

Master Gardener

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Preventing and Managing Plant Diseases

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The first and best defense against plant diseases is a healthy plant, which is the main task of an accomplished gardener. Preventing and managing plant disease begins even before planting, with site preparation and plant selection.

When a plant does not look normal, or as expected, a gardener may assume that the plant is diseased and control measures are needed. To properly diagnose plant problems, the gardener needs to have background knowledge about the plant, the current environment, and the typical diseases or other problems to which the plant is susceptible. Such information can help prevent an inaccurate diagnosis that may lead to unnecessary pesticide use, wasted time and expense, and continued plant decline.

This publication provides gardeners with information on how to establish and maintain healthy plants, and describes a systematic approach to identifying and solving problems that do occur.

Disease is a response

A plant disease is defined as a malfunction in the plant in response to continuous irritation by an infectious causal agent, also known as a pathogen. A plant disease can cause many types of symptoms that may affect the plant's ability to yield, reproduce or grow properly.

Diagnosing a disease can sometimes be difficult, and differentiating between a true disease and an abiotic disorder is crucial to developing an effective management plan. The causal agents of plant disease are biotic, or living, and are called pathogens. Abiotic disorders are caused by abiotic, or nonliving, factors. Understanding the difference between the two is crucial to diagnosing the cause of plant damage.

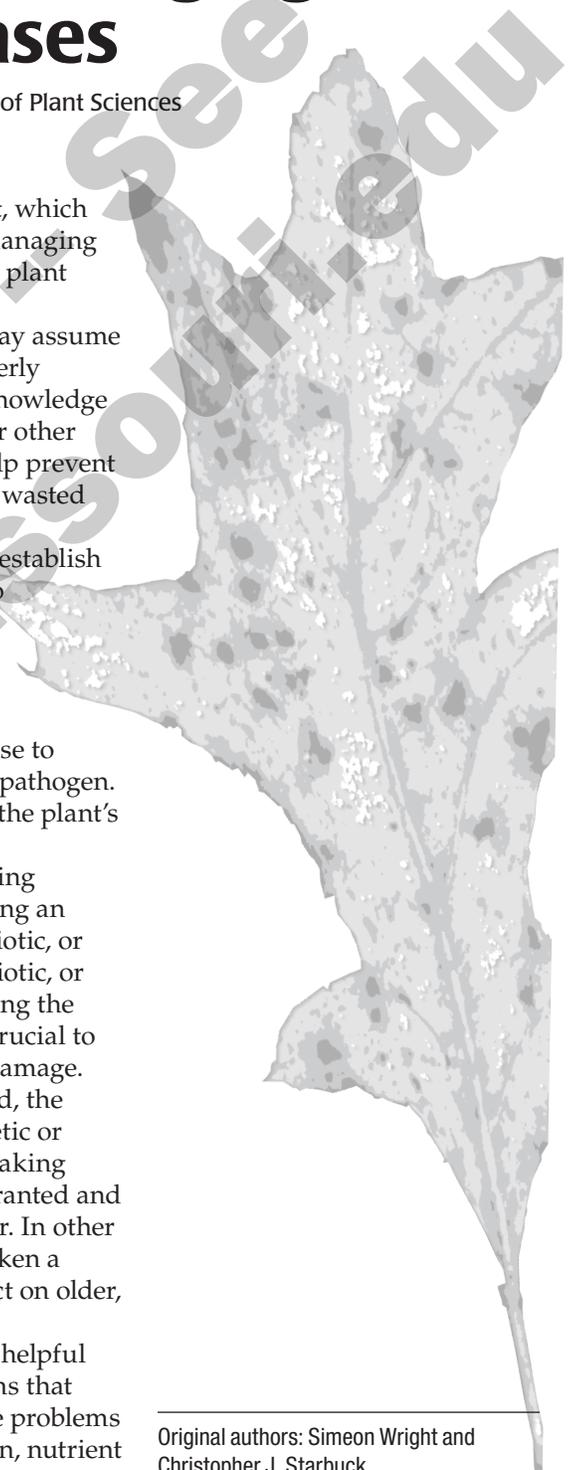
Even if a disease is confirmed, the problems caused may be cosmetic or cause minor yield reduction, making costly control measures unwarranted and not worth the expense or bother. In other situations, a disease might weaken a young plant but have little effect on older, well-established plants.

