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INTEGRATED PEST MANAGEMENT FOR GREENHOUSE CROPS

PEST MANAGEMENT SYSTEMS GUIDE

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By Lane Greer and Steve Diver
NCAT Agricultural Specialists

Abstract: *This publication covers IPM for greenhouse crops, both vegetable and ornamental. Monitoring, sanitation, biological controls, biorational pesticides, insect growth regulators, and disease control methods are discussed. Tables include information on the newest biorational pesticides and biological control organisms.*

General Greenhouse IPM

Insects and diseases are a major challenge to greenhouse production. IPM is an important tool in the management of these pests. The primary goal of IPM is to optimize pest control in an economically and ecologically sound way. IPM involves the integration of cultural, physical, biological, and chemical practices to grow crops with minimal use of pesticides. Monitoring, sampling, and record keeping are used to determine when control options are needed to keep pests below an economically damaging threshold. Pest management, not eradication, is the goal of IPM.

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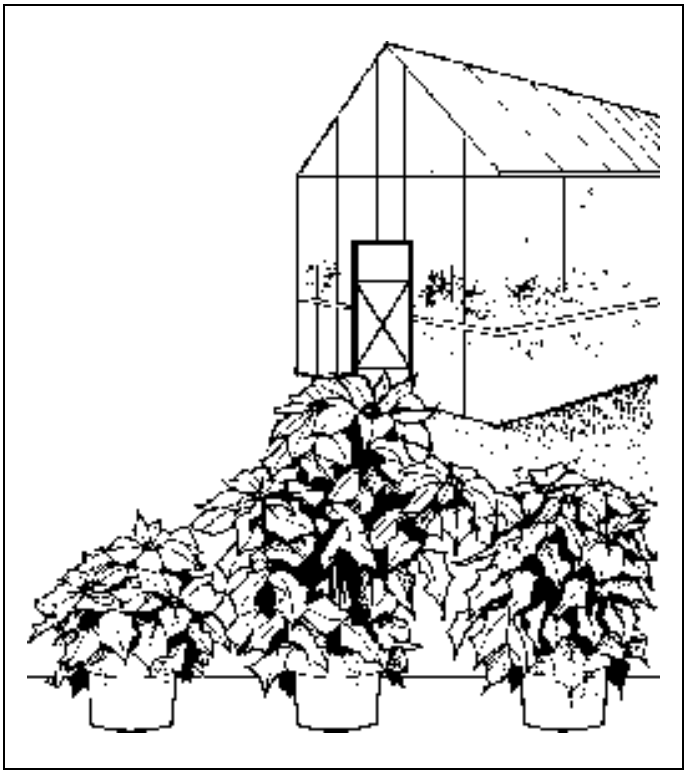

A Guide to Insects and Related Pests of Floricultural Crops in New England: For Commercial Growers (1), a University of Massachusetts Cooperative Extension System publication, outlines the basic strategy on greenhouse IPM:

> IPM is a simple, practical, and, most important, flexible way to manage insects, mites, diseases, weeds and vertebrates.
>
> Integrated pest management is adaptable to all greenhouse-grown crops and involves specific techniques to manage pests. These techniques are:
>
> - Monitoring or scouting program
> - individual plant inspection
> - yellow, blue, and hot pink sticky cards
> - indicator plants

- Pest identification and life stages
- Record keeping to identify trends and direction for your pest management program
- Exclusion techniques to prevent pests from entering the production area
  - Insect screens to exclude aphids, whiteflies, and thrips from entering through doors and ventilating systems
- Cultural practices to prevent problems
  - soil testing
  - sanitation
- Biological controls, living organisms used to reduce the incidence of pest organisms
- Insect growth regulators, insecticides that interfere with normal insect development or the molting process
- Chemical controls
  - proper choice of pesticides
  - proper timing of pesticide application
  - proper application procedure

It is important to understand the life cycle and behavior of insect pests in order to develop an effective control strategy. Knowledge about the weak link in a pest's life cycle can help growers choose the most appropriate control strategy.

There are several practices that will increase the success of an IPM program (2):

- Cover all soil floor surfaces with concrete, black plastic or weed barrier.
- Use resistant varieties of plants.
- Keep people and "pet plants" out of crop areas as much as possible.
- Pasteurize growing medium.
- Keep doors closed.

Greenhouse Insect and Mite Control

Major insect and mite pests of greenhouse crops include aphids, thrips, whiteflies, fungus gnats, mealybugs, shore flies, spider mites, leafminers and scales. In addition to damaging the crop, some insects vector diseases like tomato spotted wilt virus.

This publication deals with general greenhouse IPM principles. ATTRA has more information on specific greenhouse pests. Request *Greenhouse IPM: Sustainable Aphid Control*, *Greenhouse IPM: Sustainable Whitefly Control*, or *Greenhouse IPM: Sustainable Thrips Control*. ATTRA also has specific information on the other greenhouse pests mentioned above.

A selection of the better publications on greenhouse IPM is listed in the **Resources** section below. The publications from Applied Bio-Nomics, The Green Spot, and California Environmental Protection Agency are essential references that every IPM grower should have on his or her bookshelf.

Crop Scouting and Trapping

To detect early infestations, a crop scouting program that includes both sticky trap cards (usually yellow) and visual inspection is critical. Scouting should be done once a week, and more often after an infestation is detected. Regular scouting is also necessary to monitor the efficacy of control measures. A hand lens is a useful tool to detect live pests as well as signs of pest activity— e.g., frass (feces), cast skins, honeydew, etc.

Monitoring records can be kept on paper or in a computer. (Computers are usually better for producing graphs, which show trends more easily.) State and federal regulations will soon require that all greenhouses that apply pesticides keep records on what was applied. If plant injury symptoms appear, the grower can see quickly what chemicals or biocontrols have been used, and how the environment affected the crop (3). And, thorough records are invaluable in negotiations with suppliers for compensation for problems traced to receipt of diseased stock (3).

At a minimum, records should include:
- Minimum and maximum temperatures for each day
- Counts from sticky cards, changed weekly
- Counts of pests on the plants, including stage of growth (egg, immature, adult)

- Plant growth and development based on measurements of selected, flagged plants
- Root health based on weekly check of random plants
- Growing medium pH and soluble salts of random plants
- Specific crop observation (height, leaf color, bud development, etc.)

See **Appendix I: Monitoring and Scouting Techniques for Greenhouse Plants** for more specific information.

Sticky Ribbons

Sticky ribbons are long sticky insect strips that are hung throughout the greenhouse as a means of reducing insect populations of whiteflies, leafminers, aphids, fungus gnats, and thrips. Unlike sticky *traps* that are used for monitoring, the primary purpose of sticky *ribbons* is to reduce the numbers of flying insect pests by simply catching them.

Sanitation

Sanitation is key for controlling pests in greenhouses. The goal of sanitation is to eliminate all possible sources of the pest. Weeds inside and near the outside of the greenhouse can harbor pests. It's best to pull the weeds inside the greenhouse rather than spray them, since insects may survive the spray and migrate onto crops. Bag all weeds and dispose of them outside the greenhouse.

In addition, a 10–30 foot vegetation-free zone around the outside perimeter of the greenhouse—especially near vents and opening—can provide a dramatic decrease in pests. A heavy-duty geotextile weed barrier (e.g., DeWitt Sunbelt® Weed Barrier) covered with bark mulch or gravel can provide a pleasant vegetation-free zone, and eliminate the need for herbicides.

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

Inside the greenhouse, a clean stock program should be in place. This includes temporary quarantine and inspection of all plants upon arrival from other greenhouses, and regular monitoring of stock plants used for propagation. If a separate section of the greenhouse can't be dedicated to this purpose, flag all incoming plants. All new plant material should be thoroughly inspected (with a 10X hand lens) for the presence of pests to ensure that no infested plants are introduced into the greenhouse. Workers in the greenhouse should avoid wearing yellow clothing, since many pests are attracted to this color and may hitch a ride on the fabric from one greenhouse to the next.

Screening

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

Biological Control

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

Implementing a biological control program in a greenhouse is management intensive and requires more knowledge on the part of the grower than do traditional pest control programs. Proper species identification is very important before a control program using predators or parasites is initiated. Release rate, timing, placement, temperature, and pesticide use also influence the success or failure of biological control efforts. Rigorous monitoring is necessary for proper timing of biocontrol agent releases, as is a reliable supply of the natural enemies.

Knowing the lifespan of the beneficials selected is important too, since fewer releases are required if sufficient numbers of parasites or predators are maintained. Some species of beneficials live only a few days and therefore must be released biweekly. Other species live for several weeks; consequently, they are released less frequently.

The level of control provided by a natural enemy will also vary with crop species. It is therefore more difficult for bedding and other container-plant growers to implement biocontrol, since they produce a wide variety of crops.

One of the most important things to keep in mind when using biologicals is that even residual insecticide can harm them. This happened to a grower who tried to use *Encarsia formosa*, a parasitic wasp, on his poinsettias (4). The previous crop had been sprayed with a pesticide two months before applying the wasps, but all the wasps were killed by the residual.

Biologicals also allow more thorough coverage than spraying and a more efficient use of labor, since workers don't have to wait for re-entry into the greenhouse (4).

