NEW ENGLAND GREENHOUSE FLORICULTURE GUIDE

A Management Guide for Insects, Diseases, Weeds, and Growth Regulators

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SECTION C: DISEASE MANAGEMENT

INTRODUCTION

How to Use This Section

This section provides information on pathogens, management practices and chemicals for the control of plant diseases of greenhouse crops. Please read *General Management Practices* (page **Error! Bookmark not defined.**) for a brief summary of environmental, cultural and chemical practices that help prevent and manage plant diseases. Please see *Causes of Plant Diseases* (page **Error! Bookmark not defined.**) for an overview of fungi, bacteria, viruses and nematodes that cause plant diseases. *Diseases of Interior Landscape Plants* (page C.7) provides information about managing diseases on plants in interiorscape installations. Table C–3, *Chemical Control of Plant Diseases* (page 17), provides disease-by-disease specifics for chemical control of plant diseases. This section, which sometimes refers to other sections for more detailed information, allows you to scan most of the common diseases that occur on greenhouse crops.

This section does not address disease management of vegetables or herbs grown as bedding plants in greenhouses.

Disease management information for vegetables grown as bedding plants is available on-line at www.nevegetable.org.

Herb disease management information is available on-line at www.ipm.uconn.edu/pa_greenhouse.

A Word About Chemical Recommendations

Fungicides play an important role in Integrated Pest Management (IPM). Sometimes they are the most effective component, but in other cases, their use may be ineffective, inappropriate or illegal. To maximize the usefulness of fungicide treatments, use them in an informed and intelligent manner. An accurate diagnosis of disease (the cause of the symptoms) is necessary for the development of an effective IPM program. It is important to identify the pathogen, its host range, know the optimum conditions for its development, and its sensitivity to specific fungicides.

These fungicide recommendations serve as a guide for selecting appropriate materials. One or more additional fungicides or formulations may be labeled for a particular disease other than what is listed. Note that some fungicides are labeled for more crops than others. Keep in mind that a material's *effectiveness* is not related to the number of crops on its label. Other factors to consider are formulation (wettable powder, flowable, etc.), residue, spectrum of activity, resistance management, and safety. Pesticide users are responsible for making sure products are registered for use on specific crops in their respective states, and for using products according to label directions.

Resistance Management

It is important to use fungicides wisely to prevent them from losing effectiveness. Fungicides with different active ingredients (a.i.) should be rotated to prevent development of resistance. Resistance may result in poor or no disease control.

Fungicides are classified as systemic (penetrant) or protectant (contact). *Systemic* chemicals are absorbed into plant tissues. *Protectant* materials act as a barrier to fungal infection, and do not penetrate plant tissue. In addition, fungicides are grouped by their mode of action (MoA), and each MoA group is assigned a Fungicide Resistance Action Committee Group number (FRAC code). Most systemic fungicides are specific in their mode of action; thus, it requires very little change in the genetics of fungus populations for resistance to develop. Protectant fungicides are less likely to develop resistance problems, as they have multi-site modes of action (FRAC codes preceded by "M"). Cross-resistance can also occur among a.i. within a chemical group.

To prevent the development of resistance, alternate applications among different MoA groups, or mix or rotate systemic/protectant fungicides. A list of fungicide names, companies, REIs, EPA registration numbers and FRAC Codes is provided in Table C–1 on page C.8. You can find more information about FRAC codes at: www.frac.info/home.

GENERAL MANAGEMENT PRACTICES

It is important to know what disease you are trying to prevent or control. When diseases are not successfully controlled or become recurring problems, it is often because the cause was not accurately identified. Considering that many fungicides have a narrow spectrum of activity, an accurate diagnosis is particularly important. Also, non-infectious diseases can mimic those caused by microorganisms.

Fungicides cannot correct a problem caused by high soluble salts, poor aeration or nutrient imbalance.

Become familiar with the major diseases that affect each crop grown, the symptoms associated with each disease, the conditions that favor disease development and how to manage each disease. Three components are required for disease to develop: a susceptible host plant, the pathogen, and environmental conditions favorable for disease development. These three components comprise the three sides of the "disease triangle." Aim your management practices at reducing one or more sides of the triangle, thus reducing the amount of disease.

Important principles of plant disease management include the use of resistant cultivars, sanitation, sound cultural practices and often fungicides. A holistic or integrated approach to plant disease control by incorporating genetic resistance, cultural management techniques, and chemical controls is the best approach and is highly encouraged.

Resistant Cultivars

A safe and low input way to manage plant diseases is to grow resistant cultivars (varieties) of a crop. If a particular disease is prevalent in your geographic area, determine if appropriate resistant cultivars are available.

Sanitation

Sanitation greatly enhances management of greenhouse diseases. Remove all diseased plants from the greenhouse. Discard unsold stock at the end of each cropping cycle. Plants carried over from previous crops may harbor plant pathogens and insect pests. Inspect each lot of plants and, if disease is present, discard or treat them immediately. Maintain a disease prevention program for stock plants. Inspect stock plants for disease symptoms and do not take cuttings from infected plants. If a knife is used to take cuttings, dip it in a disinfectant, such as a 10% household bleach solution, Physan® or ZeroTol 2.0® before moving from one stock plant to the next. Transport the cuttings in clean containers and work on a sanitized surface. Clean newspaper provides a relatively sanitary surface.