Plant diseases often provide helpful clues to the underlying problems that made a plant susceptible. These problems might include poor site selection, nutrient

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imbalance, water stress, or improper mulching, irrigation or pruning practices. In many cases, if you can address the underlying cause of the plant's problems, the disease process will be thwarted, and the plant can regain its health and vigor to resist such problems in the future.

When control measures are required, you must decide which management techniques are most appropriate. An integrated pest management, or IPM, strategy is most prudent and effective because it involves employing a combination of management techniques. Cultural practices and plant selection are the first line of defense. Pesticides may be required and can be a part of an IPM program, but should be viewed as a last resort. Pesticides are often overused, particularly when one simply wants to solve a pest problem quickly rather than understand why it occurred. When pesticides are needed, select the least toxic product that is designed for that specific plant and disease.

When pesticides are necessary, follow the recommended application methods and rates described on the pesticide label. A little extra is definitely not better when it comes to the application rate. Repeated use of some pesticides can cause the target organisms to develop resistance, which could make future applications less effective. In some cases, pesticides can also harm human health, the environment, or nontarget organisms, including birds and beneficial insects that might help keep other plant problems in check.

Plant disease triangle

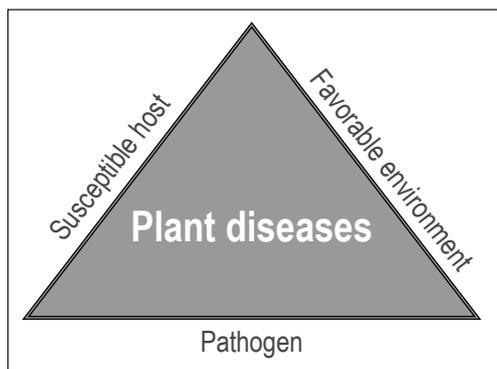


Figure 1. Plant disease occurrence triangle.

A disease that has a biotic cause is only likely to occur when three conditions are present.

A triangle is often used to illustrate how plant diseases occur. A disease will only occur when three conditions are present, as represented by the three sides of the triangle (Figure 1):

- A **pathogen**, or disease-causing organism, such as a bacterium or a fungus, meets a...
- **susceptible host plant**, during...
- **favorable environmental conditions** for disease development.

A disease will only develop in the presence of all three conditions. The presence of the pathogen is the first condition, but there is considerably more to disease development. The likelihood for disease on a resistant plant is greatly minimized, so plant selection can be a key factor in disease management. Lastly, environmental conditions must be conducive for the disease to occur. These conditions allow for pathogen growth and reproduction while reducing plant vigor and predisposing the plant to infection. For example, a sun-loving plant grown in shade will be less vigorous and therefore susceptible to attack, and the shade will extend the leaf wetness period, creating favorable conditions for foliar disease.

The best management approach is to exclude any of the three conditions that form the triangle sides. Keeping these conditions in mind will help you gain insights into plant diseases and their control.

Disease cycle

The disease cycle is another important concept that describes the life cycle of a pathogen and the chain of events involved in disease development (Figure 2). If the spread of inoculum can be prevented, the disease can often be managed.

A typical disease cycle includes the following events:

- Production of infectious inoculum.
- Spread of the inoculum.
- Penetration of inoculum into the host plant.

Inoculum

Inoculum is any part of a pathogen that can cause infection, including fungal spores, bacterial cells, viral particles or nematodes.

- Infection within the host plant.
- Secondary cycles to produce new inoculum.
- Survival between growing seasons.

Depending on the disease, inocula are most commonly fungal spores, or mycelium; bacterial cells; viral particles; or individual nematodes. These can reside in seed, crop residue, soil, weeds or other crops. Inoculum may be spread by the wind, by water splashing during irrigation or rainfall, or by a human action such as pruning with infected shears. Inoculum may also be carried by vectors, often insects, that feed on an infected plant and transmit the disease to a nondiseased plant.

Pathogens in temperate climates must have a way to survive the winter when their host plants are dormant or absent. Considering how these pathogens overwinter can help identify what control measures will be most effective. In perennial plants, some pathogens can live through the winter in infected plant parts, such as roots, bulbs, stems and bud scales. Pathogens that infect annual plants must form resistant resting structures, survive in seeds or vectors, or spread from warmer regions where the host plants grow during the winter.

