UMass Extension

CHECKLIST
DISEASE MANAGEMENT

- ✓ 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.
- ✓ After the greenhouse has been sanitized, avoid recontamination 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.
- ✓ Provide a hook to keep hose nozzles off the floor.
- ✓ Use horizontal air flow to minimize temperature differentials and cold spots where condensation is likely to occur.
- ✓ Use resistant cultivars whenever possible.
- ✓ At the end of each cropping cycle, discard unsold stock. Plants carried over from previous crops may harbor plant pathogens.
- ✓ Maintain a disease prevention program for stock plants. Inspect stock plants for disease and do not take cuttings from infected plants.
- ✓ During propagation, dip cutting tools in a disinfectant before moving from one stock plant to another.
- ✓ Monitor seedlings for damping off and vegetative cuttings. Look for localized symptoms such as root lesions, cutting end rot, leaf spots, and shoot blights.
- ✓ Monitor roots for root rot symptoms.
- ✓ Inspect incoming cuttings.
- ✓ Properly identify the disease.
- ✓ To prevent root rot diseases, select a well-drained medium, test for soluble salts periodically, and apply water for optimum growth of the crop.
- ✓ Space plants for good air movement and sunlight. This results in rapid drying of foliage and better spray coverage.
- ✓ Irrigate early enough in the day to allow foliage to remain dry overnight.
- ✓ Water sparingly during periods of cloudy and rainy weather.

- ✓ Learn to manipulate the greenhouse environment for disease management. Heat and vent to lower humidity in the greenhouse.
- ✓ 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.
- ✓ Biofungicides are fungicides that contain living organisms such as fungi and bacteria. They must be used preventatively as they will not cure diseased plants.
- ✓ When growing in ground beds (soil of the greenhouse), treat with steam to kill disease organisms. It may be necessary to wait several weeks to allow for the dissipation or conversion of ammonium. This time also allows beneficial microorganisms to reestablish.
- ✓ To prevent the development of resistance, alternate applications among different modes of action (MoA) groups, or mix or rotate systemic/protectant fungicides.
- ✓ Use grafted tomato plants to protect against some diseases.
- ✓ Do not reuse growing media.
- ✓ When working with plants such as cleaning or propagating, work in blocks and clean hands and tools between blocks. If gloves are worn, clean or change gloves between blocks.
- ✓ Use separate greenhouses for vegetable plants and ornamental plants.

DISEASE MANAGEMENT

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, 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 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. At the end of each cropping cycle, discard unsold stock. Plants carried over from previous crops may harbor plant pathogens. 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 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, or commercial product for this purpose 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 recontamination 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. Commercial disinfectant products are available that are made for this purpose.

Keep hose nozzles off the floor.
Photo: Tina Smith, UMass Extension

When working with plants such as cleaning or propagating, work in blocks and clean hands and tools between blocks. If gloves are worn, clean or change them between blocks. The same is true when working with incoming plants, always work in blocks and if possible keep plants from different suppliers separated.

Cultural Practices
Soil-borne pathogens are spread by splashing of spores and/or contaminated soil. Drip irrigation and ebb-and-flow systems help minimize splashing and 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.

Root rots caused by the fungi *Pythium* and *Phytophthora* are enhanced by high soil moisture and high soluble salts. *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.

Use separate greenhouses for vegetable plants and ornamental plants to protect vegetable plants from tospoviruses; protect cucurbit seedlings from powdery mildew and to make it easier to treat vegetable plants if pesticides are needed.

High relative humidity is one of the major factors contributing to mildew and 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 the air cools in the evening, especially during spring and fall, the moisture-holding capacity drops until the dew point is reached and water begins to condense on surfaces.

Relative humidity can be lowered 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. Humidity can further be reduced by watering early in the day when the warm air can absorb moisture from wet surfaces.

3. Moving air in the closed greenhouse helps reduce water on plant surfaces. A horizontal air flow 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.

Overgrown plants are more prone to diseases such as *Botrytis* and make it difficult to obtain adequate fungicide coverage. Proper planting dates, plant nutrition, watering practices and height management techniques help to prevent lush, overgrown plants. Proper spacing will also lower humidity within the plant canopy.

Horizontal Air Flow

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.

Horizontal Air Flow Fan
Photo: Tina Smith, UMass Extension

Air is also 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 four small fans to keep air moving at 50 to 100 feet/min in the above 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. Experiments instrumenting a number of houses seldom had more than 2 degrees 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 is also eliminated.

Disease Prevention

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, the dew point is reached and condensation occurs, supporting disease organisms. 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 having 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 degrees 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 location of fans is important for smooth air flow. In free-standing 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, use the same spacing, 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 way to check this is to use a smoke bomb, available from heating system suppliers or Superior Signal Co., Inc., P.O. Box 96, Spotswood, NJ 08884, or use a fogger. Place the smoke or fog behind one of the fans after the air flow has stabilized. Watch its movement. Short circuiting is easy to observe. Incense sticks also work well, especially for detecting turbulence in the air flow.