Before growing a crop, clear the greenhouse of plant debris, weeds, flats and tools. Wash and disinfect empty benches, potting tables, storage shelves, tools and pots to remove media and plant debris. Ventilate the area if using sodium hypochlorite (household bleach) for this purpose, as bleach can be toxic to some plants, especially poinsettia.

After the greenhouse has been sanitized, avoid recontaminating it with pathogens. Purchase seeds, bulbs and cuttings from reliable sources. Use culture-indexed cuttings, if available, to reduce the chance of introducing pathogens. Seeds and bulbs should be disinfected by chemical and/or heat treatment, preferably by the seed company.

Growing media are easily reinfested by way of dirty hose nozzles and tools. Provide a hook to keep hose nozzles off the floor. Hang up tools after cleaning them with soap and water. Sodium hypochlorite (household bleach) diluted at the rate of 1 part bleach (5.25%) to 9 parts water is a good general disinfectant for tools, pots and bench tops. Rinse with water after treatment to prevent corrosion of metallic surfaces. See Table C-3 for commercially available disinfectant products made for this purpose.

Cultural Practices

High relative humidity is one of the major factors contributing to powdery and downy mildew and other disease problems in the greenhouse, especially *botrytis* blight. High humidity is especially troublesome when greenhouses are tightly sealed to conserve energy. Cool nights also increase humidity. Warm air holds more moisture than cold air. During warm days the greenhouse air picks up moisture. As air cools in the evening, especially during spring and fall, its moisture-holding capacity drops until the dew point is reached and water begins to condense on surfaces.

Condensation can be reduced by three methods:

1. Keep the vents open an inch or so (or run exhaust fans at low capacity) when the heat comes on in the late afternoon. This allows cooler air to enter the greenhouse while warm moist air leaves. As the entering cooler air is heated, relative humidity drops. After 5 to 10 minutes, close vents or turn off fans.
2. When extremely moist conditions exist in a greenhouse, it may be necessary to exchange the air several times at night. Equipment can be purchased to turn on exhaust fans at predetermined times. The fans should remain on long enough to exhaust one volume of air. Heat loss is small, since the mass of the exhausted air is small relative to the combined mass of the greenhouse structure, plants, media, floor, etc., which hold heat inside the greenhouse. Watering

early in the day when the warm air can absorb moisture from wet surfaces can further reduce humidity.

3. Moving air in the closed greenhouse helps reduce water condensation on plant surfaces. A horizontal air flow fan system or the overhead polyethylene ventilation tube system minimizes temperature differentials and cold spots where condensation is likely to occur. The horizontal air flow (HAF) system is described below.

Splashing of spores and/or contaminated soil spread soil-borne pathogens. Drip and ebb-and-flow irrigation systems help minimize pot-to-pot splashing of soil associated with hand watering. They also eliminate the use of a hose nozzle, which may periodically touch the growing medium along the bench. However, ebb-and-flow systems can become contaminated with pathogens and result in rapid and widespread infection of the crop.

High soil moisture and high soluble salts enhance root rots caused by the fungi *Pythium* and *Phytophthora*. *Rhizoctonia* is favored by a drier medium. Select a well-drained medium, test for soluble salts periodically, and apply water for optimum growth of the crop.

Horizontal Air Flow

John W. Bartok, Jr., Extension Professor Emeritus (Agricultural Engineer), University of Connecticut

Horizontal Air Flow (HAF) is based on the principle that air moving in a coherent pattern in a building such as a greenhouse needs only enough energy to overcome turbulence and friction losses to keep it moving. In other words, it just has to be "kicked along." The fans need to be sized and placed properly to do this.

Air is heavy. The air over each square foot of floor area in a typical greenhouse weighs about one pound. A 30 by 100-foot greenhouse contains about 1.5 tons of air. Once the air is moving it coasts along like an auto traveling on a level road. That is why HAF is so efficient. It takes only 4 small fans to keep air moving at 50 to 100 feet/min in a 30 by 100-foot greenhouse.

Uniform Temperature

As air moves in a horizontal pattern down one side and back the other in a free-standing greenhouse or down one bay and back in an adjacent bay in a gutter-connected house, mixing occurs from side to side and floor to ceiling. We have instrumented a number of houses and seldom see more than 2°F difference between any two points. Because of the constant movement of the air, heat supplied at one end is carried to all parts of the greenhouse quickly. Stratification of air is also eliminated.

Fewer Disease Problems

Research has shown that air movement of 50–100 ft/min is adequate to keep nighttime leaf temperatures almost identical with the surrounding air. When leaf temperatures are allowed to cool much below the air temperature, condensation occurs as the dew point is reached, supporting disease development. Radiant cooling on clear nights, especially in non-IR poly covered houses, cools plant leaves several degrees below air temperature. HAF reduces this difference.