Common rust of sweet corn, *Puccinia sorghi*, is an example of a disease spread by wind. This fungal disease does not survive long outside of living plant tissue. Because sweet corn plants do not live through cold Midwestern winters, most of the sweet corn rust inoculum (as fungal spores) blows north each season from living corn plants in the South. Thus, an understanding of

Vectors

Vectors are living organisms that facilitate the spread of disease by carrying inoculum of a disease from one host plant to another. Herbivore insects or other arthropods most commonly serve as vectors of plant disease.

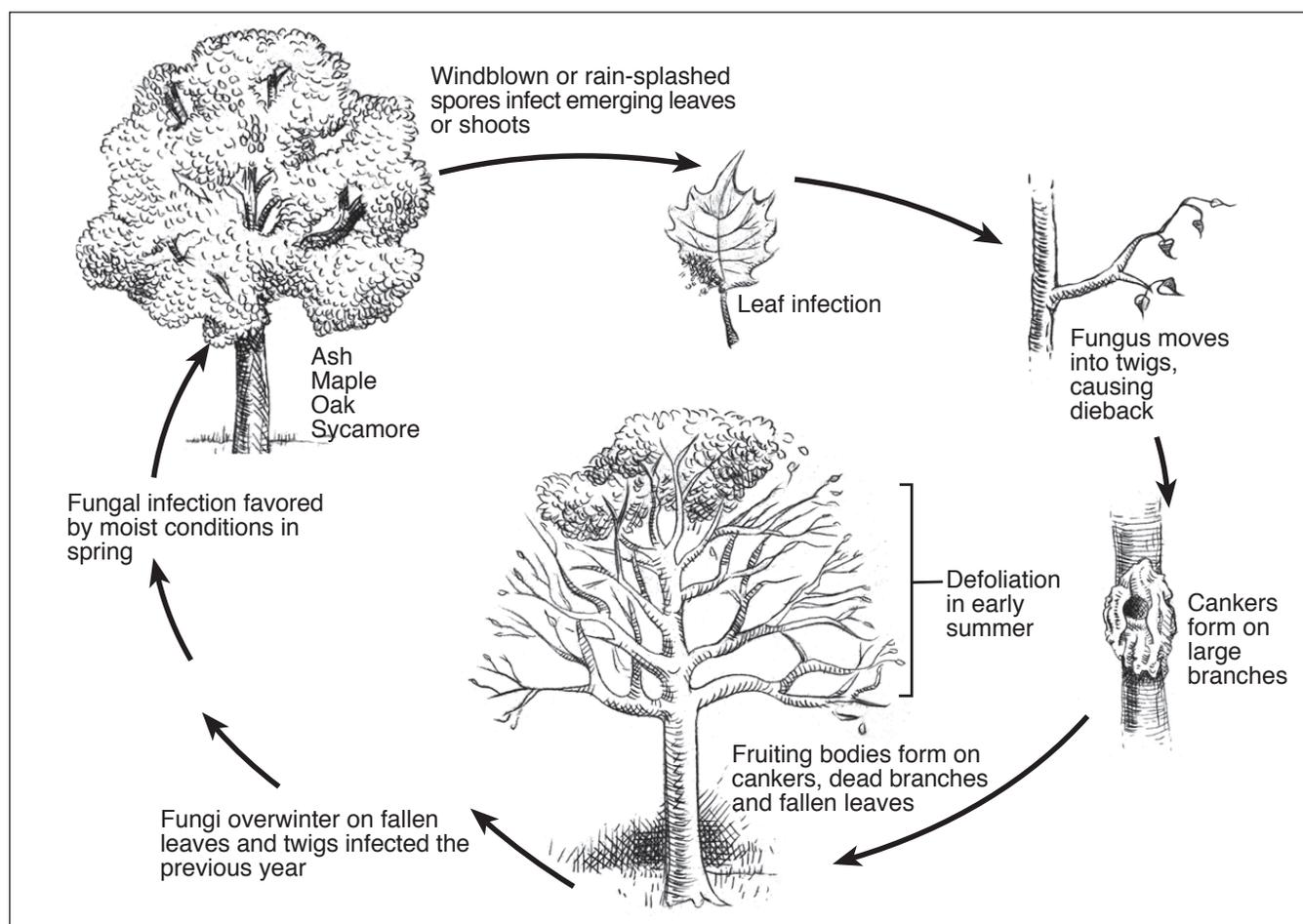


Figure 2. Example of a disease cycle.