Generally, the best time to release beneficials is at the first sign of a pest infestation. Early morning and dusk are the optimum release times.

Suppliers of biocontrol agents can provide technical assistance and help growers get started in a biocontrol program. When requesting assistance or ordering beneficials from a supplier, the grower should be able to provide information such as: what the pest is, how much square footage is affected, crop rotations, fertility programs, and pesticides that have been used in the greenhouse.

The Canadian greenhouse vegetable industry—which is about four times the size of the U.S. industry—is largely based on biological controls. In 1995, tomato growers in British Columbia spent 50 cents per square meter per season on biological control, primarily on the parasitic wasp *Encarsia formosa* (5).

There are several items to keep in mind when using biological controls (6):

- No single pest control method is 100% effective.
- This method often involves more work at first than chemical control, and it may require changes in production methods.
- Biologicals are often highly susceptible to pesticides. When choosing pesticides, select those with the shortest residual life and the highest specificity.
- Since many biologicals work slowly, they are best used when pest numbers are fairly low.
- Most predators and parasites perform best at moderate temperatures (65–85°F) and humidities (60–90%).
- If the greenhouse is allowed a dormant period (either very hot or very cold), the beneficials will die.
- If the pest level is very high when beneficials are first introduced, they probably will not provide enough control.
- The effectiveness of the same beneficial may be different on different plants. For instance, beneficials are often less effective on hairy-leaved plants like tomatoes.
- If all the plants leave the greenhouse, so will the beneficials.

- If all the pests are destroyed, the beneficials will starve.
- Some plants exude substances toxic to beneficials.

See **Appendix II: Beneficial Organisms** for more information on biological control agents.

Insect Growth Regulators

Insect growth regulators (IGRs) are another least-toxic pesticide control option for pests. IGRs typically kill insects by disrupting their development. They have a complex mode of action that precludes insects from rapidly developing resistance. IGRs can work in one of several ways: 1) they can mimic juvenile hormones, so that insects never enter the reproductive stage of development; 2) they can interfere with the production of chitin, which makes up the shell of most insects; or 3) they can interfere with the molting process.

IGRs usually work through ingestion, so good spray coverage is essential. They generally don't affect non-target species—such as humans, birds, fish or other vertebrates. For most IGRs there are minimal re-entry restrictions. IGRs typically take several days to have an effect on pest populations. Because

Table 1. Selected Insect Growth Regulators

Brand Name	Supplier	Active against
Adept	Uniroyal Chemicals	fungus gnats
Azatin	Hydro-Gardens, Olympic Horticultural Products	whiteflies, leafminers, thrips, mealybugs, fungus gnats, aphids, cabbage loopers, diamondback moths, armyworms
Citation	Novartis	leafminers, fungus gnats, shore flies
Confirm	Rohm & Haas	caterpillars
Dimilin	Uniroyal Chemicals	beet armyworm, whiteflies, fungus gnats, shore flies
Distance	Valent	whiteflies, fungus gnats, shore flies
Enstar II	Wellmark Intl.	whiteflies, fungus gnats, aphids, soft and armored scales, mealybugs
Insegar	Novartis	caterpillars, psyllids, scales
Neemazad	Thermo Trilogy	whiteflies, leafminers, thrips, mealybugs, fungus gnats, aphids, cabbage loopers, diamondback moths, armyworms
Neemix	Thermo Trilogy	whiteflies, leafminers, thrips, mealybugs, fungus gnats, aphids, loopers, diamondback moths, armyworms, cabbage loopers
Precision	Novartis	whiteflies, soft scales, fungus gnats, shore flies, leafminers
Preclude	Whitmore Micro-Gen	whiteflies, thrips, scales, aphids
Pyrigro	Whitmore Micro-Gen	whiteflies, fungus gnats, scale
Trigard	Novartis	leafminers

IGRs do not affect mature insects, adult beneficials released into the greenhouse after an IGR application are not likely to be affected. Use of IGRs is generally prohibited by organic certification organizations because the products are synthetic.

IGRs can sometimes be used in conjunction with biological control efforts and may provide growers with a "safety net" should beneficials fail to keep the pests below economically damaging levels. Table 1 lists some well-known insect growth regulators. (See the **Resources** section for suppliers.)

Biorational Pesticides

The integration of biorational pesticides (also known as least-toxic or biopesticides) in greenhouses is often necessary in addition to cultural and biological control measures. When the use of a pesticide is necessary, materials should be selected that are least harmful to the predators and parasites released into the greenhouse. Insecticidal soap, horticultural oils, and the bacterium *Bacillus thuringiensis* are examples of insecticides that can be safely integrated into a biological control program. The advantages of biopesticides over conventional chemicals are their selectivity to a targeted pest, lower toxicity to beneficial insects and greenhouse workers, and shorter re-entry intervals (REI).

Enhanced control with pesticides is achieved with thorough spray coverage. Wider plant spacing and removal of dead lower leaves improves pesticide coverage and pest control.

Beauveria bassiana

BotaniGard™ (from Mycotech) and Naturalis-O™ (from SePro) are the two commercial formulations of *B. bassiana* that are available for greenhouse use. *B. bassiana* is a naturally occurring fungus that attacks a wide range of pests—including aphids, whiteflies, thrips and spider mites. *B. bassiana* has been found to be compatible with predators such as *Encarsia* spp., *Eretmocerus* spp. and *Chrysoperla* spp.

Spinosad

Early in 1999, Conserve SC™ from Dow AgroSciences was registered for use on greenhouse ornamentals. The active ingredient comes from the soil-inhabiting actinomycete *Saccharopolyspora spinosa*. Conserve is effective against many different species of caterpillars, leafminers, and thrips. Experiments performed at the Ohio State University showed that Conserve provided excellent control of Western flower thrips (7).

Hot Pepper Wax and Garlic Extract

These products are actually insect repellents. Hot Pepper Wax™ contains paraffin (refined wax) and capsaicin (the "hot" in hot peppers). Another study at Ohio State showed that Hot Pepper Wax did not control Western flower thrips, but was effective against two-spotted spider mite (7). Products containing garlic also work to repel insects.

See **Appendix III: Biorational Pesticides** for information on products formulated for specific pests.

Greenhouse Disease Control

The greenhouse climate is ideal for the development of plant diseases. An integration of cultural practices, environmental control, biological control, and natural control products will be needed to prevent widespread outbreak.

Many fungicides are also toxic to beneficial organisms, and should be avoided if possible. Alternative disease control techniques include the use of disease resistant varieties, disease-free seeds and plants, well-drained soil, air circulation, weed eradication, humidity control, sanitation, disease-suppressive composts, compost watery extracts, and microbial antagonists.

Disease control may be classified into two approaches: 1) those aimed at the root environment, and 2) those aimed at the aerial environment.

The Root Environment

Soil disinfection (i.e., sterilization) is an important part of soil-borne disease control when raising vegetables by the ground culture method or when soil-based potting mixes are used. Soil-borne diseases include damping-off (*Pythium* and *Rhizoctonia*), black root rot (*Thielaviopsis*), and several other root rots and wilts caused by *Fusarium* and *Phytophthera*. Potting mixes based on compost, peat moss, vermiculite, perlite, and bark are typically pathogen-free and do not require prior sterilization.

Sterilization involves heating the soil to 212°F for 30 minutes, a process that kills most organisms in the soil. Chemical changes also occur in the soil and may affect plant nutrient uptake to the following crop. Pasteurization involves heating the soil to only 160°F for 30 minutes. While most harmful pathogens are killed at this temperature, many beneficial soil organisms survive. Thus, pasteurization is the preferred method in organic programs.

Chemical biocides, electrical heat, steam heat, and soil solarization are the primary methods of soil disinfection in greenhouse production. A fifth method of disease suppression is biological control. Soil fumigants such as methyl bromide are, of course, restricted in organic production.

Electrical heat treatment, which is done inside a steel chamber surrounded by heating coils, is limited to treating about a cubic yard of soil at a time. Its primary use is in the pasteurization of small batches of sand and soil for potting mixes.

Accordingly, steam pasteurization and soil solarization are the two most viable options for sterilizing greenhouse soils or large volumes of soil-based mixes. Biological control is complementary to these two methods.

Steaming

Steam was the primary method of soil sterilization in the greenhouse industry prior to the emergence of soil fumigants. Steam heat is highly effective and environmentally safe. Equipment and fuel costs are expensive, however, and treatment between crops is labor and time consuming. These are the chief reasons many growers shifted to soilless mixes.

There are three methods of steaming in common use today (8):

1) Tarping an area and piping in steam for 6–8 hours, heating and sterilizing the top 8 inches of soil;
2) Pumping steam into subsurface drainage pipes, sterilizing the top 2 feet of soil; and,
3) Negative pressure steaming, where pumps pull steam applied at the surface through pipes buried 2 feet deep and 10 feet apart.

Solarization

Soil solarization is the process of tarping moist soils with clear polyethylene to trap solar radiation and raise soil temperatures to levels lethal to most pathogens and weed seeds. Solarization is most effective when applied for at least 30 days in midsummer. Two layers of polyethylene, separated by fillers (i.e., pvc pipes or 2'x 4's) spaced every few feet to create an air space, increases the efficiency of solarization.

