UF UNIVERSITY of FLORIDA
IFAS Extension

PP-202

Professional Disease Management Guide for Ornamental Plants[1]

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The ornamental plant industry thrives in Florida because of the warm, humid environment that makes Florida a gardener's paradise and a compatible location to mass produce numerous plant species. These ideal conditions also are suitable for the development of a wide variety of plant pathogens, including bacteria, fungi, and viruses. Mild winters in Florida also facilitate survival of some insects that can spread plant pathogens, especially viruses. In addition, Florida serves as a major port of entry for the international trade of ornamental plants. Trade carries the risk of introducing exotic invasive pathogens that could threaten ornamental and agricultural industries in Florida and throughout the United States, so growers are required to follow certain phytosanitory regulations. These challenges require growers to develop the most efficient production plans possible, incorporating as many tactics as they can to maximize plant health and minimize opportunities for pest and disease outbreaks—a concept known as integrated pest management (IPM). This publication is intended to be used by growers, landscape professionals, and other pest control operators as a reference for managing ornamental plant diseases. Management tactics are outlined under the following key components of an IPM program: prevention, cultural control, scouting, physical control, biological control, and chemical control. Tables 1–4 contain important information about commercial products currently available for the management of ornamental plant diseases. In addition, a list of useful websites and additional resources is available at the end of this document to supplement the information provided.

Disease Prevention

Once symptoms of a disease or pest problem are evident, management can be difficult, costly, or even impossible. Some basic management practices can help prevent pest problems from occurring in the first place. The following precautions can reduce the likelihood of plant disease development and spread.

Exclusion

Exclusion implies that healthy plants or pathogen-free planting media are kept in an isolated area that excludes plant pathogens. Plants are often grown in a nursery or greenhouse where care is taken to ensure that planting stock and media are pathogen free. When ordering seeds, bulbs, or tubers, find out if they are certified to be pathogen free. If possible, purchase planting media that has been pasteurized to kill plant pathogens and pests. All media should be stored in original bags until use or in covered containers to prevent contamination by plant pathogens. Some procedures for reducing pathogen populations in

1. This document is PP-202, one of a series of the Plant Pathology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date August 2004. Revised June 2012. Visit the EDIS website at http://edis.ifas.ufl.edu.

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native soil and planting stock are listed below (see section on Physical Control). If new plants are brought into a production system from an outside source, it is wise to isolate them from other plantings for a period of time to make sure they are free of pathogens and pests.

Avoidance

Avoidance measures are precautions taken to enable plants to escape pathogens that are present in the growing environment.

Avoid plant damage – Take care not to damage plants during installation and landscape maintenance. Damaged roots and other plant parts provide entry sites for disease-causing organisms. Rough handling of root balls can cause broken roots and interfere with the plant's ability to take up water and nutrients. Make sure the plants are secured during transport and placed gently (not dropped) into planting holes. Once established, avoid damage to trees and shrubs from line trimmers. Such damage interferes with the vascular system of the plant and creates an infection court.

Overpruning weakens trees and shrubs, making them more susceptible to attack by pathogens and pests. No more than 30% of the foliage should be removed at one time. Unless absolutely necessary, do not remove branches that are more than about half the diameter of the trunk. Large wounds take longer to heal and are more likely to decay than small wounds. Do not use tree-wound paint on tree pruning wounds because the microenvironment beneath bubbling or deteriorating paint can provide an ideal niche for damaging microorganisms.

Using "immature" planting mixes that contain incompletely composted bark or fresh manure may result in damage to plants from the release of heat and toxic compounds. Manure should be completely dry and loose before adding to planting mix. Be sure to thoroughly combine all constituents into a uniform blend. If in doubt, premixed potting soils purchased wholesale at nurseries or in garden centers provide an alternative to mixing your own.

Insects and nematodes cause feeding damage, which provides ideal sites of entry for many pathogenic fungi and bacteria. Some may also spread viruses. For example, western flower thrips and five other thrips species can transmit tomato spotted wilt virus to many plants, including chrysanthemum, gloxinia, and impatiens. The stubby root nematode can transmit tobacco rattle virus to several ornamental plants, including gladiolus, iris, tulip, and orchid. Maintaining these organisms below damaging levels reduces feeding damage, helps maintain plant health, and may also reduce the incidence of certain insect- and nematode-vectored plant pathogens.

Manipulate planting time – Manipulating the growing period to a time when climatic conditions do not favor disease development can help avoid losses. This may be a good option for plants with seasonal versatility and no resistant varieties. Pentas are very susceptible to *Phytophthora* root rot and blight during warm, wet weather. Planting pentas either before or after the rainy season is a good way to avoid losses.