Carbon Dioxide

During daylight hours, photosynthesis depletes the carbon dioxide that is in the boundary layer of air next to the leaf. Moving air replaces this depleted air with fresh air with a higher carbon dioxide content. If carbon dioxide is being added, a lower level is usually adequate to get the same plant responses, for instance, 800–1000 ppm rather than 1200–1500 ppm.

Cooling Effect

During warm days in the spring and fall, solar radiation warms exposed leaf surfaces to as much as 15°F above air temperature. This can cause burning of the leaves, flowers or fruit. HAF removes this excess heat and increases plant growth. These are some of the major benefits from HAF; now let's look at some of the installation techniques.

Fan Capacity

To keep the air mass moving at the 50–100 ft/min speed, requires a certain amount of energy to overcome turbulence and friction losses. A rule of thumb based on greenhouse trials and smoke bomb tests is 2 cu ft/min fan capacity for each square foot of floor area. For example, in a 30 by 100-foot greenhouse the total cfm fan capacity needed is 30 x 100 x 2 = 6000 cfm. Four 1600 cfm output fans would be needed. This can be reduced slightly in houses with plants grown only on the floor. It may need to be increased slightly in houses with crops such as tomatoes, roses or hanging baskets.

Type of Fan

Use a circulating fan, not an exhaust fan. Circulating fans operate against zero static pressure and have higher efficiencies than exhaust fans that are designed with higher static pressure to force air through louvers. Because the fans operate 24 hours/day for 8–9 months of the year, they should be as efficient as possible. Before purchasing, compare fans on an energy efficiency rating (EER), cfm output/watt of electricity input. If the manufacturer does not provide this information you can calculate it by dividing the cfm output by amps x volts. For example, a 1/15 hp, 16-inch diameter fan has an output of 1656 cfm and uses 0.9 amps @ 115 volts. EER = 1656/(0.9 x 115) = 16 cfm/watt. Efficiencies of 14–16 are standard. Better fans have efficiencies of 18 or higher. Generally, permanent split capacitor (PSC) motors have a higher efficiency than shaded pole motors.

Multi-speed and Variable Speed Fans

This adds considerable cost to the fan and cannot be justified for most applications, as air movement to 150 ft/min does not affect plant growth.

Home Type Circulating Fans

These low cost fans have been used by some growers with good results and by others with poor results. One grower who installed a set of these had some fail after 4 months.

Fan Location

Correct siting of fans is important for smooth air flow. In freestanding greenhouses, fans should generally be located 1/4 of the width from the sidewall. This puts them in the center of the air mass that is being moved. In gutter-connected houses, where the air mass is moving down one bay and back the other, the fan should be located in the center of the bay.

In both types of houses, the first fan is best located 10 to 15 feet from one end wall. This boosts the air coming around the corner. Subsequent fans are usually located 30 to 50 feet apart with the last fan at least 50 feet from the end wall. On the opposite side or bay, the same spacings hold with the first fan located 10 to 15 ft from the opposite end wall.

Height of the fans is not critical but should be above head height to be out of the way. In many greenhouses a truss or collar tie can be used for support. Note: to keep long hair from being drawn into the fan, blades should be enclosed with an OSHA approved guard. If the house contains hanging baskets, a location a couple of feet above or below them is best. One problem that can occur with a poor installation is short-circuiting of the air across the house before it reaches the next fan. This shows up as cold spots or areas of poor growth and is caused by not adding enough energy to the air or having the fans too far apart. The easiest ways to check this are to use a smoke bomb, available from a heating system supplier or from Superior Signal Co., Inc., P.O. Box 96, Spotswood, NJ 08884 (www.superiorsignal.com), or use a fogger. Place the smoke or fog behind one of the fans after the airflow has stabilized. Watch its movement. Short-circuiting is easy to observe. Incense sticks also work well, especially for detecting turbulence in the air flow.

In early fall or late spring operation, the HAF system should be shut off when exhaust fans or vents are needed to cool the greenhouse. A power relay can be wired into the circuit so that either one or the other is activated at one time. Maintenance is also important for efficient operation. Clean dust and dirt from fans to increase air flow and reduce motor temperature.

Fungicides

Too often it is assumed that disease control is synonymous with fungicide use. Fungicides can provide excellent control of some diseases, but for others they may be ineffective, unavailable or illegal. In general, use broad-spectrum fungicides (or a combination of several materials) on a preventive basis to control root diseases. For most foliage diseases, fungicides should be applied when disease is first evident. For valuable crops or when conditions are known to be favorable for disease development, apply fungicides on a preventive basis.

Thorough coverage is important. In the case of soil drenches, it may be necessary to apply additional water to push the fungicide deeper into the growing media. Most foliar fungicides act as protectants on the plant surface, killing spores after they germinate and absorb the toxicant. Thus it is important to thoroughly cover foliage before spores land on the surface. Additional applications are usually needed to protect new growth.

Soil Treatment

Field soil, whether used by itself or as an amendment to a soilless medium, must be treated to eliminate soil-borne plant pathogens, insects and weed seeds. After the soil has been treated, take care to avoid reinfestation. Soil can be steam-sterilized. It is best, however, to avoid the use of field soil in greenhouse production.