Solarization in greenhouses is a proven means of soil sterilization, and is practiced worldwide in Japan, Israel, Greece, France, Italy, Belgium, Portugal, and Spain (9–11), in addition to the United States and Canada.

Solarization can also be used to pasteurize sand or soil intended for potting media, or to treat used media (12). A simple technique developed in Florida (13) is to fill a black plastic trash bag with media, which is then sealed in a transparent plastic bag. The double-wrapped media is placed in the open on asphalt or concrete and spread to a uniform depth of 3 inches.

As long as the trashbag received one full day of sunshine from April through August, the temperatures reached or exceeded 113°F for more than 2 hours. This temperature, which was monitored with a thermometer inserted into the media, was considered the minimum treatment period for plant-parasitic nematodes. This method yields about 24 liters of media.

Biological control of pathogens in greenhouse soils and potting mixes is accomplished through natural control via cultural practices, and secondly, through applied biocontrols. The introduction of biocontrol agents, or antagonists, is the next form of biological soil disinfection. Biological fungicides are a promising alternative to synthetic fungicides.

There are several new biocontrols available for suppressing root diseases (14). One product is RootShield™, a biofungicide that controls root diseases caused by *Pythium, Rhizoctonia, Fusarium*, and *Sclerotinia*. RootShield contains the fungus *Trichoderma harzianum* and is sold either as granules or a drench. SoilGard 12G™ is another biofungicide that controls *Pythium, Fusarium, Rhizoctonia, Phytophthora* and *Thielaviopsis* (when co-applied with sulfur). The active ingredient is the fungus *Gliocladium virens*. SoilGard is sold as granules that can be incorporated into the soil mix. Another product is MycoStop™, sold as a wettable powder. MycoStop contains the actinomycete *Streptomyces griseoviridis* and controls *Fusarium*, although it may control other root diseases. See **Appendix II: Biorational Pesticides** for further information.

Deny™ (from Stine Seed) contains the bacterium *Burkholderia (Pseudomonas) cepacia* and controls diseases caused by *Rhizoctonia, Fusarium*, and *Pythium*. It also provides some nematode control. Intercept™ (from Soil Technologies) also uses *B. cepacia* to control disease.

Cultural practices that promote soil health include crop rotation and use of tilled-in crop residues and green manures or organic amendments brought in from off site.

The beneficial effect of crop rotation on plant health and yield is probably due to changes in soil microflora. These shifts result in increasing numbers of beneficial microorganisms (including nitrifying and other useful bacteria, antagonists of pathogens, etc.), and in decreasing numbers of noxious ones (pathogens and antagonists of beneficial microorganisms) (15).

In some greenhouses, a short-term break crop—such as annual ryegrass, oats, buckwheat, or rapeseed—may fit into the rotation and be used to increase organic matter. Another option is to rely on organic amendments or green leaf manures brought in from off site. Amendments such as fresh residues, composts, and manures result in soil improvement through a proliferation of microflora.

Green leaf manures are field-grown cover crops that are chopped and harvested green, then transported inside the greenhouse to be incorporated into the soil. Many studies have shown that crucifer residues from rapeseed and oilseed radish cover crops produce toxic gases that suppress soilborne pathogens. Additionally, soil solarization, following incorporation of cruciferous residues, increases the efficiency of soilborne pathogen control.

The role of composts as a slow-release nutrient source in organic production is well established. Recently, the role of composts as amendments for the control of soilborne plant pathogens has increased interest in similar use in conventional agriculture. Much of the pioneering research on this topic has been conducted by Dr. Harry Hoitink (16–18) at Ohio State University.

In container production, disease -suppressive composts are commercially available in both peat and soil-based media. Dr. Frank Regulski, who is President of BioComp, Inc., an Edenton, N.C., company that developed a series of disease-suppressive mixes, said that suppressive properties come from a certain composting technique that yields antibiotic (antagonistic) and competitive (saprophytic) responses (19).

Natural disease-suppressive potting mixes—based on composts—are available through several commercial sources. These products may, however, contain starter fertilizers and wetting agents which would restrict their use in organic certification programs. Contact the manufacturers for clarification on these ingredients. Some companies will blend a special batch that excludes restricted ingredients, therefore making them suitable for organic production. For more information on these companies, ask for ATTRA's publication *Disease Suppressive Potting Mixes* <http://www.attra.org/attra-pub/dspotmix.html>. This publication also discusses how to inoculate potting mixes with mycorrhizae. Mycorrhizae colonize plant roots and protect them against certain pathogenic fungi, including various *Pythium* and *Fusarium* species (20).

The Aerial Environment

Foliar and stem diseases include gray mold (*Botrytis*), powdery mildew (*Erysiphe spp*.), early blight (*Alternaria spp*.), soft rot (*Erwinia spp*.), and several other fungal and viral diseases caused by *Xanthomonas*, *Fusarium*, and *Psuedomonas*.

Greenhouse climates are warm, humid, and wind-free—an ideal environment for the development of many foliar and stem diseases. For the majority of pathogenic fungi and bacteria, infection usually occurs when a film or drop of water on the plant surface persists. Unless temperature, humidity, and ventilation are well regulated, this surface water can remain in the greenhouse until infection becomes assured (21).

Integrated disease management, therefore, is based on climate control for disease infection and optimum crop yield and quality. It eliminates inoculum through high standards of hygiene (sterilizing soil or using soilless media, obtaining disease-free planting material, chlorine bleach rinses of footwear & equipment, vegetative-free floors, etc.), cultural practices for limiting disease spread, biological and pesticidal control, and, most important, when available, resistant germplasm (21).

Environmental Control

Temperature and humidity regulation—functions of heating and cooling, ventilation, vapor pressure, and structure—are increasingly becoming computerized. Expert software that reduces disease-infective conditions while promoting crop growth is available through commercial vendors.

Agricultural engineers at the Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio, are knowledgeable about computer environment controlled greenhouses and should be able to direct you to appropriate systems. Contact:

Ohio Agricultural Research and
Development Center
1680 Madison Avenue
Wooster, OH 44691-6900
330-263-3700

Foliar Products

Greenhouse growers have fewer alternative control products for diseases than for insects. Copper- and sulfur-based fungicides are the only commercial fungicides acceptable in certified organic programs. Coppers exhibit both fungicidal and bacterial control properties. Sulfurs are noted for control of mildews. Alternative disease control strategies, although based more on grower's experience and limited research, include compost watery extracts (see ATTRA's publication *Compost Teas for Plant Disease Control* for more information), biodynamic herbal extracts (see ATTRA's publication *Biodynamic Farming and Compost Preparation*) and foliar feeding (see next page).

Biofungicides for foliar disease control are also available. AQ10™ contains the fungus *Ampelomyces quisqualis* and controls powdery mildew. Trichodex™ controls botrytis. TopShield™ contains *Trichoderma harzianum* and

controls botrytis and powdery mildew. TopShield should become commercially available in 1999. See **Appendix III: Biorational Pesticides** for further information.

Foliar Feeding

Foliar feeding is used by many organic growers to induce resistance to foliar disease. Seaweed and fish emulsion are the two products most commonly applied. More sophisticated foliar programs are being formulated in conjunction with refractometers and radionics instruments. Although the mechanism for resistance is not clear, modification of the leaf surface and enhanced plant nutrition is suspected. It has been stated that foliar fertilization indirectly protects against plant pathogens by increasing natural plant immunity through improvement of the plant's nutritional status (22).

Evidence is also strong that foliar feeding can have a dramatic effect on the rhizosphere microflora via changes in root exudates (15). Such changes in root exudates may lead to an increase of antagonists and thus enhance biological control of pathogens in the root environment as well (15). Further information on foliar feeding is available from ATTRA on request.

Baking Soda

Baking soda has for many years been used in Europe as a mild fungicide by rose growers and organic gardeners. Recently, plant pathologists at Cornell University confirmed through research that baking soda exhibits fungicidal activity against powdery mildew and several other diseases on ornamentals (23). They determined that a mixture of 0.5% baking soda (about 5 level teaspoons per gallon of water) and 0.5% horticultural oil showed the greatest activity.

A new product containing baking soda, called Remedy™, is now available for use as a pesticide. Remedy is effective against black spot, powdery mildew, leaf spots, anthracnose, phoma, phytophthora, scab, and botrytis. Remedy should be applied at the first sign of disease and repeated at one- or two-week intervals until the problem subsides. A six-ounce bottle (enough to make 12 gallons of spray) is available for $15 from:

Gardener's Supply Company
128 Intervale Rd.
Burlington, VT 05401
800-955-3370

For more information on how to use baking soda, ask for ATTRA's publication *Using Baking Soda as a Fungicide*.

Related ATTRA Publications:

Organic Potting Mixes
Disease Suppressive Potting Mixes
Integrated Pest Management
Using Baking Soda as a Fungicide
Compost Teas for Plant Disease Control
Biodynamic Farming and Compost Preparation
Greenhouse IPM:
Sustainable Aphid Control
Sustainable Thrips Control
Sustainable Whitefly Control

References:

1) Gentile, A.G., and D.T. Scanlon; Revised by Tina Smith. 1992. A Guide to Insects and Related Pests of Floricultural Crops in New England: For Commercial Growers. University of Massachusetts Cooperative Extension System. 36 p.