Sanitation

Sanitation practices are cleanliness measures that can reduce unintentional spread of plant pathogens from diseased to healthy plants directly through mechanical transmission or indirectly from pathogen reservoirs.

Avoid mechanical transmission of pathogens – Hands and pruning tools can be readily contaminated when working with diseased plants, especially if the causal agent is bacterial, viral, or present in the vascular system (i.e., vascular wilts). *Fusarium* wilt of queen palms is a devastating disease that can be transmitted through pruning, thus readily spreading to other queen palms in a nursery or landscape. Routinely sanitize all items that come into contact with plants, soil, or debris. A 10%–20% solution of household bleach in water makes a good disinfectant for tools and soles of shoes but is quite corrosive. Examples of commercial disinfectants marketed toward plant production personnel include Consan Triple Action 20, Green Shield, and Physan 20. Sanitizer dispensers for hands, tools, and foot baths should be set up at production house entrances. Washing followed by steam sterilization is an excellent method of reducing pathogen populations on trays, pots, and other production tools. Read and follow the temperature recommendations in manufacturers' guidelines to avoid heat damage. The use of disposable transplant trays may also reduce the spread of disease. Concrete walkways in production houses are helpful because they can be regularly cleaned and disinfested easily.

Eliminate pathogen reservoirs – Always move diseased plants away from healthy plants and either destroy them or treat them in an isolated area. Plant debris and cull piles are excellent reservoirs for plant pathogens and should be kept away from and downwind of healthy plants and production areas. Personnel should disinfest hands, shoes, and tools after handling rogued, diseased, or decaying plant material before resuming regular duties.

Weeds often harbor pathogens and the insects that spread them. Suppress weeds in landscapes, plant production systems, and, as feasible, in surrounding areas. Weed control also reduces competition for water and nutrients and increases air circulation. Mulch can help control weeds, improve soil structure, and increase water retention in the soil.

Occasionally, plant pathogens are inoculated onto healthy plants through irrigation systems. This commonly occurs when irrigating with surface water from ditches or holding ponds or when irrigating with an ebb-and-flow system. Treatment with ultraviolet light or a chemical sanitizer can reduce pathogens in contaminated irrigation water.

Cultural Control

Cultural control means employing good horticultural practices to optimize plant health and decrease plant stress, which in turn decreases the likelihood of disease development.

Proper Cultivation

The first line of defense in the management of plant pest problems is to provide the required conditions for optimal plant growth and development. The location's soil type, soil porosity, sunlight exposure, soil pH, and microclimate should all be considered before a plant species is chosen to avoid conditions that are not conducive to healthy growth. Planting in improper locations can increase plant stress and the likelihood of pest problems. This may lead to more frequent pesticide applications, which may be ineffective and increase labor costs. Transplants are particularly vulnerable to plant pathogens during the first few weeks after planting and may require special care to prevent disease outbreaks.

Fertilization and Irrigation

Adequate fertilization is needed to avoid nutrient deficiencies and keep plants healthy enough to resist and recuperate from diseases. Some diseases can be avoided altogether with careful fertilizer applications tailored to specific ornamental plant species. Too much nitrogen, however, can encourage excessive growth of new shoots, which may be more susceptible to plant pathogens than hardened mature growth. One method used to control fireblight, a bacterial disease of some ornamental fruit trees, is to decrease nitrogen fertilization and irrigation to inhibit the formation of new shoots where the pathogen may attack. In extreme cases, overfertilization can also cause an excess of soluble salts in the soil. When this happens, scorching of the leaves or "salt burn" may occur because damaged plant roots cannot take up enough water. Do not assume that more is better with regard to the application of fertilizers and chemicals to plants. **Always follow label rates**.

Soils with poor drainage become waterlogged if overirrigated. Overwatering is a major catalyst for the development of many root and crown diseases, including those caused by *Phytophthora* and *Fusarium*. The lack of oxygen in waterlogged conditions causes many root cells to collapse, diminishing water and nutrient uptake. Other cells may become nonselective, allowing toxic metals and substances to be taken up by the plant. Many plant poisons, such as nitrites, are produced by microorganisms that thrive in wet (anaerobic) conditions. Further damage occurs from organisms known as facultative parasites that are attracted to decaying tissue. In waterlogged conditions, most ornamental plants, especially succulent annuals, lose vigor, wilt, and develop leaves that are pale green or yellowish. Some plants have mechanisms or specialized structures adapted to survival in wet soils. See *Landscape Plants for Wet Sites* under the Additional Resources section to choose appropriate plants for wet conditions.

Prolonged leaf wetness should be avoided to minimize foliar diseases. Adequate plant spacing promotes better air circulation, thereby decreasing periods of leaf wetness. Early morning irrigation, subirrigation, or the use of a drip system also is recommended. Water quality varies depending on the source and should be tested to ensure that pH and soluble salts are at acceptable levels for healthy plant growth.

