mich. State Univ. trials.
Flurprimidol	Topflor	20 to 60 ppm spray (0.67 to 2 oz/gal)	
		1 to 2 ppm drench (0.017 to 0.067 fl oz/gal; apply 3 fl oz/5-in pot)	One application of 1 to 2 ppm (at the start of vernalization) or two applications of 1 ppm (at the start of vernalization) and 0.5 ppm (at the end of the vernalizatioin period) to 5-inch pots provided excellent results in NC State Univ. trials.
PANSY			
To control plant height			
Ancymidol	Abide/ A-Rest	3 to 15 ppm spray (1.5 to 7.3 fl oz/gal)	
Paclobutrazol	Bonzi/ Paczol/ Piccolo	5 to 15 ppm spray (0.16 to 0.48 fl oz/gal)	Apply when plants are 2 in. in diameter. Use higher rates for higher temperatures and more vigorous cultivars. Late applications may delay flowering.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
Uniconazole	Concise/ Sumagic	1 to 6 ppm spray (0.23 to 1.40 fl oz/gal)	Apply when plants are 3 to 4 in. tall. Use higher rates for higher temperatures and more vigorous cultivars. Late applications may delay flowering.
Flurprimidol	Topflor	2.5 to 7.5 ppm spray (0.08 to 0.25 fl oz/gal)	Based on NC State Univ. trials. Adjust rates for other locations. Pansies are very responsive to Topflor, so start trials with lower rates.
POINSETTIA			
To control plant height			
Ancymidol	Abide/ A-Rest	0.06 to 0.25 mg a.i. (0.5 to 2 ppm) drench for a 6-in. pot (0.25 to 1 fl oz/ gal of drench solution; apply 4 fl oz/6-in. pot)	Drench volume and mg a.i. vary with pot size. Start with lower rates.
daminozide	B-Nine/ Dazide	2,000 to 3,000 ppm spray (0.31 to 0.47 oz/gal)	Not effective in NC State Univ. studies.
Daminozide + Chlormequat chloride	B-Nine/ Dazide + Chlormequat E-Pro/ Citadel/ Cycocel	800 to 2,500 ppm (0.13 to 0.39 oz/gal) + 1,000 to 1,500 ppm chlormequat chloride (1.08 to 1.63 fl oz/gal) applied as a tank-mix spray	Use the higher rates of this tank-mix spray on stock plants and for finishing crops in very warm regions. Outside of very warm areas, use the lower rates. Late applications can delay flowering and reduce bract size.
Paclobutrazol	Bonzi/ Paczol/ Piccolo	10 to 30 ppm spray (0.32 to 0.96 fl oz/gal)	Begin applications to slower-growing cultivars in cool climates when axillary shoots are 2 to 3 in. long. For vigorous growing cultivars in warm climates, begin applications when axillary shoots are 1.5 to 3 in. long. See label for other precautions.
Paclobutrazol	Bonzi/ Downsize/ Paczol/ Piccolo	0.237 to 0.473 mg a.i. (0.25 to 3 ppm) drench for a 6-in. pot (0.064 to 0.128 fl oz/gal of drench solution; apply 4 fl oz/6-in. pot)	Drenches generally have less of an effect on bract size than sprays. Drench volume and mg a.i. vary with pot size. Start with lower rates.
Uniconazole	Concise	2.5 to 10 ppm spray (0.58 to 2.56 fl oz/gal)	Apply when lateral shoots are 1.5 to 2.5 in. tall (10 to 14 days after pinching) before short day initation. Test for cultivar sensitivity. Multiple lower rate applications may give more satisfactory response.
Chlormequat chloride	Chlomequat E-Pro/ Citadel/ Cycocel	800 to 1,500 ppm spray (0.87 to 1.63 fl oz/gal)	For natural season crops in N.C., don't apply chlormequat chloride after mid-October to November 1. Late applications can reduce bract size and delay flowering.

Table 12.3 Growth Regulators for Floricultural Crops in Greenhouses (continued)

Chemical Name	Trade Name	Rate	Precautions and Remarks
		3,000 to 4,000 ppm drench (3.25 to 4.34 fl oz/gal of drench solution)	Drench volume varies with pot size. Consult the label for recommended volumes.
Uniconazole	Sumagic	2.5 to 10 ppm spray (0.58 to 2.33 fl oz/gal)	
Flurprimidol	Topflor	2.5 to 80 ppm spray (0.08 to 2.69 fl oz/gal)	Use lower rates for less vigorous cultivars. See label for additional rate recommendations.
		0.03 to 0.5 mg a.i. (0.25 to 4.2 ppm) drench for a 6-in. pot	
6-benzyladenine + gibberellins A4A7	Fascination	3 ppm spray (0.02 fl oz/gal)	Use an early-season application during vegetative growth prior to the start of short days and flower initiation if promoting vegetative growth. See label for additional precautions before use.
6-benzyladenine + gibberellins A4A7	Fascination/ Fresco	3 to 10 ppm spray (0.02 to 0.07 fl oz/gal)	Use a late-season application to promote bract expansion. See label for additional precautions before use.