Steam

Treatment with steam is preferred over fumigants because it is faster, very effective and safe. Proper steam treatment kills all pathogens, and nearly all weed seeds. The soil moisture content prior to steaming is important. Proper soil moisture is approximately the same as for good planting conditions: soil squeezed in the hand should crumble easily. The temperature of the entire soil mass should be raised to 160–180°F for 30 minutes. It is important to use several accurate thermometers placed in one or more corners and the center of the soil. If it is difficult to achieve uniform steam throughout the soil, sample the soil with several thermometers to find the coolest area, wait for it to reach 160°F, and then start timing the 30-minute steam treatment.

Steaming soil can result in some undesirable effects such as overkill of beneficial soil microorganisms and accumulation of ammonium nitrogen and toxic forms of manganese. Test soil that is high in organic matter for ammonium levels after steaming. Several weeks may be necessary to allow for the dissipation or conversion of ammonium. This time also allows beneficial microorganisms to reestablish.

The use of aerated steam at 140–160°F reduces the undesirable effects produced by higher temperatures. In addition to being biologically efficient, aerated steam saves energy.

Causes of Plant Diseases

Bacteria

Bacteria are very small microorganisms. Under the high power (1,000 X) of a compound microscope they appear as tiny rods. To put their size into perspective, approximately 600 bacteria lined up end-to-end would measure 1/16″. Bacteria can multiply very rapidly, doubling their populations every 30–60 minutes.

With few exceptions, plant pathogenic bacteria cause disease by colonizing the internal tissues of plants, thereby interrupting normal growth and function. Bacteria cause a variety of symptoms including leaf spot, bud rot, canker, vascular wilt, soft rot and galls. Symptoms caused by bacteria are often not distinguishable from those caused by fungi. Soft rot bacteria like *Erwinia chrysanthemi* invade the space between cells and dissolve the cementing material (pectin), resulting in the characteristic symptoms of soft rot. On the same host, *Pseudomonas cichorii*, which is unable to produce pectic enzymes, causes a dry lesion as opposed to a soft rot.

Bacteria that colonize the vascular system cause systemic disease. When bacteria become systemic, they are transported relatively rapidly throughout the vascular system. The plant wilts due to the plugging of the water-conducting cells. Some systemic bacteria, such as *Xanthomonas campestris pv. pelargonii*, also produce pectic enzymes that cause rot in later stages of disease.

Management of Bacterial Diseases

Copper products are very toxic to bacteria as well as many fungi. However, pesticides are only marginally effective unless coupled with sound cultural practices. Since water splash, insects, handling and pesticide applications spread bacteria, diseased plants should be promptly isolated from healthy plants or discarded.

Space plants adequately to allow for quick drying after watering. Discontinue overhead watering when bacterial diseases are evident. Reduce relative humidity and avoid prolonged periods of leaf wetness. When propagating geraniums, snap cuttings from the plant or, if a knife is used, disinfest it at least when moving from one stock plant to the next. Wholesale propagators of geraniums should culture-index stock plants.

Viruses

Viruses are ultra-microscopic, infectious particles composed of nucleic acid surrounded by a protein coat. Virus particles multiply only within living host plant cells where they disrupt normal cell functions. Viruses can spread systemically throughout the host plant, and plants may be infected even when symptoms of disease are not apparent. Many different viruses can infect floricultural crops. Some, like cymbidium mosaic virus, have a narrow host range. Others, like cucumber mosaic virus and impatiens necrotic spot virus, can infect a wide variety of greenhouse plants as well as vegetable crops and weeds.

Symptoms of virus infection are most evident on foliage. Mosaic, which is a variable pattern of chlorotic and healthy tissue on the same leaf, is a common symptom. Other foliar symptoms include leaf crinkle or distortion, chlorotic streaking (especially in monocots), ringspots, line patterns and distinct yellowing of veins. Flowers of virus-infected plants may be deformed, or show streaks or flecks of abnormal petal color. A subtler but very common symptom of virus disease is stunting of the plant. Symptoms may be masked under certain environmental conditions or at particular times of the year, making their diagnosis more difficult.

The spread of viruses in greenhouses occurs in a variety of ways, depending on the virus. Mechanical transmission through handling of plants or use of infested tools is an efficient means of spreading tobacco mosaic virus. However, most viruses are not easily spread in this manner. Some, such as tomato ringspot virus, can be transmitted through infected seed. The most efficient way to spread viruses in floriculture crops is by vegetative propagation of infected stock plants. In this manner, viruses are passed on through successive crops. Insects such as aphids, thrips, mites and leafhoppers are the most important vectors of viruses.

General Management Practices for Virus Diseases

It is of primary importance to have the virus disease accurately identified. Casual on-site diagnosis is often inaccurate due to confusion of symptoms with other viruses, nutritional disorders, chemical injury, insect feeding and other problems. Serological techniques are currently available to accurately identify a wide range of viruses. Once identified, more specific control strategies can be developed.