During 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 the 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 surface of the plant and kill spores after they germinate and absorb the toxicant. Thus it is important to have thorough coverage of the foliage before spores land on the surface. Additional applications are usually needed to protect new growth.

Biofungicides
Biofungicides are fungicides that contain living organisms such as fungi and bacteria. They must be used preventatively as they will not cure diseased plants. Biofungicides may suppress plant diseases by competition, attacking or feeding on the pathogen, or by producing secondary toxins that can inhibit the growth of pathogens. Many different types of biofungicides are being used with variable results by growers. These variable results may be due to differences in the

particular crop or plant, the soil mix used, the soil pH, the fertilizer program and the level of disease pressure.

Advantages of using biological fungicides include: lower re-entry interval (REI) than traditional fungicides, may be on the Organic Materials Review Institute (OMRI) list and may be less phytotoxic to plants.

Soil Treatment

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. Steam treatment will also eliminate insects and weed seeds. After the soil has been treated, take care to avoid reinfestation. Soil can be fumigated with a chemical registered for that purpose. It is best, however, to avoid the use of field soil in greenhouse production of container crops.

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 160–180ºF 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 obtain uniform steam throughout the soil, sample the soil with several thermometers to find the coolest area, wait for it to reach 160ºF, 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 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 140–160ºF 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 indistinguishable 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 Practices for 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 bacteria are spread by water splash, insects, handling and pesticide applications, 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 more subtle 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.

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 the 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.

INSV on Impatiens
Photo: Tina Smith, UMass Extension

Nematodes

With a few exceptions, nematodes are not an important problem in the floriculture industry in New England. 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 (1/32–¼″ 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. Depending on the genus of nematode and the host involved, roots, stems or leaves may be colonized. 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 the 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 areas, 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 nematode may occur in field soil or as a bulb inhabitant. Foliar nematodes are brought into the greenhouse on plant material.

Management Practices for Nematodes: Nematode problems can be avoided by using a soilless medium, purchasing plant material from a reputable source, and inspecting plants known to be commonly infected. When the bulb and stem nematode or foliar nematode appears, destroy infected plants and do not reuse media. When root-knot nematodes occur in beds, steam or fumigate the soil prior to the next crop.

Fungi

The majority of plant diseases are caused by fungi. Fungi are not plants and are distinct from plants in their inability to photosynthesize. Fungi are filamentous, highly branched microorganisms that grow over or through the substrate that provides them with nutrients. Those fungi that have evolved into plant pathogens attack living plants, and in horticultural crops, cause loss of yield or aesthetic value. Fungi are extremely diverse in their ecology, growth habits, form and pathogenicity. Symptoms of fungal diseases are also highly variable. Fungi that survive and reproduce in the soil are termed soil-borne. They are the principal cause of damping-off, and root and crown rot. Soil-borne fungi generally do not produce air-borne spores but are easily transported from contaminated soil to pathogen-free soil by tools, hose ends, transplants, water-splash and hands. Fungi that cause disease of stems, foliage and flowers usually produce spores that are easily disseminated by air currents, splashing water or insects.

***Botrytis* spores (fungi) on greenhouse tomato.**
Photo: Leanne Pundt, UConn

Fungicides: 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. A pesticide's effectiveness is not related to the number of crops on its label. 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 Massachusetts, and for using products according to label directions.

Resistance Management

It is important to use fungicides intelligently to prevent them from losing effectiveness. 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 genetic change in 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 members 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, REI, EPA registration numbers and FRAC Codes is provided in Table C–8 on page. You can find more information about FRAC codes at: www.frac.info/frac/index.htm.

Grafting for Disease Management

Increasingly greenhouse tomato growers are using grafting to both decrease susceptibility to root diseases and to increase fruit production through increased plant vigor. Grafting involves splicing the fruit-producing shoot (called the 'scion') of a desirable cultivar onto the disease resistant rootstock from of another cultivar. The two cultivars most widely used for rootstock in the greenhouse are 'Maxifort' and 'Beaufort'. Both cultivars offer enhanced disease resistance to *Pyrenochaeta lycopersici* (Corky Root), most common species of nematodes, *Verticillium* sp, *Fusarium oxysporum* races 1 and 2, and *Fusarium oxysporum* fsp and *Radicis-lycopersici* (crown rot). In addition, 'Maxifort' confers a very vigorous growth habit while 'Beaufort' confers moderate plant vigor. For information on grafting tomatoes see the fact sheet: Grafting Techniques for Greenhouse Tomatoes at:
http://www.hort.uconn.edu/ipm/greenhs/htms/Tomgraft.htm

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