Chapter 13
Cultural Requirements and Pests of Major Greenhouse Crops: Bedding Plants, Herbs, Cut Flowers and Vegetable Transplants

Stanton Gill, Extension Specialist
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Introduction

Bedding plants, whether flowering transplants or vegetable transplants, may only be in the greenhouse for a short period of time, yet still must be kept pest-free and of high quality. Part of the challenge in growing these crops is that there are few pesticides labeled for them: no growth regulators, and few insecticides or fungicides. Most of the pesticides that are labeled are for ornamental bedding plants, not vegetable bedding plants.

Integrated pest management (IPM) tactics offer the most practical way to effectively manage pests on vegetable bedding plants. Growers can improve bedding plant production while minimizing their reliance on routine pesticide applications through the use of regular monitoring of fertility, pH, root health and insect and disease problems. The utilization of many different management options (cultural, physical, mechanical, biological and chemical) is the best way to minimize both pest problems and pesticide use and costs.

When producing vegetable and bedding plant transplants, make sure the crop is grown at the appropriate temperature. For example, some cole crops (e.g. broccoli) may flower prematurely ("button") if grown at too low a temperature. Vegetable bedding plants also benefit from a gradual hardening off period before they are transplanted into the field by gradually exposing them to outdoor growing conditions and reducing watering at the end of the growing period. Up-to-date cultural requirements of each crop can be obtained from your seed supplier. Pay particular attention to scheduling times, light, temperature, and nutritional requirements in order to grow healthy transplants.

Table 13.1 Bedding Plants, Flowering Pot Plants, and Other Tropical Plants Grown In The Greenhouse Key to Levels of Fertilization

*Light fertilization—SME and PourThru EC of 0.25 to 0.50 mS/cm;
**Medium fertilization— SME and PourThru EC of 0.50 to 1.5 mS/cm;
***Heavy fertilization—SME and PourThru EC of 1.50 to 2.5 mS/cm.

Plant (Common name/ Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
African Violet *Saintpaulia ionantha*	Cyclamen mite, mealybugs, whiteflies	*Botrytis*, *Phytophthora* blight, foliar nematode, powdery mildew, *Pythium* root rot, *Rhizoctonia* stem/ crown rot, tospovirus	Very sensitive to cold. Water must be room temperature or injury that resembles a virus or leaf spot disease can occur. Ammonium toxicity can cause leaf yellowing. pH: 5.9–6.4. Light fertilization*
Ageratum *Ageratum houstonianum*	Aphids, whiteflies	None serious	Leave seed exposed to light during germination. Light fertilization*
Azalea *Rhododendron obtusum* *R. simsii*	Lace bugs	Foliar nematode, *Cylindrocladium* blight, root rot, *Phytophthora* root and crown rot	Sensitive to salt Light fertilization*
Bacopa *Sutera cordata*	Spider mites	None serious	Use well-drained mix.
Begonia *Begonia* x *semperflorens cultorum* (*Begonia tuberhybrida*) (*Begonia socotrana* x *B. tuberhybrida*)	Broad mites, fungus gnats, thrips	Bacterial leaf spot, crown gall, cucumber mosaic virus, tospovirus, foliar nematode, powdery mildew, root rots	pH: 5.7–6.3 Light fertilization*
Black-eyed Susan vine *Thunbergia alatus*	Spider mites, whitefly, aphids, leafminer	*Rhizoctonia*, *Pythium* root rot	pH: 5.8–6.2 Medium fertilization*
Bougainvillea *Bougainvillea* spp.	Aphids, mites		Medium fertilization**
Browallia *Browallia speciosa*	Aphids, mites	Tospovirus	
Calla lily *Zantedeschia* sp.	Aphids, spider mites, thrips	Virus, bacterial soft rot of rhizomes	Light fertilization*
Carnation *Dianthus caryophyllus*		Fungal leaf spots	pH: 6.2–6.8 Medium fertilization**

Table 13.1 Bedding Plants, Flowering Pot Plants, and Other Tropical Plants Grown In The Greenhouse Key to Levels of Fertilization (continued)

Plant (Common name/ Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Celosia *Celosia cristata* *C. plumosus* *C. spicata*	Aphids	*Rhizoctonia* damping-off , bacterial leaf spot	Sensitive to cold and to salt Light fertilization*
Chrysanthemum, Florists' *Dendranthema grandiflora*	Aphids, thrips	*Pythium* root and stem rot, tospovirus, *Botrytis*, bacterial leaf spots, fungal leaf spots, Fusarium wilt, foliar nematode	Requires high nitrogen levels pH: 5.7–6.2 Light fertilization*
Cineraria *Pericallis* x *hybrida*	Aphids	Tospovirus, *Botrytis*, *Rhizoctonia* and *Pythium* damping-off	Light fertilization*
Coleus *Solenostemon scutellarioides*	Aphids, slugs, whiteflies, mealybugs	Tospovirus, downy mildew , *Rhizoctonia* root rot/blight, *Botrytis*	Very sensitive to salt Light fertilization*
Cyclamen *Cyclamen persicum*	Fungus gnats, thrips, cyclamen mites	Tospovirus, *Rhizoctonia* root rot, Fusarium corm rot/wilt, bacterial soft rot of corms, *Botrytis*	pH: 5.1–5.8 Light fertilization*
Dahlia *Dahlia* x *hybrida*	Aphids	Tospovirus, root knot nematode, foliar nematode, *Botrytis*, *Pythium*, and *Rhizoctonia* stem/ root/ cutting rot, other viruses	Medium fertilization**
Daisy, sunscape *Osteospermum*	Thrips	None serious	
Dusty miller *Senecio*	Aphids	None serious	Medium fertilization**
Flowering tobacco *Nicotiana*	Whiteflies	TMV, other viruses damping off	Expose seed to light during germination. Medium fertilization**
Fuchsia *Fuchsia* x *hybrida*	Whiteflies	*Botrytis*, tospovirus, black root rot, rust	Light fertilization*
Gardenia *Gardenia jasminoides*	Aphids, mealybugs, spider mites	*Botrytis*	Overwatering or temperature swings can cause bud drop. Light fertilization*
Gazania *Gazania*	Thrips	None serious	
Gerbera daisy *Gerbera jamesonii*	Aphids, thrips	Tospovirus, powdery mildew	pH: 5.6–5.9 Light fertilization*