2) Kuack, David. 1995. Janet Bandy on implementing an effective IPM program. Greenhouse Management and Production. April. p. 56–57.

3) Dutky, Ethel. 1995. Here's how to cut your losses due to disease. GMPro. October. p. 63–65.

4) Aylsworth, Jean. 1993. Biological controls catch on with growers. Greenhouse Grower. December. p. 77–78, 80–81.

5) Gillespie, D.R. 1995? Development of integrated pest management and biological control systems for the production of greenhouse crops. http://res.agr.ca/agassiz/studies/gill95.htm. 6 p.

6) DeAngelis, J.D. 1991. Introduction to Biological Pest Control in Greenhouses. Oregon State Univ. Extension Service, Corvallis, OR. 6 p.

7) Lindquist, Richard K. 1998. Evaluations of non-conventional pesticides for insect and mite control on greenhouse ornamental plants. Greenhouse Product News. July. p. 52–55.

8) Klassen, Parry. 1993. Mulling over methyl bromide. Greenhouse Grower. August. p. 118 & 120.

9) Mahrer, Yitzhak. 1991. Physical properties of solar heating of soils by plastic mulching in the field and in glasshouses and simulation models. p. 75, 81–86. In: Jaacov Katan James E. DeVay (ed.) Soil Solarization. CRC Press, Boca Raton, FL.

10) Garibaldi, Angelo, and M. Lodovica Bullino. 1991. Soil solarization in Southern European countries, with emphasis on soilborne disease control of protected crops. p. 227–235. In: Jaacov Katan and James E. DeVay (ed.) Soil Solarization. CRC Press, Boca Raton, FL.

11) Horiuchi, Seizo. 1991. Soil solarization in Japan. p. 215, 218–223, 225. In: Jaacov Katan and James E. DeVay (ed.) Soil Solarization. CRC Press, Boca Raton, FL.

12) Gamliel, A. et al. No date. Solarization for the Recycling of Container Media. The Hebrew University of Jerusalem, Rehovot, Israel. Unpublished manuscript. 8 p.

13) Giblin, R.M., and S.D. Verkade. 1987. Solarization of small volumes of potting soil for disinfection of plant-parasitic nematodes. p. 174–176. In: Proc. Fla. State Hort. Soc. Vol. 100.

14) Chase, A.R. 1998. New bactericides and fungicides for disease control on ornamentals. Greenhouse Product News. December. p. 22–24.

15) Gindrat, D. 1979. Biological soil disinfection. p. 253–287. In: D. Mulder (ed.) Soil Disinfection. Elsevier Scientific Publishing Co., New York, NY.

16) Dr. Harry Hoitink
Department of Plant Pathology
Ohio Agricultural Research and Development Center
The Ohio State University
1680 Madison Avenue
Wooster, OH 44691-4096

17) Hoitink, Harry A., and Peter C. Fahy. 1986. Basis for the control of soilborne plant pathogens with composts. Annual Reviews of Phytopathology. Vol. 24. p. 93–114.

18) Hoitink, H.A.J., Y. Inbar, and M.J. Boehm. 1991. Status of compost-amended potting mixes naturally suppressive to soilborne diseases of floricultural crops. Plant Disease. September. p. 869–873.

19) Roberts, Dan R. 1992. Insect-, disease-suppressive mixers help growers minimize crop losses. Greenhouse Manager. September. p. 68, 70–71.

20) Anon. 1992. Mycori-Mix contains beneficial fungi, suppresses pythium. Greenhouse Manager. September. p. 68.

21) Jarvis, William R. 1992. Managing Diseases in Greenhouse Crops. American Phytopathological Society, St. Paul, MN. p. 3, 5, & 220–221.

22) Nowosielski, O. et al. 1988. A biological basis for the efficiency of plant protecting foliar fertilizers in vegetable production. Acta Horticulture. Vol. 222. p. 105–116.

23) Anon. 1990. Baking soda can ward off fungus. Greenhouse Manager. June. p. 24.

Resources:

Books:

Applied Bio-nomics, Ltd. (ed). 1993. Biological Technical Manual. Applied Bio-nomics, Ltd., Sidney, B.C. 490 p.

A comprehensive text on the biology and use of beneficial insects and mites for biological control in greenhouses. The manual includes biology, life cycles, release instructions, pesticide compatibilities, and crop programs for greenhouse tomatoes, poinsettias, floricultural crops, and interior plantscapes. It has been in revision for several years and is unavailable for purchase. However, you might be able to obtain a copy through inter-library loan or at a used bookstore.

Casey, Christine (ed.) 1997. Integrated Pest Management for Bedding Plants. IPM No. 407. Cornell University Cooperative Extension, Ithaca, NY. 109 p.

Covers scouting methods, how to develop and evaluate a management strategy, case studies, key pests, diseases and disorders, and biological controls. Also contains sources of scouting supplies and scouting forms. Available for $12.75 from:

Media Services Resource Center
Cornell University
7-8 Business & Technology Park
Ithaca, NY 14850
607-255-2080
607-255-9946 fax

Cherim, Michael S. 1998. The Green Methods Manual: The Original Bio-Control Primer, 4th ed. Green Spot Publishing, Nottingham, NH. 238 p.

Excellent resource on biological controls. Also includes information on cultural and mechanical pest management methods. Available for $9.95 from:

The Green Spot, Ltd.
Publishing Division
93 Priest Rd.
Nottingham, NH 03290-6204
603-942-8925

Daughtrey, Margery and Christine Chase. 1992. The Ball Field Guide to Diseases of Greenhouse Ornamentals. Ball Publishing, Batavia, IL. 218 p.

Available for $67 from:

Ball Publishing
335 N. River St.
PO Box 9
Batavia, IL 60510
630-208-9080
http://www.growertalks.com

Gill, Stanton and John Sanderson. 1998. Ball Identification Guide to Greenhouse Pests and Beneficials. Ball Publishing, Batavia, IL. 244 p.

Available for $67 from Ball Publishing (see address above).

Green, Thomas A. (ed.) 1998. 1998 IPM Almanac. Gempler's, Belleville, WI. 178 p.

Excellent source of IPM info. Introduces the grower to IPM techniques. Provides comprehensive checklists for specific crops and gives numerous resources. Available for $4.95 from:

Gempler's
100 Countryside Dr.
PO Box 270
Belleville, WI 53508
800-382-8473
800-551-1128 fax
http://www.gemplers.com

Hunter, Charles D. 1997. Suppliers of Beneficial Organisms in North America. PM 97-01. California Environmental Protection Agency, Department of Pesticide Regulation. Sacramento, CA. 32 p.

The booklet lists 143 commercial suppliers of more than 130 beneficial organisms used for biological control, including a special section on greenhouse biological control. The booklet can be downloaded from their website, or free, single copies can be obtained from:

California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring and Pest Management Branch
Attn: Beneficial Organisms Booklet
1220 N. Street, Room 161
Sacramento, CA 95814-5624
916-324-4100
http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm

Hussey, N.W. and N. Scopes (ed). 1985. Biological Pest Control: The Glasshouse Experience. Cornell University Press, Ithaca, NY. 240 p.

This book is a comprehensive work that explains the life cycles of both pests and biological control agents. All of the major and minor greenhouse pests are covered. This book is no longer in print, but you may be able to get it through inter-library loan or at a used bookstore.

Lindquist, Richard. 1998. Identification of Insects and Related Pests of Horticultural Plants. Ohio Florists' Assocation, Columbus, OH. 44 p.

Illustrates the life cycle and crop damage of ten major pests. The 20-page Appendix: Insect Cocktail *provides information on combining chemical and biological tools for use against pests. Available for $27 from:*

Ohio Florists' Association
2130 Stella Court, Suite 200
Columbia, OH 43215
614-487-1117

Malais, M. and W.J. Ravensburg. 1992. Knowing and Recognizing: The Biology of Glasshouse Pests and Their Natural Enemies. Koppert B.V., Berkel en Rodenrijs, Netherlands. 109 p.

This book includes photographs, drawings, and life cycle diagrams for both pests and beneficials of greenhouse crops. In the U.S., it is available for $50 through:

IPM Laboratories, Inc.
P.O. Box 300
Locke, NY 13092-0300
315-497-2063
315-497-3129 Fax

Meister, Richard T. (ed.) 1999. Insect and Disease Control Guide. Meister Publishing, Willoughby, OH. 602 p.

Extensive annual listing of controls for insects and disease for greenhouse and field crops. Available for $54 from:

Meister Publishing Company
37733 Euclid Ave.
Willoughby, OH 44094-5992
800-572-7740
Email: meisterpro_sales@meisterpubl.com
http://www.meisterpro.com

Jarvis, William. 1995. Managing Diseases in Greenhouse Crops. American Phytopathological Press, St. Paul, Minnesota. 228 p.

This is the definitive text on managing diseases in greenhouses. Included are useful sections on biological control and integrated disease management. The style is more akin to an academic book rather than a grower's manual, yet little else has been published on this topic. It lists for about $85 + $5 s&h. Contact:

APS Press
3340 Pilot Knob Road
St. Paul, MN 55121-2097
612-454-7250

Powell, Charles C. and Richard K. Lindquist. 1997. Ball Pest and Disease Manual. 2nd edition. Ball Publishing, Batavia, IL. 426 p.