There are no chemical control measures for virus diseases other than those directed at the vectors. Management practices include starting crops with virus-free seed or cuttings, eradicating weed hosts, reducing insect vectors and destroying diseased plants. Some propagation specialists provide virus-indexed plant material. In the virus-indexing process, stock plants are evaluated for the presence of specific viruses through the use of indicator plants or serology and molecular techniques. Virus-indexed plants are not immune or resistant to subsequent virus infection. Proper sanitation practices are necessary to prevent virus infection. Weed control and removal of crop debris can eliminate possible reservoirs of virus-infected material.

Insect control may help to inhibit the spread of certain viruses. Reduction or elimination of thrips is essential for controlling the spread of the tospoviruses INSV and TSWV (see below). Reduced handling of plants can minimize the mechanical transmission of tobacco mosaic virus. Destroy virus-infected plants.

Management Practices for Tospovirus

Tospovirus is a virus family that includes impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV). Tospoviruses, particularly INSV, are the most important viruses in the floriculture industry. These viruses are spread by Western flower thrips. The virus is not seedborne but is brought into the greenhouse on plants that have been exposed to the virus. Once the thrips in the greenhouse pick up the virus they can transmit it to weeds and crops. To manage tospoviruses, it is necessary to get rid of all infected plant material, eliminate thrips and eradicate all weeds. Do not grow vegetable transplants in the same greenhouse as ornamental bedding plants. Inspect plants carefully for symptoms of virus and thrips before bringing new plants into the greenhouse.

Nematodes

With a few exceptions, nematodes are not an important problem in New England's floriculture industry. There are several reasons for this. Soilless media are devoid of plant parasitic nematodes and subsequent contamination is not likely. Also, the relatively short length of time most crops are grown limits the ability of nematodes to build up to damaging levels.

Nematodes are small (1/32–1/4″ long) roundworms that are common inhabitants of field soil. Most nematodes are not parasitic to plants but prey on microorganisms, insects and other nematodes. Plant parasitic nematodes are specialized to parasitize plants. Roots, stems or leaves may be colonized, depending on the genus of nematode and the host involved. With regard to root-colonizing species, root-knot nematodes (*Meloidogyne* spp.) are among the most important in outdoor crops such as herbaceous perennials. As the common name implies, symptoms appear as galls of various sizes (up to ¼″ diameter) on roots. Root-knot nematodes have a fairly wide host range that includes many greenhouse plants. The bulb and stem nematodes (*Ditylenchus* spp.) occur in hyacinth, narcissus, tulip, mountain and annual phlox, and iris, as well as other plants. Colonized bulbs may display necrotic tissue, and leaves may produce swellings and distorted growth. Foliar nematodes (*Aphelenchoides* spp.) occur on *Anemone*, Indian rubber plant, birds nest fern, African violet, gloxinia, Rieger begonia, chrysanthemum, *Monarda*, *Phlox subulata*, Boston fern, Easter lily, *Lamium* and *Peperomia*. Symptoms may be mistaken for those of fungal or bacterial infections.

Root-knot nematodes occur primarily as contaminants of field soil but they may also be brought in on plant material. The bulb and stem nematodes may occur in field soil or as bulb inhabitants. Foliar nematodes are brought into the greenhouse on plant material.

Management of Nematodes

Use a soilless medium, purchase plant material from a reputable source, and inspect plants that are known to be commonly infected, in order to avoid nematode problems. When bulb and stem nematodes or foliar nematodes appear, destroy infected plants and do not re-use the media. When root-knot nematodes occur in beds, steam or fumigate the soil between crops. Soil can be fumigated with Basamid® (dazomet).

Diseases of Interior Landscape Plants

Interior landscape plants are generally propagated in the southern United States, where they are exposed to a multitude of fungal, bacterial, viral and nematode diseases. However, once they are planted in an interiorscape site, cultural and environmental factors usually become more important than infectious diseases. The exception is when a root disease occurs.

Notify your supplier immediately if a shipment of interior plants arrives with an unacceptable amount of disease or insect infestation. Occasional leaf spotting is generally not a concern unless the plants are placed in a humid environment and subjected to frequent wetting of the foliage. Fluoride toxicity is often confused with infectious disease. Municipal water supplies are often treated with fluoride. Spider plant, Ti plant (*Cordyline*) and dracaena are highly susceptible to fluoride damage. Peacock plant (*Calathea*), aglaonema, areca palm, corn plant and prayer plant, among others, are moderately susceptible. Marginal necrosis and spotting, often with yellow margins, are typical symptoms of fluoride toxicity.

Some field-grown plant material may become infected with phytophthora or become infested with root-knot nematodes. Laboratory examination is necessary to diagnose these diseases.

Management of Diseases of Interior Landscape Plants

When only a few leaves are spotted, remove affected leaves. When cankers or injury to a branch occur, prune out the affected area. Root-knot nematode injury and root rot cannot be corrected; remove and destroy affected plants. When fluoride injury occurs, the damage may reduce the quality of the plant to the extent that it should be discarded. For fluoride-sensitive plants, maintain the soil above pH 6.0–6.5 to reduce the availability of fluoride.

If plants are grouped together in an interiorscape, and some are found to have root rot, a fungicide drench may be warranted to protect the other plants. An accurate diagnosis of the cause of root rot and identification of the associated plant material are important.