Table 13.1 Bedding Plants, Flowering Pot Plants, and Other Tropical Plants Grown In The Greenhouse Key to Levels of Fertilization (continued)

Plant (Common name/ Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Gloxinia *Sinningia speciosa*	Aphids, fungus gnats, thrips	Tospovirus, *Botrytis*, *Phytophthora* crown rot	pH: 5.6–5.9 Light fertilization*
Hibiscus *Hibiscus rosa-sinensis*	Aphids, mealybugs, spider mites, whitefly	Bacterial leaf spots, fungal leaf spots, foliar nematode	Medium fertilization**
Hydrangea *Hydrangea macrophylla*	Whiteflies	Powdery mildew, virus	Medium fertilization**
Impatiens *Impatiens wallerana*	Aphids, fungus gnats, thrips	*Pythium* root rot, *Rhizoctonia* root rot, tospovirus; If plugs come in with leaf spots (bacterial or fungal) it can be troublesome; otherwise leaf spots are uncommon.	Light fertilization*
Ivy geranium *Pelargonium peltatum*	Fungus gnats	Botrytis, bacterial blight (*Xanthomonas*)	Oedema may be a symptom-free host for bacterial blight: never grow near zonal geranium. Salt sensitive. Light fertilization*
Lantana *Lantana camara*	Thrips, whiteflies	Foliar nematode	
Lilies (Asiatic and Oriental) Lilium hybrids and Easter lily *Lilium longiflorum*	Aphids, fungus gnats, thrips	Viruses, *Botrytis*, *Pythium* root rot, *Rhizoctonia* root rot	pH: 6.1–6.4 Medium fertilization**
Lobelia *Lobelia erinus*	Spider mites, thrips	Tospovirus	Medium fertilization**
Marigolds *Tagetes*	Aphids, whiteflies	*Botrytis*, fungal leaf spots, white mold (Sclerotinia), *Rhizoctonia* web blight	Some varieties very sensitive to air pollution. pH: 6.0–6.5 Light fertilization*
New Guinea impatiens *Impatiens* x *hawkeri*	Broad mites, fungus gnats, thrips	Tospovirus, *Pythium* root rot, *Rhizoctonia* root rot/blight Myrothecium leaf blight.	pH: 5.7–6.2. Light fertilization*
Pansy *Viola* x *wittrockiana*	Aphids, variegated fritillary caterpillar, whiteflies	Black root rot, *Pythium* root rot, *Rhizoctonia* blight, fungal leaf spots, anthracnose (*Colletotrichum*), *Botrytis*	pH: 5.4–5.8 Light fertilization*

Table 13.1 Bedding Plants, Flowering Pot Plants, and Other Tropical Plants Grown In The Greenhouse Key to Levels of Fertilization (continued)

Plant (Common name/ Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Periwinkle *Vinca minor*, *V. major*		Tospovirus, *Phomopsis* blight (*V. minor*)	Can be a "hidden host" for tospovirus because symptoms can be inconspicuous.
Periwinkle, Madagascar *Catharanthus roseus*	Green peach aphids	Tospovirus, other viruses, black root rot, *Pythium* root rot, *Phytophthora* crown rot	pH: 5.4–5.8 Very sensitive to cold. Minimum temperature: 60° F
Petunia *Petunia* x *hybrida* and other species	Aphids, thrips	Tobacco mosaic virus, tospovirus, other viruses, *Rhizoctonia* damping-off, black root rot, *Botrytis*	Some varieties sensitive to ozone. pH: 5.4–5.8
Phlox *Phlox drummondii*	Aphids	*Botrytis*, fungal leaf spots, foliar nematode, stem and bulb nematode (*Ditylenchus*), powdery mildew, viruses	Medium fertilization**
Poinsettia *Euphorbia pulcherrima*	Fungus gnats, Lewis mite, mealybugs, twospotted spider mites, Whiteflies	*Botrytis*, *Pythium* root rot, *Rhizoctonia*, poinsettia scab	
Primrose *Primula acaulis*	Thrips, whiteflies	Tospovirus, other viruses, *Botrytis*, fungal leaf spots	Light fertilization*
Regal geranium *Pelargonium* x *domesticum*	Thrips, whiteflies	Virus, *Botrytis*	May be a symptom-free host for bacterial blight: never grow near zonal geraniums. pH: 6.0–6.5
Salvia *Salvia splendens* *S. farinacea* *Salvia* x *superba*	Whiteflies, green peach aphids, melon aphids	*Pythium* and *Rhizoctonia* damping-off, tospovirus, downy mildew	pH: 5.4–5.8 100 ppm based on nitrogen Light fertilization*
Scaevola *Scaevola aemula*		TMV, *Pythium* root rot	
Snapdragon *Antirrhinum majus*	Aphids, thrips	Tospovirus, *Pythium* root rot, downy mildew, rust	Chill seeds for several days before sowing to improve germination. pH: 5.4–5.8 100–200 ppm based on nitrogen and potassium Light fertilization*
Stock *Matthiola incana*	Aphids	*Rhizoctonia* root rot, black root rot	