Host Resistance

Ornamental plant cultivars generally are not selected based on their resistance to plant pathogens. However, differences in relative susceptibilities of cultivars to some pathogens exist and should be considered when and where appropriate. Antique roses, for example, are generally more tolerant of black spot and other diseases than most of the more recently developed rose hybrids. 'Natchez' is a crapemyrtle cultivar that is commonly used in Florida because of its resistance to powdery mildew.

Systemically acquired resistance (SAR) has shown promise in reducing disease in a number of crops. This phenomenon is a reaction in a plant that is triggered by various substances, including salicylic acid, chitosan, and monopotassium phosphate. Applications of certain microorganisms, including the plant-growth-promoting rhizobacteria *Pseudomonas* and nonpathogenic isolates of *Fusarium oxysporum*, have also induced SAR. A bacterial protein, harpin, is commercially produced and sold under the trade name Messenger® and may offer some protection against plant pathogens in food commodities, trees, ornamentals, and turfgrasses. For more information on harpin, see the Useful Websites section.

Crop Rotation

Many plant pathogens cause disease only on a narrow range of closely related hosts. Continuous cultivation of the same types of plants in an area for long periods of time can result in elevated populations of pathogens and other pests in the soil. Periodic rotation of plants that are susceptible to different pathogens may decrease populations of harmful organisms and reduce the incidence of these problems. Pest outbreaks tend to spread quickly within monoculture systems. When appropriate, use plants of many different families and species, or at least use different cultivars. Plant diversity decreases damage from pathogens and pests that attack specific kinds of plants.

Scouting

Monitoring for plant problems on a routine basis is the cornerstone of any IPM program and is essential in detecting early pest infestations to prevent economic loss. It is important to correctly ascertain the cause(s) of plant problems so that appropriate measures can be taken to correct them. This can be tricky because sometimes plants respond in similar ways to different types of stresses. Before disease management steps are taken, other possibilities, such as insect or mite damage, nutrient or water imbalances, and pesticide damage, should be ruled out. If the plant's recent history is unknown, ask questions and observe the surroundings to obtain clues that could lead you to a correct diagnosis.

Signs and Symptoms

Plant disease symptoms are often similar to damage caused by abiotic stresses. The ability to distinguish between the two is important. One should also be able to recognize characteristics of healthy plants, such as normal speckling, spotting, or variegation that may be confused with disease symptoms.

Signs refer to some part of a pathogen and are visible during certain environmental conditions. Signs are typically more difficult to find, but include felty or moldy fungal sporulation, cobweb-like fungal growth (mycelia), fruiting bodies (i.e., mushrooms [large], pycnidia [tiny]), sclerotia, and bacterial ooze. There are several references with color pictures illustrating common diseases of ornamental plants (see Additional Resources and Useful Websites) that may be helpful. If in doubt, contact your local Extension agent, university specialist, or a professional consultant for advice. A digital image of a plant disease sample can be submitted to university specialists free of charge by using the Distance Diagnostic and Identification System (DDIS) through UF/IFAS Extension (http://ddis.ifas.ufl.edu/). Some disease problems can be diagnosed from a picture, but most will need to be diagnosed via a sample sent to a UF/IFAS or commercial diagnostic laboratory for correct diagnosis. This fee-based service ensures an accurate diagnosis and provides valuable documentation of the problem. Ask if digital diagnosis is available from your county Extension office.

Thresholds

The presence of a pest or disease may not always require treatment. Over time, a level of damage considered economically or aesthetically unacceptable (i.e., economic threshold) should be set, as should a damage level at which action must be taken to prevent reaching this point (i.e., action threshold). In most cases, there are no set recommendations for thresholds because various systems differ widely in conditions that affect disease pressure and in plant damage tolerances. In general, the threshold for damage to ornamental plants is very low or zero because of inherent aesthetic considerations.

Record-keeping

It is wise to document all management practices as well as pest and disease outbreaks, including conditions under which they occur, control measures taken (rates, number of applications, effectiveness, etc.), and any other information that may be useful in predicting and managing problems in the future. Keep log sheets in chemical/fertilizer sheds and require employees to document pertinent information, such as his/her name, date, chemical name, rate, amount, sprayer used, and site each time an application is made. Besides being required by laws regulating pesticide usage, good records can aid in problem solving and may provide legal support in cases of false allegations. Adequate record keeping is also necessary and reduces regulatory costs for exporting plant material to other states and countries.

Physical Control

Physical control of disease-causing organisms is obtained through mechanical procedures applied directly to plants or substrates that reduce or eradicate pathogen populations. Examples follow.