Typical disease cycle of anthracnose caused by *Gnomia* spp.

how much inoculum is present in the South influences management decisions farther north.

Insect pollinators aid the spread of fire blight of apple and pear caused by the bacterium *Erwinia amylovora*. The bacteria overwinter in the margins of old cankers, and exude from the stem in rain. A bee or other pollinator species may pick up the bacteria and serve as a vector, introducing the pathogen to a new plant through the flower. Although trying to control the vector is unwise, the old cankers can be carefully pruned out and disposed of to limit the initial source of inoculum.

Plant damage can be caused by either a plant disease or an abiotic disorder. Often, however, these two problems are found together, because an underlying abiotic factor often makes a plant more vulnerable to pathogen attack.

Abiotic disorder causes

Abiotic plant disorders are not directly associated with a living organism, but instead are damage caused by a physical, environmental or chemical factor. Often, samples received by plant diagnostic centers have problems that are primarily caused by an abiotic factor. Many other plant samples do have a plant disease or pest problem, but also have an underlying abiotic disorder that made the plant more susceptible. For example, many plants have distinct habitat preferences and will easily develop problems if grown in an unsuitable location. In such circumstances, abiotic factors will make a plant more susceptible to infection by the biotic disease organisms discussed in the next section.

Physical

People, rather than insects or diseases, are often responsible for a plant's problems. Plant problems caused by people can be categorized as physical or mechanical. These problems include poor planting methods that allow limited area for root growth, improper mulching, construction-related injury, soil compaction, girdling of stems or trunks, or improper pruning. For example, plants should be pruned in the fall, just prior to dormancy. Pruning during the growing season can injure the plant and, if infected pruning shears are used, introduce a pathogen to the open wound.

Storms that produce high winds, heavy snow, or ice can cause considerable tree damage. Damage from hail or lightning strikes can kill trees, crops and ornamental plants. However, plant death resulting from a moderate weather event is often the sign of a preexisting condition.

In some cases, physical problems can be corrected and the plant will recover. For example, proper pruning to remove torn limbs might allow a tree to recover from minor damage after a storm. Plants that were given a bad start through incorrect planting methods, however, often cannot be saved. By the time symptoms appear, you may be unable to address the cause and restore plant vigor.

Environmental

Environmental factors are the most common source of a plant disorder. Often, symptoms develop on one side of the plant, or group of plants, based on where stress occurred (Figure 3). Other times the entire plant may be affected.

Extremes in temperature and moisture are common environmental culprits. Drought stress can cause leaf scorch, leaf drop or even branch dieback. Cold injury in winter can cause leaf burn and dieback of evergreens. When the soil is saturated for many days during the growing season, plants

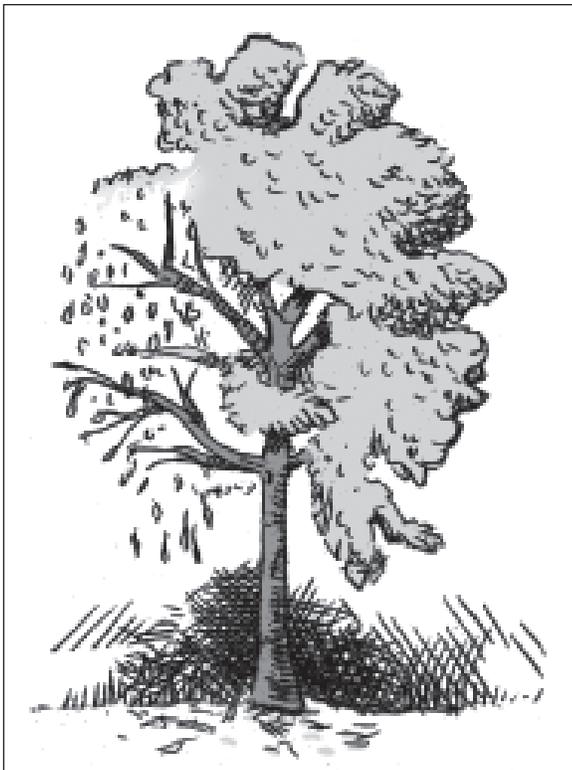


Figure 3. Symptoms of abiotic plant injury.