Table C–1: Fungicides for interiorscapes (see labels for rates, restrictions and application methods)

Group (FRAC Code)	Common Name	Trade Name
MBC fungicides (Benzimidazoles & Thiophanates) (1)	thiophanate-methyl	3336 WP, 3336 F
		T-Methyl SPC 50 WSB
		T-Methyl SPC Granular
Phosphonates (33)	phosphorus acid (and salts)	KPhite 7LP, Alude; Alude Systemic Fungicide, Rampart
DMI (demethylation inhibitor) (3)	triflumizole	Terraguard SC
imidazoles		
PhenylAmide (4)	mefenoxam	Subdue Maxx, Subdue GR
PhenylPyrrole (12)	fludioxinil	Medallion, Medallion WDG, Emblem
Quinone outside Inhibitor (QoI) (11)	trifloxystrobin	Compass, Compass O
	pyraclostrobin	Empress Intrinsic
	fluoxastrobin	Disarm O
Combination*	dimethomorph (40) & ametoctradin (45)	Orvego
	fluxapyroxad (7) & pyraclostrobin (11)	Orkestra
	fludioxonil (12) & mefenoxam (4)	Hurricane WDG
	pyraclostrobin (11) & boscalid (7)	Pageant Intrinsic
	thiophanate-methyl (1) & chlorothalonil (M5)	Spectro 90 WDG
Mycopesticides* (NC)	*Streptomyces lydicus*	Actinovate SP**
(Bacillus sp. = 44)	*Bacillus amyloliquefaciens*	Double Nickel 55**, Double Nickel LC**,
		Triathlon BA**
	Bacillus subtilis	Cease**,
		2-3-2 Companion Liquid Biological Fungicide – Greenhouse, Nursery & Ornamental Crops
	Gliocladium catenulatum	Prestop
Inorganic protectants* (M1) (copper, fixed copper, different copper salts)	copper hydroxide	Nu-Cop 3L, Nu-Cop 50 DF**,
		Nu-Cop HB, Nu-Cop 50 WP**,
		Champ WG**, Champ Formula 2 Flowable, Champ DP
	copper sulfate pentahydrate	Phyton 27, Phyton 35
	copper octanoate	Camelot O**
	basic copper sulfate	Cuproxat
(Not classified)	hydrogen peroxide	X3
	potassium bicarbonate	Milstop**

* Note: This table is intended to help you manage the development of fungicide resistance. Do not use the same fungicide repeatedly, and rotate among fungicide groups. Fungicide groups marked with an asterisk (*) are not known to result in resistance development.

** Material is approved for use in organic production.

Fungi

Fungi cause the majority of plant diseases. Fungi do not photosynthesize, so are distinct from plants. Fungi are filamentous, highly branched microorganisms that grow over or through the substrate that provides them with nutrients. Fungi that have evolved into plant pathogens attack living plants, and in horticultural crops, cause loss of yield or aesthetic value. Fungi are very diverse in their ecology, growth habits, form and pathogenicity. Symptoms of fungal diseases also vary greatly. Fungi that live and reproduce in soil ("soil-borne fungi") are the principle cause of damping-off, and root and crown rot. They generally don't produce air-borne spores but are moved from contaminated soil to clean soil easily by tools, water-splash, transplants, hose ends, and hands. Fungi that infect stems, foliage and flowers usually produce spores that are easily spread by air currents, splashing water or insects.

Damping-off

Damping-off is a disease of germinating seeds and young seedlings. Several common fungi are capable of causing damping-off, including *Rhizoctonia, Alternaria, Sclerotinia* and the water molds *Pythium* and *Phytophthora*. Several other fungi (and a few bacteria) are also known to cause damping-off. Although seedlings are most susceptible to damping-off, the same pathogens may cause root rot on older plants.

Symptoms of damping-off may include one or any combination of the following: bare spaces where seed was planted, and rotted or wilting of seedlings, often with a stem lesion that appears dark or water-soaked, necrotic and sunken. The roots of young plants may be affected or they may not have any symptoms. Plants often die in a circular pattern because fungi grow radially from the point of contamination.

Environmental conditions and cultural practices can result in symptoms that resemble damping-off. Hot water from sun-baked pipes and hoses, overfertilization, low temperatures, drought, heat stress, gas fumes and chemical injury can all kill seedlings. However, in these cases initial symptoms occur on the foliage or upper part of the seedlings. When the seedlings collapse, the stem at the soil line is usually firm and healthy and the root system is usually unaffected. An exception to this would be over-fertilization. In this case, roots often appear desiccated or shriveled.

Management of Damping-off

To prevent damping-off, use a pasteurized soil medium and/or treat soil or seed prior to planting (see the fungicides listed for root rot). It is not necessary to steam or fumigate commercial soilless media, but protective fungicides are often applied soon after planting for crops prone to root rot. Store media in covered containers to avoid contamination. Avoid overwatering and overfertilization.

The biological controls Mycostop® and PlantShield® are used to prevent damping off and root rot caused by certain fungi.