Steam Sterilization

Steam has been used to disinfest soil for over 100 years, and it is practical for the sterilization of soil to be used for potting and transplanting and for intensive in-soil production of high-value crops. An application of aerated steam to maintain a uniform soil temperature of 60°C –70°C (140°F –158°F) for 30 minutes is sufficient to eliminate most disease-causing organisms present in the soil. Be sure the soil is free of clods, large pieces of plant debris, and excessive moisture, which will hamper the penetration of the steam if present.

Soil Solarization

Soil solarization is an option for managing soilborne pests in production systems and sunny landscape settings during periods of little cloud cover and rain. This technique uses clear plastic to trap the radiant energy of the sun, which heats the soil to temperatures sufficient to destroy many plant pathogens and other pests without completely eliminating beneficial organisms. Soil solarization is often used when producing high-quality bedding plants, such as cut flowers.

Hot Water Treatment

Seeds, bulbs, tubers, and cuttings can be immersed in hot water to kill potential pests, including pathogens. Daffodil and Easter lily bulbs are commonly treated with hot water to kill any nematodes that may be present. Accurate time and temperature controls must be in place for the hot water treatment to be successful. The temperature for pathogen inactivation must not exceed the critical damage threshold for the propagative material being disinfested.

Biological Control

Biological control is the use of beneficial microorganisms to suppress soilborne and foliar plant pathogens. Products containing bacteria, such as *Bacillus, Pseudomonas*, and *Streptomyces*, and fungi, such as *Gliocladium* and *Trichoderma*, have reduced a variety of fungal plant pathogens in various experiments, especially when incorporated into transplant media or used as seed treatments. Products containing biological control agents that are currently available for disease management of ornamentals are listed in Table 3, along with the active organism(s) and disease applications. Ongoing research at universities and federal facilities continues to evaluate and develop new biocontrols as well as expand the labeling of existing products. The use of organic soil amendments (e.g., compost, sewage sludge, etc.) may enhance populations of beneficial microorganisms already present in the soil. Biological control technologies are environmentally friendly IPM tools with great potential, but, currently, biological controls do not adequately control ornamental plant diseases on their own in most cases.

Chemical Control

Regardless of what other IPM strategies are used, it is sometimes necessary to apply chemical pesticides (i.e., fungicides, bactericides, etc.) to manage plant diseases. Pesticide application should be based on scouting reports and the presence of environmental conditions conducive to disease development in established planting systems. Avoid using routine "calendar sprays," which can be wasteful and may impact populations of beneficial organisms.

Pesticides may be applied to ornamental plants in a granular form, a liquid foliar spray, or a drench. Most chemicals used in disease management are applied as sprays aimed at fungal pathogens on leaves and other aboveground plant parts. Pesticides may be applied before planting to soil and planting stock in a drench or dip, respectively. Gaseous soil fumigants are sometimes applied as a preplant treatment in mass plant production systems and kill most organisms in the soil, including fungi, bacteria, nematodes, and weed seed. Fumigants are highly toxic; therefore, extreme safety precautions must be taken to protect workers.

Choosing a Pesticide

Correct diagnosis of a target disease is essential to choosing an appropriate pesticide (see Scouting section). Some products target only certain pathogens, while others are effective against a broad range of organisms. A chemical can be chosen from Table 1 based on the disease group, which describes one or more of the following: the type of symptom exhibited by the plant (e.g., blight, scab, rot), the part of the plant affected (e.g., flower, leaf, root), the type of pathogen causing the disease (e.g., downy mildew, powdery mildew), or the specific pathogen causing the disease (e.g., *Phytophthora, Stromatinia*). Disease groups describing general symptoms (i.e., leaf spots, blights, scabs) may be caused by many different pathogens. It is not likely that every chemical listed for such disease groups will control every possible pathogen for that disease group. Chemicals labeled for each disease group are listed by common name. The common name is the active ingredient contained within a product, which is sold under a trade name. For example, azoxystrobin (common name) is the active ingredient in the fungicide Heritage® (trade name).

Trade names available for each chemical in Table 1 are listed in Table 2, along with the activity of each. There is usually more than one product available for each active ingredient, and some products contain more than one chemical. A chemical's activity refers to its mobility in the plant and should be considered when choosing a product. Systemic fungicides (S) usually move upward within a plant, though there are a few that also move downward. They may be applied as foliar sprays, seed treatments, root dips, soil drenches, or tree injections. Locally systemic fungicides (LS) have limited mobility in the direct vicinity of application. Almost all systemic fungicides disrupt only one or a few steps in fungal metabolism. Therefore, resistance to these chemicals usually occurs within a few years if used frequently. It is best to use these products in combination or rotation with broad-spectrum contact fungicides to delay development of resistance. Advantages of using systemic fungicides include longer residual activity and survival of possible beneficial organisms on the plant surface. Fungicides may have protective or curative activity. Most fungicides and bactericides are protectants (P) and must be present on or in the plant in advance of the pathogen in order to prevent infection. These chemicals may be applied when environmental conditions are conducive to a disease outbreak. Products with curative activity (C) may be applied after infection but prior to severe disease symptoms. Some chemicals have both protective and curative activity that may depend on the rate of application. Resistance to many contact pesticides is slow to develop or nonexistent because many different metabolic pathways of target organisms are disrupted.