Injury from nonliving, environmental factors typically occurs on one side or area of a plant or group of plants.

may develop yellowed foliage because of the lack of oxygen in the soil or poor nutrient uptake from nonfunctioning roots.

Too much or too little shade is a typical problem. For example, hydrangeas commonly wilt and scorch when they are not mulched and watered carefully to keep the soil moist during dry conditions. They do best in a location with afternoon shade that alleviates the effect of high summer temperatures. In contrast, lilacs or junipers will be stunted if planted in too much shade.

Certain plants have a fairly specific range of soil conditions in which they thrive. These plants will have problems if grown in soil that has a nutrient imbalance or an improper pH. The interplay between soil pH and nutrient availability is important for plant growth, so a complete soil test can be helpful in diagnosing a potential plant disorder. Pin oak and blueberries, for example, like acidic soils and commonly develop leaf chlorosis when the soil pH is neutral or alkaline. Conversely, soils that are exceedingly alkaline may become deficient in nutrients such as iron and zinc. Also, if you fertilize every year with a complete fertilizer containing nitrogen (N), phosphorus (P) and potassium (K), the P or K may eventually build up in the soil and interfere with uptake of other micronutrients, such as magnesium, manganese and iron. Thus, fertilizer applications of most nutrients (other than nitrogen) should be made based on a soil test.

Generally, plants have a limited geographic range where they will grow and perform well. Many plants are simply poor choices for temperate Midwestern growing conditions or for the specific site where they are planted. In such cases, manipulating environmental conditions, applying pesticides or attempting other control measures may still not result in a healthy plant. Selecting plants well suited to the local environment gives you the best chance of having thriving, disease-resistant plantings. Become familiar with the plant zone you live in (see “plant hardiness zone maps” under *related websites*). In Missouri, these zones have shifted significantly in the past 15 years, with most of Missouri now in Zone 6.

Chemical

Nontarget effects from chemicals in the environment may also cause abiotic disorders in plants. Pesticide and, more specifically, herbicide injury is the most common cause of phytotoxicity, with symptoms varying depending on the product used. The most common symptoms are leaf cupping and distortion caused by either spray drift on foliage or root uptake by ornamentals and vegetables. Broadleaf weed killers applied to nearby lawns or crop fields can cause sudden decline in sensitive crops, such as tomatoes or peppers, and can cause leaf curling in ornamental trees when applied incorrectly (Figure 4).

Other chemical causes of abiotic injury include ice-melting salts or air pollutants. Ice-melting salts that wash off sidewalks and streets onto plants and soil often cause severe wilting or browning of leaf margins of trees, shrubs or turfgrass. Air pollutants that damage plants include sulfur dioxide and hydrogen fluoride from industrial sources. Incompletely burned hydrocarbons released from automobiles in heavily populated areas can result in production of both ozone and peroxyacetyl nitrate, known as PAN. These harmful gases enter plants through the stomata and cause a characteristic flecking or bronzing of leaves.



Figure 4. Growth regulator herbicide injury to a maple following an improper herbicide application.

Chlorosis

Chlorosis is a condition in which leaves contain a reduced amount of chlorophyll and, thus, appear yellow rather than green. This “chlorotic” condition may be caused by nutrient deficiencies, herbicide damage, genetic mutations or biotic diseases.

Phytotoxicity

Phytotoxic means “toxic, or poisonous, to plants.” Phytotoxicity most often refers to plant injury caused by chemicals. Phytotoxic effects can be caused by a pesticide or other chemical deliberately applied to a plant. Phytotoxicity is often caused by herbicides targeting weeds that unintentionally reach a desired, sensitive plant through the air, water or soil. When a plant that was not the target is harmed, these are also called nontarget effects.

Plant disease pathogen types

Fungi

Fungi are the most common causal agent of plant disease. These microscopic organisms lack chlorophyll and are visible as mats of threadlike filaments called hypha that make up the mycelium, which are “resting structures” that include rhizomorphs and sclerotia. Many fungi reproduce by spores and produce conspicuous fruiting bodies that can aid in identification. These fruiting bodies are called the signs of the pathogen.