Features specific information on plant pathology and entomolgy in flower and foliage crops. Contains detailed diagnostic and corrective information. Additionally, the Index of Host Plants, Diseases and Pests is very helpful. Available for $63 from Ball Publishing (see address above).

Steiner, Marilyn Y. and Don P. Elliot. 1987. Biological Pest Management for Interior Plantscapes, 2nd edition. Alberta Public Affairs Bureau, Edmonton, Alberta, Canada. 32 p.

An informative booklet on pest management in interior plantscapes. The authors detail life cycle information and provide cultural, biological and chemical control options for major greenhouse pests. Copies can be ordered for about $15 from:

Pauline Coleman
Alberta Research Council
Crop & Plant Management
Bag 4000
Vegreville, AB
Canada T9C 1T4
780-632-8211

Greenhouse Grower magazine publishes IPM manuals on the control of greenhouse whiteflies and thrips. The two publications, *Win the War on Whiteflies*, and *Get a Grip on Thrips*, are an assortment of selected articles published in the magazine over the span of several years. They are available for $12 each from Meister Publishing Company (see address above).

Articles:

Greenhouse IPM in General:

Grossman, Joel. 1996. Entomological Society of America's 1995 meeting--part 3: *Nicotiana* sugar esters vs. whiteflies. The IPM Practitioner. April. p. 14–15.

Willmott, Jim. 1998. Reduce disease by managing the greenhouse environment. Northeast Greenhouse IPM Notes. October. p. 1–2.

Biological Control:

DeAngelis, J.D. 1991. Introduction to Biological Pest Control in Greenhouses, EC 1376. Oregon State Univ. Extension Service, Corvallis, OR.

Gilkeson, Linda A. 1992. A pest-by-pest IPM primer. American Vegetable Grower. May. p. 46, 48.

Hoddle, M.S., R.G. van Driesche, J.P. Sanderson. 1998. Biology and use of the whitefly parasitoid *Encarsia formosa*. Annual Review of Entomology. Vol. 43. p. 645–669.

Kuack, David. 1995. What's it take to be successful with biologicals? Greenhouse Management and Production. April. p. 22–26.

Lowe, Peter. 1993. How to get started with biological control: Tips from a Danish grower. Greenhouse Manager. September. p. 92, 94, 96, 98, 100.

Matteoni, Jim, et al. 1993. Chemical effects on greenhouse biological control agents. GrowerTalks. August. p. 81–83, 85.

Wardlow, Leslie R. 1998. IPM in ornamentals: A guide to biocontrol. GrowerTalks. September. p. 78, 80, 82.

IGRs:

Immaraju, John and Timothy Wood. 1992. Insect growth regulators widen the pest-control window. Grower Talks. November. p. 55, 57, 59.

Biorational Pesticides:

Brownbridge, Michael. 1998. Making the most of biopesticides. Greenhouse Grower. July. p. 85–86, 88, 93–96.

Brownbridge, Michael, Margaret Skinner, and Bruce L. Parker. 1998. Factors affecting the efficacy of fungal preparations in ornamental pest management. Ohio Florists' Association Bulletin, No. 824. June. p. 14–16.

Miller, Fredric and Susan Uetz. 1998. Evaluating biorational pesticides for controlling arthropod pests and their phytotoxic effects on greenhouse crops. HortTechnology. April-June. p. 185–192.

Diseases:

Menzies, J.G., and R.R. Belanger. 1996. Recent advances in cultural management of diseases of greenhouse crops. Canadian Journal of Plant Pathology. Vol. 18, No. 2. p. 186–193.

Periodicals:

Bio-Integral Resource Center (BIRC) is a leader in the field of integrated pest management. BIRC publishes *The IPM Practitioner* and *Common Sense Pest Quarterly*. In addition, they publish a directory of IPM products and beneficial insects. BIRC also offers booklets and reprints on least-toxic controls for selected pests. For a copy of BIRC's catalog & list of services, contact:

Bio-Integral Resource Center (BIRC)
P.O. Box 7414
Berkeley, CA 94707
510-524-2567
510-524-1758 fax
Email: birc@igc.apc.org
http://www.igc.apc.org/birc/

Cornell and Rutgers Cooperative Extension publish *Northeast Greenhouse IPM Notes,* formerly titled *Greenhouse IPM Update*, a monthly newsletter designed to help growers incorporate IPM into their operations throughout the growing season. The newsletter reports on new products, publications, and current issues in greenhouse IPM, as well as providing the most up-to-date information on individual pests and crops. The hard copy version costs $30 a year for growers and $25 for educators, but the newsletter is free over the Internet. Contact:

Northeast Greenhouse IPM Notes
Cornell Cooperative Extension
246 Griffing Avenue
Riverhead, NY 11901-3086
516-727-7850
http://www.cce.cornell.edu/suffolk/greenhouse-notes/

Connecticut Greenhouse Newsletter
Contact: Richard J. McAvoy
University of Connecticut
Dept. of Plant Science
1376 Storrs Rd.
Storrs, CT 06269-4067
860-486-0627
860-486-0682 fax
$9/year for 6 issues

Midwest Biological Control News
Dept. of Entomology
University of Wisconsin
1630 Linden Dr.
Madison, WI 53706
608-262-9914
http://www.wisc.edu/entomology/mbcn/mbcn.html
$18/year for 12 issues

Growing for Market
P.O. Box 3747
Lawrence, KS 66046
800-307-8949
785-748-0605
785-748-0609 fax
$27/year for 12 issues

Trade Publications:

Greenhouse Grower
Meister Publishing Company
37733 Euclid Ave.
Willoughby, OH 44094
440-942-2000
440-942-0662 Fax
$29/year for 12 issues; Buyer's Issue every summer has lists of pest control suppliers

GMPro (Greenhouse Management & Production)
Branch-Smith Publishing
PO Box 1868
Fort Worth, TX 76101
800-434-6776
817-882-4120
817-882-4121 Fax
http://www.greenbeam.com
12 issues/year; free to qualified greenhouse growers; $96/year for non-growers

Greenhouse Product News
Scranton Gillette Communications, Inc.
380 E. Northwest Hwy.
Des Plaines, IL 60016-2282
847-298-6622
847-390-0408 Fax
Email: editorgpn@aol.com
http://www.greenhouseproductnews.com
$30/year for 12 issues

GrowerTalks
Ball Publising Co.
P.O. Box 9
335 N. River Street
Batavia, IL 60510-0009
630-208-9080
630-208-9350 Fax
Email: GrowerTalk@aol.com or gtalks@xnet.com
http://www.growertalks.com
$25/year for 14 issues

Web Sites:

http://www.canr.uconn.edu/ces/ipm/
University of Connecticut's web site on IPM and greenhouse IPM

http://www.nysaes.cornell.edu/ipmnet/index.html
IPM in the Northeast Region; web site maintained by Cornell University

http://www.barc.usda.gov/psi/bpdl/bioprod.htm
Commercial Biocontrol Products for Use Against Soilborne Crop Diseases

Video:

Integrated Pest Management in Greenhouses. 27 minutes.
Shows the unique problems and opportunities involved with managing pests in production greenhouses. Covers economic thresholds and how to apply an IPM program to coordinate physical, biological, cultural, horticultural, and chemical controls. Comes with a 72-page book on greenhouse pest problems. Available for $95 from:
San Luis Video Publishing
PO Box 6715
Los Osos, CA 93412
805-528-8322
805-528-7227 fax

Conference:

The Society of American Florists holds an annual Pest Management Conference in February. This is usually a three-day event that focuses on pest management in ornamental crops. Annual conference proceedings are available for $17.95. For more information, contact:
Society of American Florists
1601 Duke St.
Alexandria, VA 22314
800-336-4743

Biological Control Suppliers

A-1 Unique Insect Control
5504 Sperry Dr.
Citrus Heights, CA 95621
916-961-7945
916-967-7082 fax
Email: ladybugs@a-1unique.com
http://www.a-1unique.com

Abbott Laboratories
1401 Sheridan Rd.
Dept. 44C, Bldg. A1
N. Chicago, Ill 60064
800-323-9597
847-937-3729 fax

ARBICO Inc.
PO Box 4247 CRB
Tucson, AZ 85738
800-SOS-BUGS
520-825-2038 fax
Email: arbico@aol.com
http://www.arbico.com

Beneficial Insectary
14751 Oak Run Rd.
Oak Run, CA 96069
800-477-3715
530-472-3523 fax
Email: bi@insectary.com
http://www.insectary.com

BioLogic Co.
PO Box 177
Willow Hill, PA 17271
Email: pyealber@epix.net
717-349-2789/2922

BioWorks
122 N. Genesee St.
Geneva, NY 14456
800-877-9443
315-781-1793 fax

Caltec Agri-Marketing Services
PO Box 576155
Modesto, CA 95357
209-575-1295
209-575-0366 fax
http://www.caltecag.com

Dow AgroSciences
9330 Zionsville Rd.
Indianapolis, IN 46268-1054
800-258-3033
317-337-7374 fax
http://www.dowagro.com

Ecogen Inc.
2005 Cabot Blvd. W
PO Box 3023
Langhorne, PA 17271-3023
800-220-3326
215-757-2956 fax