Table 13.1 Bedding Plants, Flowering Pot Plants, and Other Tropical Plants Grown In The Greenhouse Key to Levels of Fertilization (continued)

Plant (Common name/ Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Sweet alyssum *Lobularia maritima*		*Rhizoctonia* root rot	
Sweet William *Dianthus chinensis*	Aphids	Anthracnose, fungal leaf spots, *Pythium* root rot	pH: 6.2–6.8 Medium fertilization**
Verbena *Verbena* x *hybrida*	Whiteflies, thrips	*Rhizoctonia* damping-off, black root rot, powdery mildew, *Botrytis*, viruses	Seed can be difficult to germinate. Medium fertilization**
Zinnia *Zinnia elegans*	Aphids	Bacterial leaf spot (*Xanthomonas*), powdery mildew, *Botrytis*, *Alternaria* leaf spot, *Rhizoctonia* damping-off, tospovirus	Very sensitive to cold: Minimum soil temperature for germination: 70° F Obtain clean seed: bacterial leaf spot and *Alternaria* can be in the seed. Light fertilization*
Zonal geranium *Pelargonium* x *hortorum*	Aphids, cyclamen mites	*Pythium* and *Rhizoctonia* root rot/cutting rots, black root rot, bacterial blight (*Xanthomonas*), rust (*Puccinia pelargonii-zonalis*), *Botrytis*	Oedema pH: 6.0–6.5 Light fertilization*

Chapter 14
Cultural and Pest Management for Vegetables and Herbs

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Kate Everts, Vegetable Plant Pathologist

Introduction

Vegetable bedding plants are a high value spring crop in Maryland. Whether direct seeded or grown out, vegetable bedding plants are only in the greenhouse for a short period of time. Growing a high quality, pest-free transplant in a quick turnover period can be challenging, particularly since there are a limited number of pesticides labeled for greenhouse-grown vegetable bedding plants. Most pesticides labeled for ornamental greenhouse bedding plants are not labeled for vegetable bedding plants. Additionally, there is only one plant growth regulator, Sumagic, that is labeled for fruiting vegetables.

The best way to successfully manage pests on vegetable bedding plants is therefore through the same Integrated Pest Management (IPM) methods described previously in this book. The key to an effective program is monitoring, early detection, proper identification, and early intervention.

Table 14.1 Key Pests of Vegetable Transplants Grown In The Greenhouse

*Light fertilization—SME and PourThru EC of 0.25 to 0.50 mS/cm
**Medium fertilization— SME and PourThru EC of 0.50 to 1.5 mS/cm
***Heavy fertilization—SME and PourThru EC of 1.50 to 2.5 mS/cm

Plant (Common name/Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Broccoli *Brassica oleracea*	Aphids, caterpillars	*Rhizoctonia* root rot, bacterial black rot	Obtain clean seed because bacterial black rot is seed-borne. Light fertilization*
Brussels sprouts *Brassica oleracea*	Aphids, caterpillars	*Rhizoctonia* root rot, bacterial black rot	Obtain clean seed because bacterial black rot is seed-borne. Light fertilization*
Cabbage *Brassica oleracea*	Cabbage-root fly, slugs, caterpillars	*Rhizoctonia* root rot, *Xanthomonas* (black root rot)	Obtain clean seed because bacterial black rot is seed-borne. Light fertilization* Include micronutrients.
Cantaloupe *Cucumis melo*	Aphids, mites, whiteflies	*Pythium* damping-off, leaf spotting from bacterial fruit blotch, watermelon fruit blotch	Susceptible to sunscald when removed from greenhouse and transplanted outside. Sensitive to cold. Minimum night temperature: 60 °F. Light fertilization*
CauliBroccoli *Brassica oleracea*	Aphids	*Rhizoctonia* root rot, bacterial black rot	Obtain clean seed because bacterial black rot is seed-borne. Light fertilization*
Cauliflower *Brassica oleracea*	Aphids, caterpillars	*Rhizoctonia* root rot and damping-off, bacterial black rot	Obtain clean seed because bacterial black rot is seed-borne. Medium fertilization** Include boron in fertilizer.
Chives, common *Allium schoenoprasum*	Aphids	*Rhizoctonia* root rot and damping-off	Light fertilization*
Collards *Brassica oleracea*	Caterpillars	*Rhizoctonia* root rot, bacterial black rot, downy mildew	Obtain clean seed because bacterial black rot is seed-borne. Light fertilization with micronutrients*

Table 14.1 Key Pests of Vegetable Transplants Grown In The Greenhouse (continued)