In the diagnostic lab, fungi are often identified by their growth patterns, spores or other structures. The first step is to examine infected plant tissue for signs of the pathogen with a hand lens or under the microscope. Because fungi are not always visible on plant surfaces, a lab may then test a sample by placing the affected tissue on a petri plate that contains a nutrient medium. If fungi are present, they may grow and produce the signs necessary for identification.

Fungal organisms cause various types of injury to plants. Typical fungal symptoms include seed rot, seedling blights, root and crown rots, vascular wilts, leaf spots, rusts, cankers, and stem and twig blights.

On leaves, fungi often cause lesions, or spots. The appearance within the lesions of mycelium, spores or small black dots visible with a hand lens indicates a potential fungal disease. Not all leaf spots require control measures. Fungal leaf spots can be managed by growing resistant cultivars or using cultural practices that limit the development of disease. Limiting overhead irrigation, and therefore leaf wetness duration, is an effective cultural practice for minimizing the occurrence of leaf spot diseases.

Blights — the complete death of a plant structure, such as leaves, flowers or stems — may result from many lesions that form quickly and merge. Blight diseases often occur rapidly and cause severe damage. One well-known historical example is late blight, a disease of tomatoes and potatoes that attacks stems and leaves, potato tubers and tomato fruits. This disease played a major role in the Irish famine that caused a wave of emigration during the 1800s. Cultural control measures, resistant varieties and fungicides are used to manage fungal blights.

Rots can occur on most plant parts but are most commonly seen in roots, stems and fruits. The rot that results from seedlings being attacked by soilborne fungi is commonly called damping-off. Damping-off occurs most frequently in a contaminated growing medium that is too wet. Careful watering practices and the use of sterile pots and uncontaminated, soilless seedling mixes are the most practical and effective preventives for root and stem rots. Do not reuse potting soil.

Cankers appear as sunken areas or spots where the bark is rough, missing or swollen. Sometimes sap will ooze from these areas, and a raised ring of callus material appears as the plant tries to protect the damaged area and limit disease spread. If the canker surrounds, or girdles, the stem completely, the stem or branch above will die. Canker diseases are difficult to manage. To slow their development and spread, practice good horticultural care to reduce plant stress and remove affected branches.

Vascular wilts are caused when fungi grow inside the plant vascular, or fluid-conducting, tissue, causing these tissues die. The leaves and branches wilt and die from a lack of nutrients and water, with symptoms similar to those caused by drought. Dark streaks may be visible in the vascular tissues where fungi are active. Plants with severe vascular wilt infections usually cannot be saved, but adjacent plants can sometimes be protected with fungicide injections.

Stomata, hydathodes and nectarhodes

Stomata (or stoma, when singular) are microscopic openings in the epidermis, or outer layer of plant tissues, that serve as breathing pores for gaseous exchange.

Hydathodes and nectarhodes are specialized secretory structures on leaves or blossoms, through which water or nectar may be excreted.

Bacteria

Bacteria are single-celled organisms that lack chlorophyll and reproduce by cell division. Bacterial cells often multiply quickly and clump together to form colonies. Thus bacterial diseases can begin suddenly and quickly become severe. Some types of bacteria are easily moved around in leaves and cause leaf spots. Others can multiply rapidly in the vascular system and plug it up, causing wilting and dieback. Bacterial diseases are difficult to manage because few chemical controls — antibiotics, in this case — are available and bacteria often rapidly develop resistance to them.

Some types of bacteria cause tumorlike galls. Crown gall is a common disease of many plants that occurs when soilborne bacteria cause lumpy swellings on roots and the lower stems (Figure 5). It may be seen on euonymus, grape vines, roses and fruit trees. Infection often occurs where a plant has been wounded or weakened. Cultural practices such as good sanitation and avoidance of wounding by mower or weed trimmer use can help prevent crown gall.

Several foliar diseases can be caused by bacteria. For example, leaf lesions and blight can develop, and sometimes a yellow halo may form around the margin of leaf lesions indicating a plant toxin. In some instances, the tissue falls out of the leaf, which gives it a shot-hole or ragged appearance. Under a microscope, bacterial ooze from a lesion may be evident. This ooze contains millions of bacteria that easily splash to healthy leaves in water droplets. The bacteria may enter plants through natural openings such as stomata or hydathodes in or through wounds.