Florikan ESA Corp.
1523 Edger Place
Sarasota, FL 34240
800-322-8666
941-377-3633 fax
Email: buglady@aol.com

E.C. Geiger, Inc.
Rt. 63, Box 285
Harleysville, PA 19438
215-256-6511
215-256-6110 fax
Email: geigerintl@hortnet.com

The Green Spot, Ltd.
93 Priest Rd.
Nottingham, NH 03290-6204
603-942-8925
603-942-8932
603-942-5027 voice mail
Email: GrnSpt@internetMCI.com

Harmony Farm Supply
3244 Hwy. 116 No. F
Sebastopol, CA 95472
707-823-9125
707-823-1734 fax
Email: kate@harmonyfarm.com
http://www.harmonyfarm.com

Hot Pepper Wax, Inc.
305 Third St.
Greenville, PA 16125
888-667-3785
724-646-2302 fax
Email: lindag@hotpepperwax.com
http://www.hotpepperwax.com

Hydro-Gardens, Inc.
PO Box 25845
Colorado Springs, CO 80932
719-495-2266
719-531-0506 fax
http://www.hydro-gardens.com

IGENE Biotechnology, Inc.
9110 Red Branch Rd.
Columbia, MD 21045
410-997-2599
410-730-0540 fax

International Technology Services Inc.
PO Box 19227
Boulder, CO 80308-2227
303-473-9141
303-473-9143 fax
Email: intertechserv@worldnet.att.net

IPM Laboratories
PO Box 300
Locke, NY 13092-0099
315-497-2063
315-497-3129 Fax

Koppert Biological Systems
2856 Main St. South
Ann Arbor, MI 48103
313-998-5589
313-998-5557 fax

M&R Durango, Inc.
PO Box 886
Bayfield, CO 81122
970-259-3521
970-259-3857 fax

Mycogen Crop Protection
5501 Oberlin Dr.
San Diego, CA 92121
800-745-7476
619-453-9089 fax
Email: soares@mycogen.com

Mycotech Corp.
PO Box 4109
Butte, MT 59702-4109
800-383-4310
406-782-9912 fax
Email: mycotech@montana.com

Natural Pest Controls
8864 Little Creek Dr.
Orangeville, CA 95662
916-726-0855
916-726-0855 fax
Email: natpestc@cwnet.com
http://www.naturalpestcontrol.com

Nature's Control
PO Box 35
Medford, OR 97501
800-698-6250
541-899-9121 fax
Email: bugsnc@teleport.com

Novartis Crop Protection, Inc.
PO Box 18300
Greensboro, NC 27419-8300
800-334-9481
336-632-2861 fax
http://www.cp.us.novartis.com

Olympic Horticultural Products
PO Box 1885
Bradenton, FL 34206-1885
800-659-6745
888-647-4329 fax
Email: olympic@hortnet.com
http://www.hortnet.com/olympic

Plant Health Care
440 William Pitt Way
Pittsburg, PA 15238
800-421-9051
http://www.planthealthcare.com/

Praxis
2723 116th Ave.
Allegan, MI 49010
616-673-2793
616-673-2793 fax
Email: praxis@datawise.net

Rincon-Vitova Insectaries, Inc.
PO Box 1555
Ventura, CA 93002
800-248-2847
805-643-6267 fax
Email: bugnet@west.net

Rohm & Haas Co.
100 Independence Mall West
Philadelphia, PA 19106
800-523-0762
215-592-2797 fax
http://www.rohmhaas.com

SePRO Corp.
11550 N. Meridian St., Suite 180
Carmel, IN 46032-4562
800-419-7779
317-580-8290 fax
Email: rogers@sepro.com
http://www.sepro.com

Sespe Creek Insectary
PO Box 176
Lindsay, CA 93247
209-562-6464

Soil Technologies Corp.
2103 185th St.
Fairfield, IA 52556
800-221-7645
515-472-6189 fax
Email: soiltech@lisco.com
http://www.lisco.com/soiltech

Stine Seed Co.
2225 Laredo Trail
Adel, IA 50003
800-362-2510
515-677-2716
http://www.stine.com

Stoller Enterprises, Inc.
8582 Katy Freeway, Suite 200
Houston, TX 77024
800-539-5283
713-461-4467 fax

Thermo Trilogy Corp.
9145 Guilford Rd., Ste. 175
Columbia, MD 21046
800-847-5620
301-604-7015 fax
http://www.thermotrilogy.com

Troy Biosciences
2620 N. 37th Dr.
Phoenix, AZ 85009
602-233-9047
602-254-7989 fax

Uniroyal Chemicals
Benson Rd.
Middlebury, CT 06749
800-243-2850
203-573-3394 fax
http://www.uniroyalchemical.com

Wellmark International
1000 Tower Lane, Suite 245
Bensonville, IL 60106
800-842-3135
630-227-6065 fax

Whitmore Micro-Gen
3568 Tree Court Ind. Blvd.
St. Louis, MO 63122
800-777-8570

Wilbur-Ellis Co.
191 W. Shaw Ave., Suite 107
Fresno, CA 93704-2876
209-226-1934
209-226-7630 fax

By Lane Greer and Steve Diver
NCAT Agricultural Specialists

March 1999

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Appendix I: Monitoring and Scouting Techniques for Greenhouse Plants *

	Aphids	Plant Bugs	Shore Flies	Fungus Gnats	Leaf-Miners	Mealy-bugs	Broad Mites	Spider Mites	Soft Scales	Armored Scales	Slugs	Thrips	White-flies	Cater-pillars
<u>Monitoring:</u>														
Hot pink sticky cards at top of plant												X		
Yellow sticky cards at top of pot	X	X	X	X	X							X	X	
Horizontal sticky trap at top of pot	X		X	X	X									
Trap/Indicator plants		X			X							X	X	
Place piece of potato on media			X	X										
<u>Scouting:</u>														
Inspect underside of leaf	X					X	X	X	X	X		X	X	
Inspect upper surface for stippling/small white spots								X				X		
Inspect leaves for mines within tissue					X									
Inspect new growth or terminal for feeding	X	X					X					X		
Lightly blow into flowers and look for movement											X			

	Aphids	Plant Bugs	Shore Flies	Fungus Gnats	Leaf-Miners	Mealy-bugs	Broad Mites	Spider Mites	Soft Scales	Armored Scales	Slugs	Thrips	White-flies	Cater-pillars
Tap flowers over white surface & look for movement	X							X				X		
Press lower leaf on white card and look for spots on card								X						
White or brown spots on flowers												X		
Dark area on buds that are just opening												X		
Check for leaves on media for feeding & larvae beneath			X	X										
<u>Observe for:</u>														
Honeydew or sooty mold on leaves	X					X			X	X				
Brown callused-like spots on stems/leaves									X	X				
White cottony mass on stems/leaves						X								
Holes in leaves											X			X
Small clear skeletonized spot on leaf											X			X
Cut edges of leaves											X			X
Frass on leaves														X

	Aphids	Plant Bugs	Shore Flies	Fungus Gnats	Leaf-Miners	Mealy-bugs	Broad Mites	Spider Mites	Soft Scales	Armored Scales	Slugs	Thrips	White-flies	Cater-pillars
Small black spots on leaves (fecal drops)			X									X		
Chlorotic (yellow) spots on upper leaf surface	X								X	X		X	X	
Wilting of new growth		X												
Caste skins on leaf from molting insect	X													
Curling of leaves	X						X							
Distortion of new growth	X	X				X	X						X	
Main stems of plants	X	X				X			X	X				
Slime trail on leaf											X			
Buds fail to open or uneven opening of flowers												X		
Webbing on leaves or flowers								X						
Gnat-like insects flying among plants			X	X										

* Source: Oetting, Ronald D. 1997. Table: Ornamentals - Greenhouse Plants. In: *1997 Insect Control Guide.* Meister Publishing, Willoughby, OH. p. 354-355

Appendix II: Beneficial Organisms*

Organism	Supplier	Pests Controlled	Application/Comments
Amblyseius degenerans or *Iphiseius degenerans* (predatory mite)	Intl. Technology Services, IPM Labs., Green Spot	aphids	
Amblyseius fallacis or *Neoseiulus fallacis* (predatory mite)	IPM Labs., Rincon-Vitova, Green Spot	mites	Release when pest levels are low. Prefer high humidity.
Anagyrus pseudococci (parasitic wasp)	Praxis	mealybugs	
Aphidius colemani (parasitic wasp)	Florikan, IPM Labs., Harmony Farm Supply, Praxis, Rincon-Vitova, Green Spot	aphids	Release.5-2/sq. yd.; humidity should be 70-85%, temp. 65-77°F. Release at first sign of pests and for 3 consecutive weeks thereafter. Sensitive to pesticides.
Aphidius matricariae (parasitic wasp)	Arbico, Hydro-Gardens, Green Spot	aphids	500-3000/A. Can be used in greenhouses all year long.
Aphidoletes aphidimyza (predator midge)	Nature's Control, Intl. Technology Services, IPM Laboratories, Hydro-Gardens, Arbico, Praxis, Rincon-Vitova, Harmony Farm Supply, Green Spot	aphids	1-3/10 sq.ft.; humidity should be 50-90%, temp. 60-80°F. Release when aphids are first observed; release lower numers for preventive control; apply every two weeks. Active at night; sensitive to daylength.
Aphytis melinus (parasitic wasp)	Arbico, Sespe Creek Insectary, Harmony, Hydro-Gardens, IPM Labs, Natural Pest Controls, Praxis, Green Spot	many scales	10,000-100,000/A; humidity should be 20-80%, temp. 65-95°F.