Plant (Common name/Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Cucumber *Cucumis sativus*	Slugs and snails, spider mites	*Rhizoctonia* root rot and damping-off, leaf/ cotyledon spot from bacterial fruit blotch	Sensitive to cold (min. night temperature is 60 °F). Susceptible to sunscald when removed from greenhouse and transplanted outside.
Eggplant *Solanum melongena*	Aphids	*Pythium* and *Rhizoctonia* root rots and damping-off; stunting and leaf spot from tospovirus	Very sensitive to cold. Injury occurs below 40 °F. Minimum night temperature: 60 °F.
Endive *Cichorium endivia*	Aphids, slugs	*Pythium* and *Rhizoctonia* root rot and damping-off	Light fertilization*
Escarole *Cichorium endivia*	Slugs	*Pythium* root rot	Light fertilization*
Kale *Brassica oleracea*	Caterpillars, slugs	*Rhizoctonia* root rot, bacterial black rot, downy mildew	Obtain clean seed because bacterial black rot is seed-borne.
Kolrabi *Brassica oleracea*	Caterpillars	*Rhizoctonia* root rot, bacterial black rot, downy mildew	Obtain clean seed: bacterial black rot is seed-borne. Light fertilization with micronutrients*
Lettuce *Lactuca sativa*	Root aphids, aphids on foliage, slugs	*Pythium* and *Rhizoctonia* damping-off; tospovirus	Tospovirus causes leaf spot and stunting Light fertilization*
Okra *Abelmoschus esculentus*		*Rhizoctonia* and *Pythium* root rot and damping-off, tospovirus	Difficult to germinate; need to scarify seed
Onions *Allium cepa*	Onion fly	*Rhizoctonia* damping-off *Pythium* root rot, *Rhizoctonia* root rot and damping-off	Pre-germinate
Parsley *Petroselinum crispum*		*Pythium* root rot, *Rhizoctonia* root rot and damping-off	
Peppers *Capsicum* spp.	Aphids, spider mites, thrips	Leaf spot mosaic from tospovirus and other viruses; stunting, leaf distortions, and mosaic from tobacco mosaic virus (TMV); bacterial leaf spots; *Phytophthora* root rot and wilt	Light fertilization*

Table 14.1 Key Pests of Vegetable Transplants Grown In The Greenhouse (continued)

Plant (Common name/Latin name)	Major Pests; Insects, Mites, Arthropods, Mollusks	Major Diseases	Cultural Comments
Pumpkins *Cucurbita* spp.	Aphids, thrips	*Pythium* root rot and damping-off, downy mildew	Light fertilization*
Spinach *Spinacia oleracae*	Leaf miner, slugs	*Pythium* and *Rhizoctonia* root rot damping-off, white rust, downy mildew	Light fertilization*
Squash *Cucurbita* spp.	Slugs, black bean aphids, aphids	*Pythium* and *Rhizoctonia* damping-off	Sensitive to cold Light fertilization*
Tomato *Lycopersicon* spp.	Aphids, mites, thrips, whiteflies	Bacterial spot; bacterial canker; Bacterial spot; bacterial canker; bacterial speck; Septoria leaf spot; damping-off from *Pythium*; *Rhizoctonia* stem canker from *Sclerotinia*; sclerotiorum (timber rot); *Botrytis*; tospovirus-causing leaf spot and stunting; tobacco mosaic virus causing distortions, mosaic, and stunting; damping-off from *Pythium* and *Rhizoctonia*; Cotyledon and leaf spot from bacterial fruit blotch; *Alternaria solan*i	Very sensitive to herbicide drift, especially from 2,4-D, applied near greenhouse. Obtain clean seed: many bacterial and fungal diseases may be seed-borne. Medium fertilization**
Watermelon *Citrullus vulgaris*	Spider mites, whiteflies		Sensitive to cold. Light fertilization*

Table 14.2 Fungicides and Bactericides for Greenhouse Vegetable Production

Fungicide (Trade name, Product Source) Re-entry Interval	Target Diseases	Labeled Plants	Comments
Basic Copper Sulfate (Cuprofix Disperss; United Phosphorus, Inc.) 24 hr. REI	Many diseases including angular leaf spot, downy mildew. *Alternaria* blight, anthracnose, bacterial blight, etc.	Vegetables including cucumbers, eggplant, peppers, tomatoes, etc.	Crops grown in the greenhouse may be more sensitive to copper injury so the user should determine plant sensitivity.
Bacillus pumilus (Sonata; AgraQuest) 4 hr. REI	Early blight, late blight, downy mildew, powdery mildew	Many, including brassicas, bulb vegetables, cucurbits, fruiting vegetables, leafy vegetables and root, and tuber crops	OMRI approved.
***Bacillus subtilis*, Max, QST, 713 Strain** (Serenade, Rhapsody; Agra-Quest) 4 hr, REI	Many diseases including downy mildew, powdery mildew, bacterial spot, early blight, etc.	Many, including broccoli, leafy vegetables, cucurbits, peppers, tomatoes, and others	Applied as a protectant fungicide.
Coniothyrium minitas (Contans; SipcamAdvan) 4 hr. REI	*Sclerotinia sclerotiorum, Sclerotinia minor*	Many, including leafy vegetables, brassicas, legumes, fruiting vegetables, and bulb vegetables	OMRI approved. Contains a beneficial fungus. Do not allow to stand overnight after mixing. Acts as a preventative.
Copper Hydroxide (Kocide 101, Kocide 2000, Kocide 4.5LF, Kocide DF; DuPont) 24 hr. REI	Leaf spots, anthracnose and bacterial spots	See labels for specific crops	See labels for specific usage instructions.
Copper Salts of fatty and rosin acids (Camelot; Whitemire Micro-Gen) 12 hr. REI	*Alternaria* blight, downy mildew, angular leaf spot, powdery mildew, scab, gray mold, bacterial soft rot, bacterial spot, *Cercospora* leaf spot, etc.	Vegetables such as broccoli, cabbage, cucurbits, tomato, etc.	The user should determine if Camelot can be used safely prior to use. Observe for 7 to 10 days for symptoms of injury.
Dicloran (Botran; Gowan Company) 12 hr. REI	*Sclerotinia* and sclerotium rots, pink rot, gray mold, leaf blight and neck rot	Many, including celery, lettuce, onions, garlic, and shallots.	Use adequate volume of water. May cause leaf bronzing on lettuce.