Some bacterial diseases cause blights, such as fire blight, a common disease of apples, pears and related species in the Midwest. Typical symptoms include wilted shoot tips, where succulent new shoots droop, forming a characteristic shepherd's crook, and tips turn black as they dry. Fire blight infections are typically most active in spring when insects spread the infection as they pollinate flowers. The bacteria can enter plants through nectarthodes in blossoms. Splashing rain and pruning or other wounding events can also spread the disease. To manage fire blight, use good cultural practices and select resistant cultivars.

Bacteria can also cause soft rots of fruits, vegetables, tubers and bulbs. Rots can cause rapid decline in crop quality. Affected plants often have a strong odor and mushy tissues that appear melted. Avoid mechanical injury both before and after harvest, and practice strict sanitation to help reduce the incidence of soft rots.

Plant pathogenic bacteria can be difficult to kill when protected inside the plant. To protect healthy plants, you can manipulate environmental conditions, remove infected plants, or apply protectant pesticides. Good sanitation practices are especially important to prevent problems, because



Figure 5. Crown gall symptoms.

Crown gall is caused by *Agrobacterium* and related bacteria. The lumpy swellings typical of the disease are usually seen on roots or lower stems.

a single infected seed can result in an entire tray — or even an entire greenhouse — of diseased plants. Antibiotics are not normally recommended for home garden use because of the potential for antibiotic resistance.

Viruses

Virus particles consist of a small amount of genetic material within a protective protein coat called a capsid. Viruses are so small that individual particles cannot be seen with a common light microscope. When a plant cell becomes infected with a virus, that cell replicates new viral particles that prevent normal plant cell function.

Diagnosis of viral diseases can be challenging. Visual identification is difficult, and advanced identification techniques are expensive. Typical viral symptoms include stunting and chlorosis, as well as mottling, puckering, ring spotting and mosaic patterns in leaves. In the lab, virus species may sometimes be identified by their physical characteristics when viewed at extreme magnification with a high-powered electron microscope. In other cases, advanced serological or genetic testing of plant sap is needed to confirm diagnosis.

Viruses are spread by infected seed or pollen, poor sanitation when handling or pruning plants, or vectors. The mode of transmission depends on the type of virus, but most commonly arthropods, such as aphids or mites, serve as a vector. Unfortunately, there is no cure for viral diseases. If the virus causes severe symptoms and has potential to spread to nearby plants of the same species, the infected plants should be destroyed. Other control measures include destroying nearby weedy hosts, practicing good sanitation techniques during pruning and propagation, and managing insect vectors.

Phytoplasmas

Phytoplasmas are essentially tiny, specialized bacteria that lack cell walls. They can be difficult to identify because they only survive and reproduce in living plant tissue. They cannot be isolated and cultured in a laboratory. An electron microscope is needed to detect structures of phytoplasmas in the cells of host plants. For many years, diseases caused by these organisms were thought to result from viruses, because the symptoms appear very similar.

Aster yellows is a phytoplasma-caused disease that affects many landscape and garden plants. Affected plants often develop stunted, malformed plant structures and appear chlorotic, or yellowish. Unfortunately, like viral diseases, plant diseases caused by phytoplasma have no cure. Control measures include removal of the infected plants and nearby weedy hosts, and control of leaf hoppers and other insects that may act as vectors.

Nematodes

Nematodes are unsegmented, microscopic roundworms that generally have a threadlike form. Nematodes are the most numerically abundant animal on Earth, and luckily not all nematodes are parasites or harmful to plants. Some are beneficial and kill plant pests, whereas others feed on bacteria or decaying matter. A plant parasitic nematode has a needlelike stylet, which is a tubelike structure that can pierce plant cells to withdraw nutrients.

Some nematodes live inside plants. One example is the pine wilt nematode that is responsible for the death of many Scots pines across the Midwest. Trees become infected when the vector, the pine sawyer beetle, feeds on the tree and also transmits the nematode. Affected trees quickly turn brown and should be destroyed to prevent infection of nearby healthy trees. To confirm the presence of pine wilt nematodes, a plant diagnostic clinic can test a portion of a large branch or tree trunk.