Management of Botrytis Blight

Botrytis blight, one of the most common fungal diseases of greenhouse crops, is often called "gray mold" because gray fuzzy-appearing spores develop on the infected plant surfaces. Ornamentals, herbs, vegetables and other crops are susceptible. Integrated management of environmental conditions, sound cultural practices and fungicides control this disease.

Depending on the host and environmental conditions, *Botrytis* can cause leaf and flower blight, cankers, damping-off and root rot. Plants may be attacked at any stage but new tender growth, freshly injured tissues, and senescing or dead tissue are most susceptible. Spores are produced in abundance on lesions as well as on plant debris left on benches, the greenhouse floor and in cull piles. Spores are easily disseminated by air currents and splashing water. Given the common occurrence of *Botrytis* in greenhouses and the large number of spores produced, greenhouse managers must avoid conditions that favor disease development.

Like other fungi, *Botrytis* germinates, infects and develops in a specific range of temperatures and relative humidity. Generally, spore germination and infection of the host depend on a film of moisture for 8–12 hours, relative humidity of 93% or greater, and temperatures of 55–65°F. After infection, plant tissue colonization occurs at temperatures up to 70°F. *Botrytis* is primarily a spring and fall problem, when warm days followed by cool evenings result in water condensation on plant surfaces. Regulation of temperature, humidity and leaf wetness duration can prevent disease development.

Botrytis blight cannot be controlled effectively with fungicides alone. An integrated approach is necessary for successful management of this disease:

1. Control weeds and remove plant debris between crop cycles and during production.
2. Space plants to allow good air circulation and reduce humidity within the canopy.
3. Reduce relative humidity and leaf wetness duration to prevent spore germination.

Reducing relative humidity (RH) by heating and ventilating is relatively inexpensive compared to the loss of revenue that can result from *Botrytis* blight and other plant diseases. Warm air holds considerably more moisture than cool air. In the evening, as warm air becomes cooler, RH rises until water vapor begins to form a film of moisture (dew) on surfaces. This film of moisture is essential for *Botrytis* (and other fungal pathogens) to germinate and cause infection. To prevent high RH and dew formation, turn on the heat and open the vents. The warm humid air is vented to the outside as the cooler outside air is drawn into the greenhouse. As the incoming air is heated (even if it is saturated with water), the RH drops significantly. This air exchange takes only 5 or 10 minutes. The energy necessary to run fans and provide heat is not significant. Under some conditions, this cycle may have to be repeated several times during the evening. Install timing devices can simplify the process. Moving air, even in a closed greenhouse, helps reduce moisture on plant surfaces. Horizontal airflow (HAF) produces more uniform temperatures and reduces the probability that cool spots in the greenhouse might develop a condensation problem. See page C.3 for a description of HAF. Water in the morning when it is cool, so that rising daytime temperatures cause air to absorb moisture, thereby reducing relative humidity.

Management of Crown Rot and Root Rots

Above-ground symptoms of root rot include stunted growth, yellowing and wilting. Earlier symptoms can only be detected by removing the pot to examine the roots. Healthy roots are generally white and firm; but decayed roots may be water-soaked in appearance and/or darkened and easily macerated between the fingers. Some root colonizing fungi move into the stem and cause a canker or "black leg."

Pythium is one of the most common fungi found in roots of greenhouse crops. Species of *Pythium* vary in their pathogenicity to plants and sensitivity to fungicides. *Phytophthora*, a related fungus, is generally more pathogenic than *Pythium* but occurs less frequently in greenhouses. *Phytophthora* and *Pythium* are most destructive with abundant soil moisture and high fertility. Most fungicides registered for *Pythium* and *Phytophthora* do not control *Fusarium*, *Rhizoctonia, Thielaviopsis, Sclerotinia* and *Cylindrocladium*.

Rhizoctonia is also a common cause of root disease and stem canker. Unlike *Pythium*, drier soil favors *Rhizoctonia*, so it is more active in the upper zone of soil. When relative humidity is high and foliage is wet, *Rhizoctonia* can grow over the foliage of plugs and bedding plants, resulting in a severe blight. This disease is often called web-blight because close inspection of the foliage reveals a fine webbing of fungal growth. Other crown and root pathogens occasionally seen include *Thielaviopsis, Fusarium, Sclerotinia* and *Cylindrocladium.* Most fungicides registered for use against these pathogens do not control *Pythium* and *Phytophthora*. A laboratory diagnosis is needed to determine the cause of root rot.

Sources of Root Disease Fungi

Fungi that attack root systems are natural inhabitants of the soil, where they survive indefinitely. They are easily introduced into the growing medium by soiled hands, tools, flats and colonized transplants. *Pythium* and *Rhizoctonia* live in and on dirt floors, and even in dust and debris on concrete, so it is important to keep hose ends off the floor. Fungus gnats and shore flies can also introduce plant pathogenic fungi into a crop.

Fumigation or steaming of soilless media is not necessary. However, when a soilless medium becomes contaminated with plant pathogens, root rot can develop quickly. A soilless medium amended with field soil must be treated to prevent the introduction of plant pathogens, nematodes, insects and weeds.