Table 14.2 Fungicides and Bactericides for Greenhouse Vegetable Production (continued)

Fungicide (Trade name, Product Source) Re-entry Interval	Target Diseases	Labeled Plants	Comments
Harpin Protein (Messenger; Plant Health Care, Inc.) 4 hr. REI	Increases vigor and aids in the management of disease	Many, including cucurbits, fruiting vegetables, and leafy, and cole crops	Do not use chlorinated water when mixing this product. Activates natural defense mechanisms in plants. Has no direct effect on pests or pathogens.
Horticultural oil (Ultra-Fine oil; Whitmire Micro-Gen) 4 hr. REI	Powdery mildew	Cucurbits, melons, and squash	Make appliation when disease is first noticed. See label for information on plant safety. Use lower label rates in the greenhouse.
Hydrogen Dioxide (Oxidate, Zerotol; Bio-Safe Systems LLC) 0 hr. REI	Anthracnose, downy mildew, powdery mildew, *Pythium* root rot	Many, including cole crops, cucurbit, leafy vegetables, peppers, and tomatoes	Strong oxidizing agent. Contact, oxidizing sanitizer.
Mancozeb (Dithane F-45, DF; Dow AgroSciences LLC) 24 hr. REI	Leaf spot diseases, seed treatment for damping off, seed rots and seedling blights	Tomatoes and others	Broad-spectrum protectant fungicide.
Pentachloro-Nitrobenzene PCNB (Terraclor 75 WP, Terraclor Flowable, Terraclor 15G; Chemtura Corp.) 12 hr. REI	Root and stem rot, damping off (*Rhizoctonia solani*, *Pellicularia filamentosa*)	Vegetable bedding plants. Limited to container-grown beans, broccoli, Brussel sprouts, cabbage, cauliflower, peppers, and tomatoes.	Flowable and 75WP: Apply as a soil drench. 15G: Used as growing media mix. See label for additional information.
Potassium Bicarbonate (Armicarb 100, Helena Chemical Co.; Milstop, BioWorks, Inc.; Kaligreen, Taogossi Co., Ltd) 4 hr. REI	Powdery mildew and others	Many, including cabbage, cucumber, eggplant, broccoli, cauliflower, lettuce, peppers, tomatoes, and squash	Works by contact. Disrupts the potassium ion balance in fungus cell, causing cell walls to collapse.
Propamocarb Hydrochloride (Previcur Flex; Bayer Crop Science) 12 hr. REI	*Pythium* root rot and damping off	Tomatoes, leaf lettuce, cucurbits, and peppers	See label for specific usage instructions.

Insect Control for Greenhouse Vegetable Production

The following table list the insecticides that are labeled for use on greenhouse grown vegetable transplants/ crops. Also included are the targeted pests, crops labeled for use, the pre harvest interval (PHI) and various important comments about the use of these chemicals. These products have been tested and formulated for greenhouse use. Some products, however, while not prohibited from use in the greenhouse lack information on application and use in the greenhouse environment.

Note that unless a pesticide label specifically states that a product cannot be used in a greenhouse vegetable crop, the product can be used on those crops for which it is registered.

Note: * The EPA has ventilation criteria for greenhouses: If a pesticide is being applied as a fumigant, smoke, mist, fog or aerosol, one of the following ventilation criteria must be met. The concentration of the pesticide in the air is measured to be less than or equal to any inhalation exposure level required on the labeling. If no inhalation exposure level is listed on the labeling, workers must not enter the treated area until after:

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

Table 14.3 Insecticides for Greenhouse Vegetable Production

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Azadirachtin	18B	Tetranortri-terpenoid	Aza-Direct	4	Aphids, caterpillars, leafminers, fungus gnats (except Neemix), mealybugs, rust mites, spider mites, soft scale, whiteflies and thrips (suppression) Also registered for fungal disease control. For all vegetables and herbs.	Repellant, anti-feedant, and IGR. Controls pests on contact or by ingestion. Apply as spray or drench. Constant agitation is required. Do not mix with Captan, Bordeaux mixtures, and highly alkaline products. May reduce "waxy bloom" on some crops. Can apply via drip irrigation. Reapply every 14-21 days as necessary. See label for restrictions. OMRI listed.
			Azatrol			
			Azatin XL			
			Ornazin 3% EC	12		IGR and repellent. Spray or drench. Use promptly after mixing (breaks down within 8 hours). Use with buffering agent and surfactant. Spray both sides of leaves. Do not use with Bordeaux mixture, triphenyltin hydroxide, lime sulfur, Rayplex iron, or other highly alkaline materials.
			Neemix 4.5			Repellant, anti-feedant, and IGR. Apply as spray or drench. Not labeled for fungus gnats. Spray both sides of leaves. Can use in chemigation.
			Trilogy	4		Insecticide, miticide, and fungicide. Avoid tank mixes with Captan, Sulfur, Bravo, Echo, chlorothalonil, orother similar products.
			Agroneem Plus	4	Fruiting and baby vegetables	OMRI Listed