Not all ornamental pesticides may be applied to all ornamental plants, depending on phytotoxicity and the location of the plant. Most pesticide labels have a list of plants on which the product has been tested and determined safe to treat, as well as plants not tolerant of the product. To prevent loss, it is a good idea to test an unfamiliar product on a few plants before applying it on a large scale. Products in bold font in Table 2 are legal to use on plants not listed on the label if tested and found to be safe in small-scale trials.

Pesticide Performance

Insufficient coverage is one of the most common reasons for pesticide failure. Calibrate sprayers on a regular basis and maintain them in good working order to get the best performance and coverage. Many pesticides are broken down (hydrolyzed) when mixed with water above pH 7. Be aware of the water pH. When it is above 7, use an appropriate buffering solution in the tank to maintain pH in the 6.5–7 range. For safety and efficacy, pesticides should be applied the same day they are mixed with water.

Phytotoxic effects characterized by marginal leaf scorch, leaf spotting, or distortion of new growth may occur if pesticides are applied too heavily, applied under extremely hot or dry conditions (water-stressed plants), inappropriately mixed with a spreader-sticker, or are incompatibly mixed (see Tank Mixtures section). Damage can be highly variable depending on the plant species and chemical applied.

Pesticide performance is sometimes altered by the development of pathogen resistance, which may develop if the same chemical, chemicals within the same class, or chemicals with similar modes of action are applied repeatedly. Once resistance to a particular pesticide builds up within a pest population, other products may also be rendered ineffective (i.e., cross resistance). Modes of action for each chemical class, along with resistance risk, are listed in Table 4. It is wise to use rotations of chemicals within these classes, especially when using those with high resistance risk. Chemical classes with multiple-site modes of action generally pose the least risk for the development of pathogen resistance. Fungicide labels often have specific recommendations on resistance management, which should be followed rigorously.

Tank Mixtures

Spray tank mixtures of different pesticides (i.e., fungicides, insecticides, miticides, etc.) and even fertilizers may be chemically incompatible, resulting in plant injury that does not occur if any one of the products is used alone. When applying a new mix, test on a few plants and wait 24–48 hours for signs of phytotoxicity prior to large-scale use. Physical incompatibility is also possible if combining products does not result in a uniform mixture (i.e., clumping). Products that have similar formulations, classes, or that are made by the same company may be more compatible; however, always refer to the labels and/or a compatibility chart before tank mixing.

A spreader-sticker may be added to the spray mixture to obtain better coverage and residual pesticide persistence. Note that some ornamental plants may be sensitive to spreader-stickers and other additives. Check the label for restrictions. If in doubt, test for safety on a few plants before widespread use. Mixing by mechanical agitation in the spray tank is often necessary to attain best results.

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Useful Websites

Distance Diagnostic Identification System http://edis.ifas.ufl.edu/TOPIC_DDIS

EDIS homepage http://edis.ifas.ufl.edu/

Harpin fact sheet (EPA) http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_006477.htm

IPM Florida http://ipm.ifas.ufl.edu/

Landscape Plants http://edis.ifas.ufl.edu/TOPIC_Landscape_Plants

Ornamental Pest Management at Ft. Lauderdale REC http://flrec.ifas.ufl.edu/entomo/Ornamental_Pests/ornapest.htm

Plant Information Databases http://hort.ifas.ufl.edu/database/index.shtml

Planting Trees in Landscapes http://hort.ifas.ufl.edu/woody/planting.shtml

Weed Management Guide http://edis.ifas.ufl.edu/TOPIC_GUIDE_Weed_Management_Guide

Attention

Always read, understand, and follow all label instructions, including safety precautions, required personal protective equipment (PPE), range of target organisms, rates of application, risks of phytotoxicity, and compatibility with other chemicals before application.