Management of Root Diseases

Wash used pots and flats with soap and disinfest in a 10% household bleach solution or similar agent. If field soil is used wholly or as an amendment to a soilless mix, it must be treated. Steam is the least expensive, safest and most effective method. The whole soil mass must reach 160—180°F for at least 30 minutes. For some crops, protectant fungicides should be used from the beginning of the planting cycle and repeated at regular intervals. Banrot® or other appropriate combinations of fungicides provide a broader spectrum of activity. Biological control agents such as *Trichoderma* spp., *Bacillus* spp., and *Gliocladium* spp. are available in products formulated for media treatment.

Shore fly adults can move *Pythium* and other fungi from soil to plant or from plant to plant. Fungus gnat adults do not move fungi efficiently but their larvae ingest spores of *Pythium* and mycelia of *Rhizoctonia* and deposit them into wounds they create in plant roots and stems. Thus, these two insects greatly increase the chance of spread of fungi and the severity of disease. These insects can be controlled by both biological and chemical methods.

Management of Powdery Mildew

Powdery mildew is one of the most easily recognized plant diseases. Powdery mildew fungi usually produce visible fungal growth consisting of spores and mycelium (fungal strands) on the foliage or, in some cases, on stems or flowers. On most hosts, the disease is easy to recognize but occasionally other diseases produce similar symptoms. Also, powdery mildew may damage some plants such as kalanchoe and sedum, but not develop the characteristic powdery spores.

Powdery mildew fungi behave somewhat differently from other plant pathogens such as *Botrytis.* For example, powdery mildew spores do not need free water on plant surfaces to germinate; free water may actually kill spores and inhibit disease development. Powdery mildew is most prevalent in high humidity. Powdery mildew fungi are fairly host specific; for example, they do not spread from rose to zinnia. But, plants in the same family, such as the *Asteraceae,* may be susceptible to the same powdery mildew species.

Unlike most fungi, powdery mildews only colonize the outer layer of plant cells, so chemical eradication of infections is possible. It is not necessary to *prevent* powdery mildew with fungicides. Fungicide use can be delayed until after the disease is observed.

Species of powdery mildew fungi vary in their need for humidity, temperature and moisture. Optimum temperature for disease development is 70–85°F. Poinsettia powdery mildew does not occur above 86°F, so plants kept inside during the summer months do not show obvious symptoms.

To reduce powdery mildew in greenhouses, heat at least one hour before sunset, then ventilate to exhaust moist air and reduce relative humidity below 93%. Horizontal air flow (HAF) systems (see page C.3) can also help. Avoid irrigating plants late in the day.

Management of Rust Diseases

Rust fungi are highly specialized parasites that depend on living plants for growth and development. Most have complex life cycles that include up to five different spore stages and two different hosts to complete their life cycle. Depending on their need for an alternate host, rust fungi are classified as either heteroecious or autoecious. Heteroecious rusts need two different hosts to complete their life cycle. Autoecious rusts complete their life cycle on one host.

An example of a heteroecious rust fungus is *Pucciniastrum epilobii*, the cause of fuchsia rust. In this case the fungus requires both *Abies* (fir) and *Epilobium* (fireweed) to complete its life cycle. Fuchsia is closely related to fireweed and is also a host of the fungus. The life cycle is as follows: teliospores, which allow the fungus to survive the winter, form on infected fireweed plants in autumn (teliospores have not been noted on fuchsia). In spring, the teliospores germinate and produce basidiospores that infect the needles of various species of fir (in our region, white and balsam fir). After infection, aeciospores develop and can only infect fireweed, and perhaps fuchsia, but cannot reinfect fir. The fungus then produces urediospores on infected fireweed and fuchsia. The rusty-appearing blisters on the foliage contain masses of urediospores. The urediospores reinfect fireweed and fuchsia repeatedly, but cannot infect fir. The fungus can reside in the greenhouse, spread and reinfect fuchsia as long as infected fuchsia or fireweed is present.

Geranium rust, caused by the fungus *Puccinia pelargonii-zonalis*, is an example of an autoecious rust. The geranium rust fungus only produces two kinds of spores, both on geranium. No alternate host is needed.

Some plants are infected by a number of different rust fungi, some of which may be either autoecious or heteroecious. Roses are hosts of at least 5 different rust fungi, all of which are autoecious. It is helpful to know the life cycle of a rust to manage it.

In the case of heteroecious rusts, the alternate host may be the initial source of spores. For fuchsia rust, this may be fireweed or fir. Air-borne spores from fir can infect fuchsia stock kept outdoors in summer. Stock plants brought in from elsewhere may also be a source of the disease. For heteroecious rusts, elimination of the alternate host can be helpful in managing these diseases.

Rotate Fungicides to Reduce Resistance Development

To avoid fungicide resistance, rotate among chemicals in different fungicide groups. For example, in Table C–2 (page C.12), 3336 50 WP® and OHP 6672® have the same active ingredient (thiophanate-methyl). Eagle® and Terraguard® are in the same chemical group (FRAC Group) and should not be rotated with each other. Zyban® is a mixture of thiophanate-methyl and mancozeb, and this mixture prevents the fungus from becoming resistant to thiophanate-methyl.