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Bacillus thuringiensis var Aizawai	11B1	Microbial	Agree WG		Caterpillars only: loopers, tomato fruitworms/ corn earworms, leafrollers, diamondback moths For all greenhouse vegetables, herbs, spices, and watercress	Stomach poison that must be ingested. Most effective against newly hatched, small 1st instar larvae. Insects stop feeding and die 1-5 days later. Can be applied through irrigation system. Do not combine with fungicides or fertilizers containing copper or chlorine. OMRI Listed
			XenTari			
Bacillus thuringiensis var kurstaki	11B2	Microbial	BioBit HP			
			Deliver		Fungus gnat larvae For tomatoes, leafy Tomatoes, leafy and cole crops, cucumbers, peppers, and eggplants.	Larvicide; will not control adult gnats. Can be applied by injection into drip or overhead (sprinkler) irrigation systems. Apply with adequate water by soil drench to sufficiently wet soil surface above and under benches. Do not use in combination with fertilizers or fungicides containing copper or chlorine. Do not apply soil drenches to stressed plants.
			Dipel DF			
			Dipel Pro DF			
Bacillus thuringiensis var israelensis	11A1	Microbial	Gnatrol WDG			
Beauveria bassiana	UN	Microbial	Botanigard ES	4	Aphids, thrips, psyllids, whiteflies For all greenhouse vegetables, herbs and spices	Slow acting; contains a fungus that infects insects. Must make at least 3 applications at 7-10 day intervals. Thorough spray coverage needed; must contact target pest. Treat when insect levels are low. May need repeated applications may be d. Do not use Botanigard or any ES formulations on tomatoes.
			Botanigard 22WP			
			Mycotrol O			
			Naturalis L (strain ATCC)			

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Bifenazate	25	Unclassified	Floramite SC	12	Twospotted spider mites and European red mite For tomatoes >1 inch in diameter at maturity	Not effective against rust mites or broad mites. Compatible with beneficial predatory mites. Rapidly degrades in alkaline water of high temperature. Use solutions promptly or add a commercial buffering agent. Do not use adjuvants. Use no more than 2 applications per crop/season.
Buprofezin	16	Thiadiazine	Talus 40 SC	12	Whiteflies, mealybugs, and leafhoppers on tomatoes.	IGR targeting active immature stages of insects. Suppresses egg laying and reduces egg viability. Treated pests may remain alive for 3 to 7 days, but feeding damage is low. Apply no more than twice per season, at least 28 days between applications.
Chlorfenapyr	13	Pyrazole	Pylon	12	Caterpillars (e.g. beet and yellowstriped armyworms, loopers, tomato fruitworm, hornworms, broad mites, twospotted spider mites, tomato russet mites, melon thrips, western flower thrips For peppers, tomato, egg-plant, ground cherry, pepinos, tomatillo	Do not use on tomato varieties with mature fruit less than 1 inch in diameter. Allow 5-7 days between applications. No more than 3 applications per crop. Do not apply more than 39 fl oz (0.6 lb a.i.) per acre, per crop growing cycle.

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Dinotefuran	4A	Neonicoti-noid	Safari 20 SG		Whiteflies, aphids (suppression), leafhoppers For lettuce	For vegetable transplants ONLY. Apply as transplant or post-seeding drench. One application per crop.
Endosulfan	2A	Cyclodiene	Thionex 50WP		Aphids, armyworms, blister beetles, cabbage loopers, Colorado potato and flea beetles, stink bugs, thrips, tomato fruit-worms, tomato russet mites, whiteflies For tomatoes	Restricted use. Use 1.5-2 lb/A for all pests except whiteflies. For whiteflies: Apply 1 b/100 gal - thorough coverage is needed for high populations.
			Thionex 3EC			
			Phaser 3EC			Good coverage necessary. Higher spray volume may be needed for high whitefly populations. Do not make more than 6 applications per year.
Imidacloprid	4A	Neonicoti-noid	Benefit 60WP		For aphids, leafminers, mealybug, whiteflies, thrips (suppression) For broccoli raab, Chinese broccoli, Brussels sprouts, kale, cabbage, cauliflower, collards, rape and mustard greens, ground cherry, kohlrabi, egg-plant, lettuce, pepper, potato, tomato, sugar-beet, tomatillo	Systemic insecticide. Incorporate into media before planting, or use as soil drench via micro, drip irrigation, overhead, ebb and flood irrigation, or hand-held or motorized calibrated irrigation equipment. Protection period is shorter if media has > 30 - 50% bark content. Irrigate thoroughly after application, allowing no leaching and runout from container for at least three irrigations or 10 days. Do not use packets in a tank mix with products that contain boron or release free chlorine.