Table 1. Chemicals used to manage diseases of ornamental plants[a]

Disease group[d]	Chemical common name	Chemical class
Fungal foliar blights and leaf spots	azoxystrobin	QoI (strobilurin)
	captan	phthalimide
	chlorothalonil	benzonitrile
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	chlorothalonil + zinc	benzonitrile + inorganic
	copper hydroxide	inorganic
	copper hydroxide + mancozeb	inorganic + EBDC[c]
	copper oxychloride	inorganic
	copper sulfate	inorganic
	copper sulphate pentahydrate	inorganic
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	dicloran	nitroaniline
	fenhexamide	hydroxyanilide
	ferbam	dithiocarbamate
	fludioxonil	phenylpyrrole
	flutolanil	carboxamide
	iprodione	dicarboximide
	kresoxim-methyl	QoI (strobilurin)
	mancozeb	EBDC
	maneb	EBDC
	myclobutanil	DMI (triazole)
	neem oil extract	lipid
	potassium bicarbonate	bicarbonate
	propiconazole	DMI (triazole)
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	sulfur	inorganic
	thiophanate methyl	benzimidazole
	triadimefon	DMI (triazole)
	trifloxystrobin	QoI (strobilurin)
	triflumizole	DMI (imidazole)
	vinclozolin	dicarboximide
Phytophthora blight	azoxystrobin	QoI (strobilurin)
	chlorothalonil	benzonitrile
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	chlorothalonil + zinc	benzonitrile
	cyazofamid	QiI
	dimethomorph	cinnamic acid
	fenamidone	QoI
	fosetyl-aluminum	phosphonates
	mancozeb	EBDC
	phosphorous acid	phosphonates
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide

Disease group[d]	Chemical common name	Chemical class
Bacterial leaf spots, blights	copper hydroxide	inorganic
	copper sulphate pentahydrate	inorganic
	copper hydroxide + mancozeb	inorganic + EBDC
	copper sulfate	inorganic
	fosetyl-aluminum	phosphonates
	phosphorous acid	phosphonates
Bacterial soft rot	copper hydroxide	inorganic
	copper sulphate pentahydrate	inorganic
	streptomycin sulfate	antibiotic
Downy mildew	azoxystrobin	QoI (strobilurin)
	copper hydroxide	inorganic
	copper sulphate pentahydrate	inorganic
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	cyazofamid	QiI
	dimethomorph	cinnamic acid
	fenamidone	QoI
	fosetyl-aluminum	phosphonates
	kresoxim-methyl	QoI (strobilurin)
	mancozeb	EBDC
	maneb	EBDC
	neem oil extract	lipid
	phosphorous acid	phosphonates
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	trifloxystrobin	QoI (strobilurin)
Powdery mildew	azoxystrobin	QoI (strobilurin)
	chlorothalonil	benzonitrile
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	chlorothalonil + zinc	benzonitrile
	copper hydroxide	inorganic
	copper oxychloride	inorganic
	copper sulfate	inorganic + sulfur
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	kresoxim-methyl	QoI (strobilurin)
	myclobutanil	DMI (triazole)
	neem oil extract	lipid
	piperalin	piperidines
	potassium bicarbonate	bicarbonate
	potassium salts of fatty acids	insecticidal soap
	propiconazole	DMI (triazole)
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	sulfur	inorganic

Disease group[d]	Chemical common name	Chemical class
Powdery mildew (cont.)	thiophanate methyl	benzimidazole
	triadimefon	DMI (triazole)
	trifloxystrobin	QoI (strobilurin)
	triflumizole	DMI (imidazole)
Petal, flower blights	captan	dicarboximide
	chlorothalonil	benzonitrile
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	chlorothalonil + zinc	benzonitrile
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	fenhexamid	hydroxyanilide
	ferbam	dithiocarbamate
	iprodione	dicarboximide
	mancozeb	EBDC
	maneb	EBDC
	myclobutanil	DMI (triazole)
	neem oil extract	lipid
	propiconazole	DMI (triazole)
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	triadimefon	DMI (triazole)
Rusts	azoxystrobin	QoI (strobilurin)
	chlorothalonil	benzonitrile
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	chlorothalonil + zinc	benzonitrile
	copper hydroxide + mancozeb	inorganic + EBDC
	ferbam	dithiocarbamate
	flutolanil	carboxamide
	kresoxim-methyl	QoI (strobilurin)
	mancozeb	EBDC
	maneb	EBDC
	myclobutanil	DMI (triazole)
	neem oil extract	lipid
	oxycarboxin	carboxamide
	propiconazole	DMI (triazole)
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	sulfur	inorganic
	thiophanate methyl	benzimidazole
	triadimefon	DMI (triazole)
	trifloxystrobin	QoI (strobilurin)
	triflumizole	DMI (triazole)