Organism	Supplier	Pests Controlled	Application/Comments
Chilocorus spp. (beetle)	Praxis	scales	
Chrysopa carnea (predator)	Natural Pest Controls, Beneficial Insectary, Caltec, Arbico, A-1 Unique Insect Control, Praxis, Rincon-Vitova, Hydro-Gardens	aphids, caterpillars, mealybugs, scales, spider mites, thrips, whiteflies	1 lacewing/5-30 aphids; 1000 eggs/200 sq. ft. Apply every 1-3 weeks as needed. May arrive as eggs, immatures, or adults.
Chrysoperla rufilabris (predator)	Arbico, Beneficial Insectary, IPM Labs., A-1 Unique Insect Control, Nature's Control, Praxis, Rincon-Vitova	see above	
Chrysoperla spp. (predator)	M&R Durango, Florikan, Green Spot	see above	
Coccophagus lycimnia (parasitic wasp)	Praxis	scale	
Coleomegilla imaculata (pink ladybird beetle)	Arbico	aphids, caterpillars, mites, scales, thrips, whiteflies	1/sq. ft.; shipped as larvae and eggs.
Cryptolaemus montrouzieri (predator beetle)	Arbico, Caltec, Intl. Technology Services, IPM Laboratories, Natural Pest Controls, Nature's Control, Florikan, Harmony Farm Supply, Hydro-Gardens, Praxis, Rincon-Vitova, Green Spot	aphids, mealybugs, soft scales	2-5/infested plant; humidity should be 70-80%, temp. 70-80°F. Larvae are cannibalistic; repeat as necessary for control; do not wear white while distributing.

Organism	Supplier	Pests Controlled	Application/Comments
Dacnusa siberica (parasite)	Arbico, Intl. Technology Services, Natural Pest Controls, Praxis, Koppert, Green Spot	leafminers	500-1000/A; humidity should be 50-90%; temp. 60-85°F. Apply at first appearance of pests.
Deraeocoris brevis (predator)	Green Spot	aphids, whiteflies, thrips	
Delphastus pusillus (predatory beetle)	Arbico, IPM Laboratories, Nature's Control, Harmony Farm Supply, Hydro-Gardens, Rincon-Vitova, Praxis, Green Spot	greenhouse whitefly, sweetpotato whitefly	2000/3000 sq. ft.; temperature should be 60-85°F. Will feed on spider mites if no whiteflies are available. Should be used along with *Encarsia formosa* and traps.
Diaretiella rapae (parasite)	Arbico, Praxis	aphids	Release rates vary.
Diglyphus isaea (parasite)	Arbico, Harmony Farm Supply, Natural Pest Controls, Praxis, Intl. Technology Serv., Green Spot	leafminers	Temps. should be 75-90% and humidity around 80%.
Encarsia formosa (parasitic wasp)	Arbico, Nature's Control, IPM Laboratories, Intl. Technology Services, Florikan, Harmony Farm Supply, Hydro-Gardens, Natural Pest Controls, A-1 Unique Insect Control, Praxis, Rincon-Vitova, Green Spot	greenhouse whitefly, sweetpotato whitefly, silverleaf whitefly	Release 1/sq. ft. weekly for 3 weeks when pest numbers are low. Release 2-4/sq. ft. when pest numbers are high. Apply when pests are first observed. Should be used in conjunction with traps. May be used along with other beneficials. *E. formosa* is very susceptible to chemicals. Temps. should be at least 64°F. Re-apply every two weeks.
Encarsia luteola or *E. deserti*	Hydro-Gardens	whiteflies	

Organism	Supplier	Pests Controlled	Application/Comments
Eretmocerus californicus or *E. eremicus* (parasitic wasp)	Beneficial Insectary, Hydro-Gardens, IPM Labs., Arbico, Praxis, Green Spot	greenhouse whitefly, silverleaf whitefly, sweetpotato whitefly	Capable of handling hot, dry temperatures. Introduce when whiteflies are first observed. May be used in combination with other beneficials such as green lacewings. *Eretmocerus* is more tolerant of pesticides than *Encarsia formosa.*
Euseius spp. (predatory mite)	Praxis	scale, mites	
Harmonia axyridis (Asian lady beetle)	Green Spot	scale, whiteflies, mealybugs, aphids	Temps. should be 70-85°F; humidity around 70%.
Heterorhabditis bacteriophora (beneficial nematode)	M&R Durango, Aribco, BioLogic, Hydro-Gardens, Harmony Farm Supply, Plant Health Care, Green Spot	fungus gnats, crown borers, thrips, cut-worms, grubs, Jap. beetles, black vine weevil	Application rate varies; 1 million/3000 sq. ft. is suggested. Nematodes need a moist environment to survive and move through soil. Apply in evening directly into growing medium.
Hippodamia convergens (lady beetle) (predator)	A-1 Unique Insect Control, Arbico, Caltec, IPM Labora-tories, Natural Pest Controls, Nature's Control, Harmony Farm Supply, Hydro-Gardens, Praxis, Green Spot	aphids, mites, whiteflies	Release at dusk near an immediate food source. Spray plants with water prior to release.
Hypoaspis miles (predatory mite)	Nature's Control, Arbico, Harmony Farm Supply, IPM Labs.	fungus gnats, mites, springtails	Use 5000/200 sq. ft. Live and breed in the top ½" of soil.
Hypoaspis miles (predator)	Florikan, Harmony Farm Supply, Green Spot	thrips	100-300/sq. meter

Organism	Supplier	Pests Controlled	Application/Comments
Iphiseius degenerans or *Amblyseius degenerans* (predatory mite)	Intl. Technology Services, IPM Labs., Green Spot	aphids	
Leptomastida enormis (parasitic wasp)	Praxis	mealybug	
Leptomastix dactylopii	Praxis, Arbico, IPM Labs.	mealybug	
Lindorus lophanthae or *Rhizobius lophanthae* (black lady beetle)	Harmony Farm Supply, Arbico, Green Spot	armored scales	1-2/sq. ft. Release as soon as scales are detected. Temps. should be 59-77°F, humidity 20-90%.
Lysiphlebus testaceipes (parasitic wasp)	Praxis	aphids	
Mesoseiulus longipes or *Phytoseiulus longipes* (predator)	Arbico, Nature's Control, Harmony Farm Supply	spider mites	Introduce at first sign of pests. Can tolerate hot, dry conditions (humidity 40%, temp. 70-90°F). Tolerates extremes of temp. and humidity better than other mite predators.
Metaphycus helvolus (parasite)	Arbico, IPM Labs., Harmony Farm Supply, Natural Pest Controls, Praxis, Sespe Creek Insectary, Green Spot	scale	Temps. should be 73-87°F; RH 50%. Do not overwinter in cold climates. They are attracted to lights and sticky traps.
Neoseiulus spp. or *Amblyseius* spp. (predatory mites)			
N. barkeri	IPM Laboratories, Arbico	broad mites, thrips	10-30/plant per week.
N. californicus	Arbico, Beneficial Insectary, Caltec, IPM Labs., Nature's Control, Harmony Farm Supply, Hydro-Gardens, Rincon-Vitova	spider mites	Can tolerate hot conditions (humidity 60% min.; temp. 70-90°F). Introduce at first sign of spider mites. Can survive absence of prey longer than other predator mites.

Organism	Supplier	Pests Controlled	Application/Comments
N. cucumeris	Arbico, Natural Pest Controls, Nature's Control, Intl. Technology Services, Florikan, IPM Labs., Harmony Farm Supply, Hydro-Gardens, Rincon-Vitova, Green Spot	thrips, mites	Humidity should be 70-90%, temp. 50-85°F. Introduce at first sign of pests.
N. cucumeris and *N. barkeri*	Hydro-Gardens	thrips, aphids, mites	1 predator/sq. ft.; humidity should be moderate, temp. 70°F. Establish population early. Repeat every month during periods of warm, dry weather.
Neoseiulus fallacis or *Amblyseius fallacis* (predatory mite)	IPM Labs., Rincon-Vitova, Green Spot	mites	Release when pest levels are low. Prefer high humidity.
Orius insidiosus (minute pirate bug) (predator)	Florikan, IPM Labs., Harmony Farm Supply, Arbico, Hydro-Gardens, Praxis, Koppert, Intl. Tech. Services, Green Spot	aphids, caterpillars, thrips, whiteflies, mites	1/10 sq. ft. (preventive), 1 every 2 sq. ft. when pests are present. Temperature should be 70-90°F. *Orius* are dormant September–April. Re-apply every 2-3 weeks. Very susceptible to pesticides. Works well in combination with *Neoseiulus cucumeris*.
Phytoseiulus longipes or *Mesoseiulus longipes* (predator)	Arbico, Nature's Control, Harmony Farm Supply	spider mites	Introduce at first sign of pests. Can tolerate hot, dry conditions (humidity 40%, temp. 70-90°F). Tolerates extremes of temp. and humidity better than other mite predators.
Phytoseiulus persimilis (predatory mite)	Arbico, Beneficial Insectary, Hydro-Gardens, Intl. Technology Services, Natural Pest Controls, Nature's Control, Caltec, Florikan, IPM Labs., Harmony Farm Supply, Praxis, Green Spot	spider mites	2000 mites/3000 sq. ft. or 1/5 sq. ft. Apply at first sign of spider mites. If pests persist, re-apply every 3-5 weeks. Can be used in combination with either *Galendromus occidentalis* or *Neoseiulus californicus*. May be used in combination with *Bt* or Enstar II. Also available in *P. persimilis* Ht for higher temperatures. Humidity should be 60-90%, temps. 65-80°F.