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Imidacloprid			Lada		Aphids, armored scale, (suppression), fungus gnats (larvae only), leafhoppers (inc luding glassy-winged sharpshooter), leafminers, mealybugs (including root mealybugs), soft scale, thrips (suppression), whiteflies For Chinse and raab broccoli,, Brussels Sprouts, cabbage, Chinese cabbage, cauliflower, collards, eggplants, ground cherry, kale, kohlrabi, lettuce, mustard greens, pepinos, pepper, potato, rape greens, sorghum, sugarbeet, tomatillo, and tomato.	For use on vegetable plants intended for resale only.

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Imidacloprid			Marathon II Marathon 1G		Adelgids, aphids, armored scale (suppression), fungus gnats (larvae only), leaf beetles, leafhoppers, leafminers, Japanese beeetles, psyllids, root mealybugs, root weevils, soft scales, thrips (suppression), whiteflies, white grub larvae For Chinese broccoli, cabbage, cauliflower, collards, eggplant, ground cherry, kale, kohlrabi, lettuce, mustard greens, pepinos, potatoes, rape greens, sorghum, sugarbeet, tomatillo, and tomato.	Apply as a broadcast treatment and incorporate into substrate before planting. On established plants, irrigate moderately after application to move active ingredient (a.i.) into root zone. Minimize leaching and runoff for at least 3 irrigations or 10 days, whichever is longer. Adding a nitrogen containing fertilizer, if applicable, into the solution may enhance uptake of the a.i.. Treat as a foliar or soil application. Media with 30% or more bark content may reduce period of protection. Controls fungus gnat larvae in the soil by incorporation, but no adult control. Foliar insect control is by the uptake by a healthy root system translocating the a.i. up into the plant. Control of root mealybug requires thorough incorporation of containerized media. Coverage is essential for control while minimizing leachate. Suppresses thrips on foliage, but not in buds or flowers.

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Insecticidal Soap	UN	Fatty acid	M-Pede	12	aphids, white-flies, spider mites, fungus gnats, plant bugs, thrips, caterpillars. Registered on all vegetables, herbs and spices	Works well on whiteflies and aphids if applied frequently. However, do not apply more than 3 applications over a 2 week period
Iron phosphate		Inorganic	Sluggo	N/A	Slugs on tomatoes	Scatter the bait in the plant pots of plants being damaged or around pots on greenhouse benches. Do not apply directly to plants.Apply about 1/2 teaspoon per 9-inch pot. OMRI approved.
Malathion		Organophos-phate	Malathion 8 aquamul	12	Aphids, cucumber beetles, mites, thrips, whiteflies For cucumber, egg plant, head lettuce, endive, leaf lettuce pepper, tomato, onions (bulb & green).	Be sure to check label as the plant harvest interval (PHI) differs for certain crops depending on formulation type.
Metaldehyde	UN	Aldehyde	Metalde-hyde 2%	12	Slugs and snails on most vegetables.	Apply on and beneath greenhouse benches. Keep bait from coming in contact with plants.
Nicotine	4B	Botanical	Fulex Nicotine Fumigator	Ventila-tion criteria met	Aphids, thrips. For cucumbers, lettuce, tomatoes	Restricted use. Smoke fumigator. Apply when foliage is dry.

Table 14.3 Insecticides for Greenhouse Vegetable Production (continued)

Chemical Name	IRAC	Class	Trade Name	Re-entry Interval (hours)	Pests and Crop(s) Labeled	*Comments
Oil	UN	Paraffinic Oil	Prescription Treatment Ultra-Fine Oil	4	Aphids, beetle larvae, certain caterpillars, leaf miners, thrips, whiteflies, spider mites. Registered on all vegetables, herbs and spices	Must contact pest. Maintain a two week interval between treatments. Test for phytotoxicity for each plant variety before treating. Do not exceed four applications per growing season. Oils can cause foliar injury if very hot and humid.
		Soybean Oil	Pure Spray Green Golden Pest Spray Oil			
		Petroleum Oil	Saf-T-Side Spray Oil			
Pyrethrin + PBO (Piperonyl Butoxide)	3	Botanical Unclassified	Pyrenone crop spray	12 after ventilat-tion criteria met	Aphids, beetles, caterpillars (army worms, loopers), flies, flea beetles, fungus gnats, mealybugs, whiteflies, thrips, spider mites All vegetables, herbs, spices	PBO is used to increase effectiveness of Pyrethrin, but is not OMRI approved. Can be tank mixed with other insecticides for enhanced control. See label for details. Micro total release. See directions on can for area coverage.
			Prentox pyronyl crop spray			
			Prescription Treatment Pyreth-It			
Pyriproxyfen	7C	Unclassified	Distance	12	Aphids (suppression), fungus gnat and shore fly larvae (apply as a sprench or drench), whiteflies (greenhouse, silverleaf, & sweetpotato) Tomatoes	IGR. Do not apply to tomato varieties less than one inch in diameter or to non-bell peppers. Use as a drench or sprench against fungus gnats or shore flies. Do not make more than 2 applications per season.
Spinosad	5	Microbial	Conserve		Lepidopteran (caterpillar) larvae, thrips, leafminers, pinworms on tomatoes	Not for use on greenhouse transplants that will go to the field (resistance issues). Excellent product for thrips control. Will not kill sawfly larvae.
			SpinTor 2SC			