Disease group[d]	Chemical common name	Chemical class
Scabs	azoxystrobin	QoI (strobilurin)
	chlorothalonil	benzonitrile
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	chlorothalonil + zinc	benzonitrile
	kresoxim-methyl	QoI (strobilurin)
	mancozeb	EBDC
	myclobutanil	DMI (triazole)
	potassium bicarbonate	bicarbonate
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	thiophanate methyl	benzimidazole
	triflumizole	DMI (triazole)
Cylindrocladium root rot	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	fludioxonil	phenylpyrrole
	iprodione	dicarboximide
	thiophanate methyl	benzimidazole
	triflumizole	DMI (triazole)
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
Fusarium rot (root, bulb, etc.) & wilt	azoxystrobin	QoI (strobilurin)
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	fludioxonil	phenylpyrrole
	iprodione	dicarboximide
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	thiabendazole	benzimidazole
	thiophanate methyl	benzimidazole
	triflumizole	DMI (triazole)
Gliocladium rot	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	thiophanate methyl	benzimidazole
Myrothecium stem, crown, root rot	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	thiophanate methyl	benzimidazole
	trifloxystrobin	QoI (strobilurin)

Disease group[d]	Chemical common name	Chemical class
Pythium, *Phytophthora* rot	captan	dicarboximide
	cyazofamid	QiI
	dimethomorph	cinnamic acid
	etridiazole	thiadiazole
	fenamidone	QoI
	fosetyl-aluminum	phosphonates
	mefenoxam	phenylamide
	phosphorous acid	phosphonates
	propamocarb hydrochloride	carbamate
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
Rhizoctonia rot	azoxystrobin	QoI (strobilurin)
	chlorothalonil + thiophanate methyl	benzonitrile + benzimidazole
	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	fludioxonil	phenylpyrrole
	flutolanil	carboxamide
	iprodione	dicarboximide
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	thiophanate methyl	benzimidazole
	triflumizole	DMI (triazole)
Sclerotinia blight, stem rot	cyprodinil + fludioxonil	anilinopyrimidine + phenylpyrrole
	thiophanate methyl	benzimidazole
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
	vinclozolin	dicarboximide
Sclerotium blight, stem rot	azoxystrobin	QoI (strobilurin)
	fludioxonil	phenylpyrrole
	flutolanil	carboxamide
	pyraclostrobin	QoI
	pyraclostrobin + boscalid	QoI + carboximide
Stromatinia rot	vinclozolin	dicarboximide
Thielaviopsis root rot	fludioxonil	phenylpyrrole
	thiophanate methyl	benzimidazole
	triflumizole	DMI (triazole)
Algae[b]	copper hydroxide + mancozeb	inorganic + EBDC

[a]There may be several commercial products available for each chemical. Always check the label to be sure the product is appropriate for particular plants and/or locations.
[b]Algae growth is typically an aesthetic problem and not a disease.
[c]Dithiocarbamates and relatives, including ethylene bis-dithiocarbamate (EBDC)
[d] Check label for specific range of activity of each chemical listed within a disease group.

Table 2. Commercial products that contain one or more chemicals listed in Table 1[a]

Chemical or combination	Trade names	Activity[b]
azoxystrobin	**Heritage®**	S, P, C
captan	Captan 50W	P
chlorothalonil	**Chlorostar VI F**, **Concorde DF**, **Daconil®**, Manicure, **Chlorothalonil DF**, **Echo® 720**	P
chlorothalonil + thiophanate methyl	**Spectro™ 90WG**, Consyst WDG	S, P, C
chlorothalonil + zinc	Daconil Zn®	P
copper hydroxide	**Champion WP**, **Kocide® 2000 T/N/O**, etc.	P
copper hydroxide + mancozeb	**Junction**	P
copper oxychloride	COC DF, COC WP	P
copper sulfate	Basicop	P
copper sulfate pentahydrate	**Phyton 27**	P
cyazofamid	**Segway™**	LS, P
cyprodinil + fludioxonil	**Palladium™**	P
dicloran	Botran® 75-W	P
dimethomorph	**Stature® DM**	LS, P, C
etridiazole	**Terrazole®**	P
fenamidone	**Fenstop™**	LS, P, C
fenhexamid	Decree®	S, P, C
ferbam	Ferbam Granuflo	P
fludioxonil	**Medallion®**	P
fludioxonil + mefenoxam	**Hurricane™**	S, P
flutolanil	**Prostar® 70WP**, **Contrast 70 WSP**	S, P, C
fosetyl-aluminum	**Aliette® WDG**	S[c], P
iprodione	**Chipco® 26GT**	LS, P
kresoxim-methyl	**Cygnus®**	S, P, C