Organism	Supplier	Pests Controlled	Application/Comments
Propylea quatuordecimpuncata (predatory beetle)	Praxis	aphids	
Rhizobius lophanthae or *Lindorus lophanthae* (black lady beetle)	Harmony Farm Supply, Arbico, Green Spot	armored scales	1-2/sq. ft. Release as soon as scales are detected. Temps. should be 59-77°F, RH of 20-90%.
Stethorus punctillum (spider mite destroyer)	Nature's Control, Green Spot	spider mites	100 spider mite destroyers start a colony. These lady beetles live 4-5 weeks.
Steinernema spp. (beneficial nematodes)	Hydro-Gardens, Nature's Control	cutworms, thrips, white grubs, shore flies, fungus gnats, etc.	1 million/3000 sq. ft.; temperature should be above 55°F. Apply in evening, directly to growing media. Water in in after application. Needs moist environment to
Steinernema spp.and *Heterorhabditis* spp.	Florikan, Green Spot	see above	thrive.
Steinernema carpocapsae (beneficial nematodes)	BioLogic, Thermo Trilogy, Arbico, Harmony Farm Supply, M&R Durango, Hydro-Gardens, IPM Labs., Praxis, Green Spot	moths, borers, ear-worms, rootworms, beetles, cutworms, fungus gnats, crickets, grubs, shore flies, weevils, maggots, etc.	11,000-35,000/sq. ft. Work in moist soil at temps. from 50-85°F. For best results, apply at dusk.
Steinernema feltiae (beneficial nematodes)	BioLogic, Geiger, M&R Durango, IPM Laboratories	see above	Apply when media temps. are 55-90°F.
Stethorus punctillum (lady beetle)	Praxis	spider mites	
Thripobius semiluteus (parasite)	Arbico, Nature's Control	thrips	

* Source: Greer, Lane. 1999. ATTRA Technical Specialist. Compiled from magazine articles, Extension bulletins, and product literature.

Appendix III: Biorational Pesticides*

Abamectin – produced by the soil organism *Streptomyces avermitilis*

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Avid	Novartis	spider mites, leafminers	12 hours	Many beneficials can be released one week after use.

Ampelomyces quisqualis – fungus that parasitizes powdery mildew

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
AQ10	Plant Health Care	powdery mildew	4 hours	Begin application as soon as host tissue emerges. Apply at least 2 sequential sprays 7-14 days apart. Works best under conditions of high humidity.

Azadirachtin – extract of neem seed; IGR that works through contact or ingestion

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Azatin	Green Spot	aphids, caterpillars, fungus gnats, leafhoppers, leafminers, Western flower thrips, whiteflies, psyllids	4 hours	Apply when pests first appear.
Neemazad	Thermo Trilogy	aphids, caterpillars, thrips, greenhouse whitefly, leafminers, sweetpotato whitefly, psyllids, leafhoppers	12 hours	Cannot be applied through irrigation. Low rate can be used as a preventative.

Beauveria bassiana – fungus that works through contact; exposure to non-target insects should be avoided

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Naturalis-O	SePro	aphids, caterpillars, mites, psyllids, thrips, whiteflies	4 hours	Apply when insects first appear and repeat every 7-10 days. Need good spray coverage. Not compatible with other fungicides.

Beauveria bassiana (cont.)

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
BotaniGard	Mycotech	giant whitefly, green peach aphid, black vine weevil, other aphids and whiteflies, thrips, leafhoppers, psyllids, white grubs	12 hours	See above.

Burkholderia cepacia – see Pseudomonas (Burkholderia) cepacia

Clandosan – dried material isolated from crustacean exoskeletons. Product acts in soils to stimulate growth of soil microorganisms and destroy nematodes.

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
ClandoSan 618	IGENE Biotechnology	plant-pathogenic nematodes	12 hours	Single annual application.

Garlic extracts

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Garlic Gard	Soil Tech-nologies	repels many insects		
Garlic Barrier	Green Spot	repels many insects	4 hours	Use late in the day. Can be mixed with fish oil or horticultural oil. Do not use in combination with bumblebees or honeybees.

Gliocladium virens – naturally occurring soilborne fungus that attacks soilborne, plant pathogenic fungi

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
SoilGard	Thermo Trilogy	*Rhizoctonia, Fusarium, Pythium, Phytophthora, Thielaviopsis*	4 hours	Incorporate into soil before planting.

Herbicides – sustainble herbicides labeled for greenhouse use

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
DeMoss	Mycogen	mosses, liverworts		Contains potassium salts of fatty acids. Avoid contact with desirable foliage. Apparently nonvolatile.
Scythe	Mycogen	nonselective		Contains pelargonic acid and related fatty acids. nonselective post-emergence weed control in non-crop areas. Reportedly non-volatile. Avoid contact with desirable foliage and green stems.

Horticultural oil – includes dormant and summer superior oils

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
All Seasons	Green Spot	aphids, mealybugs, scales, thrips, whiteflies, spider mites	4 hours	Use on sunny days to promote rapid drying and decrease chance of phytotoxicity. Not compatible with beneficials.

Hot pepper wax – contains capsaicin, paraffin, and mineral oil

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Hot Pepper Wax	Green Spot	aphids, loopers, beet army-worms, mites, whiteflies, thrips, mealybugs, etc.	4 hours	Also contains herbal essential oils. Not compatible with beneficials.
Hot Pepper Wax	Hot Pepper Wax, Inc.	see above		

Insecticidal soap – contains potassium salts of fatty acids

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
M-Pede	Mycogen	aphids, mealybugs, scales, thrips, whiteflies, spider mites	12 hours	Phytoxicity is often a concern, esp. after repeated applications.
Safer	Green Spot	see above	4 hours	See above.
Insecticidal soap	Olympic	see above		

Metarhizium anisopliae – not yet commercially available

Myrothecium verrucaria – biological nematicide

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
DiTera	Abbott	plant-pathogenic nematodes	4 hours	Can be used before or after planting.

Neem oil – multi-purpose organic insecticide/fungicide/miticide; kills eggs, larval and adult stages of insects

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Trilogy 90EC	Thermo Trilogy	greenhouse whitefly, silver-leaf whitefly, sweetpotato whitefly, thrips, whiteflies, leafminers, aphids, mites, psyllids, San Jose scale, scale, spider mites, downy mildew, powdery mildew, Alternaria, Botrytis, etc.	4 hours	Apply at first signs of damage. Repeat every 7-10 days as needed.
Triact 90EC	Thermo Trilogy	see above	4 hours	For ornamental crops only.

Paecilomyces fumosoroseus (PFR) – expected to become available in 1999; controls whiteflies, Western flower thrips, and spider mites

Prosper Nema – pathogenic fungi

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Prosper Nema	Arbico	nematodes	0 hours	Apply as needed to maintain control.

Pseudomonas (Burkholderia) cepacia – bacterium to control root rot diseases

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Deny	Stine Seed	*Rhizoctonia, Fusarium, Pythium*		
Intercept	Soil Tech-Nologies	*Rhizoctonia, Fusarium*, *Pythium*, nematodes		

Saccharopolyspora spinosa – soil-inhabiting actinomycete

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Conserve	Dow Agro Sciences	caterpillars, leafminers, thrips		

Soybean oil

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Golden Natur'l Spray Oil	Stoller	aphids, fungus gnats, lace bugs, leafminers, scales, mealybugs, spider mites, whiteflies	12 hours	

Streptomyces griseoviridis – naturally-occurring, soilborne bacterium

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Mycostop	Green Spot	*Fusarium, Alternaria, Phomopsis*	4 hours	Can be incorporated into medium or applied to seed.

Streptomyces lydicus – naturally-occurring, soilborne actinomycete

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Actinovate	Green Spot	*Pythium, Fusarium, Phytophthora, Sclerotinia*		Can be incorporated into medium or applied to seed.

Trichoderma harzianum - fungus

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
Bio-Trek HB	Wilbur-Ellis	*Fusarium, Pythium, Rhizoctonia*	12 hours	Apply to seed.
Bio-Trek Nursery Drench	Wilbur-Ellis	*Fusarium, Pythium, Rhizoctonia*	12 hours	

Trichoderma harzianum (cont.)

Brand Name	Supplier	Pests Controlled	REI	Application/Comments
RootShield	BioWorks	*Fusarium, Pythium, Rhizoctonia, Sclerotinia*		
Trichodex	Abbott	botrytis		
TopShield	BioWorks	botrytis, powdery Mildew		

*Source: Greer, Lane. 1999. ATTRA Technical Specialist. Compiled from magazine articles, Extension bulletins, and product literature.