Chemical or combination	Trade names	Activity[b]
mancozeb	**Dithane® T/O**, **ForeRainshield**, Pentathlon DF, Protect™ T/O	P
maneb	Pentathlon	P
mefenoxam	**Subdue® MAXX®**, **Mefenoxam 2 EC**	S, P, C
myclobutanil	**Eagle® 40WP**, **Systhane® WSP**	S, P, C
neem oil extract	**Triact 70**	P, C
oxycarboxin	**Plantvax 75W**	S, P, C
phosphorous acid	Alude™, Fosphite®, **Magellan**	S[c], P
piperalin	**Pipron**	S, P, C
potassium bicarbonate	Armicarb® 100, **Kaligreen®**	P
pyraclostrobin	Insignia®	S, P, C
pyraclostrobin and boscalid	Pageant®	S, P, C
insecticidal soap	M-Pede®	P
propamocarb hydrochloride	**Banol®**	S, P
propiconazole	**Banner MAXX®**, **Propiconazole Pro**	S, P, C
streptomycin sulfate	Agrimycin 17	P
sulfur	**Sulfur 6 L**, Sulfur 90W, **Microthiol® Disperss®**, etc.	P
thiabendazole	**Mertect® 340-F**	LS, P, C
thiophanate methyl	**Cavalier Flowable, Cleary's 3336, Fungo 50**, etc.	LS, P, C
triadimefon	Bayleton® 50, Strike® 50 WDG	S, P, C
trifloxystrobin	**Compass®**	LS, P, C
triflumizole	**Terraguard® 50W**	S, P, C
vinclozolin	**Touché™ EG**	LS, P, C

[a]Trade names are listed only for example. No endorsement or criticism of any product is intended by its presence or absence from this table. Labels of products listed in **bold font** allow use on ornamental plants not listed if tested and found to be safe by the applicator. Always read and follow pesticide label instructions.
[b]Movement into the plant and type of control: S = upward systemic, LS = local systemic, P = protective, C = curative
[c]These are the only fungicides in the table with upward and downward systemic movement.

Table 3. Selected biological control products and reported disease applications[a]

Product	Organism	Claimed activity
Actinovate®	*Streptomyces lydicus*	Soilborne diseases
Binab TF WP	*Trichoderma polysporum* and *T. harzianum*	Controls a variety of fungal pathogens
BlightBan® A506	*Pseudomonas fluorescens* A506	*Erwinia amylovora*, fireblight
Companion, Kodiak®	*Bacillus subtilis*	Soilborne diseases (*Rhizoctonia*, *Phythium*, *Fusarium*, *Phytophthora*, *Sclerotinia*, anthracnose, *Botrytis*)
Contans	*Coniothyrium minitans*	Soilborne *Sclerotinia* spp.
Galltrol-A	*Agrobacterium radiobacter* 1026	Prevents crown gall
Mycostop	*Streptomyces* spp.	Wilt and root rot caused by *Pythium*, *Fusarium, Botrytis, Alternaria*, *Phomopsis*, and to a lesser extent, *Phythophthora* and *Rhizoctonia*
PlantShield	*Trichoderma harzianum*	Prevents foliar and root fungal diseases
Rhapsody® AS	*Bacillus subtilis* QST 713 strain	Anthracnose (*Colletotrichum* spp.), bacteria (*Erwinia*, *Pseudomonas*, *Xanthomonas*), black spot (*Diplocarpon rosae*), *Botrytis cinerea*, fungal leaf spots, and powdery mildew
RootShield®	*Trichoderma harzianum* T-22 strain	Prevents root rot caused by *Pythium*, *Rhizoctonia*, and *Fusarium*
Soilgard® 12G	*Trichoderma virens* GL-21	Control of damping off and root rot organisms

[a]See text for additional information

Table 4. Mode of action and resistance risk for each chemical class

Chemical class	Target	Resistance risk
anilinopyrimidine	Protein synthesis	Medium
benzimidazole	Cell mitosis	High
benzonitrile	Multisite	Low
bicarbonate	Unknown	Unknown
carbamate	Cell membrane	Low to medium
carboxamide	Fungal respiration	Moderate
cinnamic acid	Cell wall synthesis (proposed)	Low to medium
dicarboximide	Lipid peroxidation	Moderate to high
dithiocarbamate, EBDC	Multisite	Low
DMI (demethylation inhibitor)	Sterol biosynthesis	Medium
hydroxyanilide	Sterol biosynthesis	Low to medium
inorganic	Multisite	Low
lipid	Unknown	Unknown
nitroaniline	Lipid peroxidation	Low to medium
phenylamide	RNA polymerase	High
phenylpyrrole	MAP protein kinase	Low to medium
phosphonates	Unknown	Assumed low
phthalimide	Multisite	Low
piperidines	Sterol biosynthesis	Low to medium
phenylpyrrole	MAP kinase	Low to medium
QiI (quinone inside inhibitor)	Fungal respiration	High
QoI (quinone outside inhibitor) strobilurin	Fungal respiration	High
substituted aromatic	Lipid peroxidation	Low to medium
thiadiazole	Lipid peroxidation	Low to medium

Source: http://www.frac.info