Nematodes that live in the soil sometimes cause severe plant damage. In Missouri, the root-knot nematode is prevalent in the southeast area of the

state. In recent years, this nematode has been found farther north into central Missouri, perhaps because winters have been mild by historical standards. This nematode causes swollen knots at infected sites on the roots of a wide variety of plants, including certain fruits, vegetables and ornamentals.

Commercial growers can use soil fumigants to manage nematodes in the soil, but homeowners have few management options. Sanitation is important because nematodes are easily spread with infested soil or plant material. Dirty gardening tools, such as shovels or tillers with infested soil, can spread nematodes to new areas. Luckily, nematode damage is not a widespread problem for home gardeners in Missouri.

Five steps to diagnose plant problems

To accurately diagnose a plant problem and find its remedy may seem like a daunting task. In some cases, identification may require help from plant disease specialists. Before turning to the experts, however, attempt to make a diagnosis yourself. At the very least, gather evidence on potential symptoms, signs and potential abiotic stress. Even if the result is not definite, the process is a learning experience that will provide useful information.

When diagnosing plant problems, pay close attention to detail when collecting information, like a detective attempting to solve a crime. Items that are most helpful include a 10-times-magnification hand lens, digital camera, trowel, pruning shears, pocketknife, flashlight and something to keep notes on. Establish a location to keep records and reference materials.

Determine the most likely cause by following these five steps:

1. Accurately identify the host plant.
2. Determine what is normal for the plant.
3. Learn common problems for the plant.
4. Distinguish between biotic and abiotic causal factors.
5. Examine the plant for symptoms and signs.

1. Accurately identify the host

First, know the plant. Every species, variety or cultivar has a unique set of characteristics that often provide important clues to identifying the source of a problem. For potential abiotic disorders, consider the plant's preferences for soil and climatic factors such as pH, nutrient requirements, soil type, moisture level, light intensity, and temperature. Also realize that each plant species, and even different cultivars, may have plant diseases that are specific and troublesome.

If the identity of a plant is unknown, you can consult references such as those suggested at the back of this guide, or any available gardening or landscape records. Garden centers usually have someone who can help identify a plant if you bring in a stem with several leaves. Local extension centers or the University of Missouri Plant Diagnostic Clinic can also be a good resource. Most states provide similar services.

References can help you determine whether a plant is located on a site that matches its requirements. For example, a flowering dogwood tree is adapted to a woodland understory environment with excellent drainage. It is unlikely to thrive if planted in a poorly drained soil or on a south-facing slope in full sun. If the tree survives in such circumstances, it is likely to develop leaf scorch and damage from dogwood borers attracted to the stressed tree. Such problems often result from an unsuitable planting site and are unlikely to be resolved with pesticides or other treatments.

2. Determine what is normal

Read plant descriptions and observe other plants of the species, variety or cultivar to determine the normal appearance for the plant. Sometimes a

natural feature of the plant is mistaken for a symptom. For example, someone unfamiliar with the 'Golden Vicary' privet might mistake this cultivar's yellow leaf color for a sign of nitrogen deficiency. Similarly, a plant with a splotchy pattern on a leaf may be a variegated cultivar. A gardener unfamiliar with paperbark maple might be alarmed to see sheets of bark peeling from the trunk of a specimen, though it is a normal process for this plant. Conversely, bark peeling from the lower trunk of a red maple would be a legitimate cause for concern.

It can also help to observe other plants of the same species of roughly the same age and at the same time of year as the sample being evaluated. For example, during hot, dry weather, mature river birch trees often drop a significant portion of their leaves as a drought-survival mechanism. For pines, yellowing of the interior needles in the fall is likely to be part of the normal process of shedding 2- or 3-year-old leaves.

Like all living organisms, plants have life spans, with some having longer ones than others. A bur oak may live 300 years, but it is relatively rare to find a redbud older than 30. Trees late in their expected life spans often succumb to trunk decay, root rots, stem-boring insects or other pests that normally do not attack young, vigorously growing plants. If a plant has reached its normal life expectancy, you can only do so much before having to remove and replace it.

3. Learn the common diseases and disorders of the plant

Learn the common problems that affect the plant in question. Good reference materials can help as you match your observations with descriptions or photographs of typical plant diseases, and their related symptoms and signs.

A diagnostician learns to look for indications of problems that commonly affect certain species. Tall fescue is commonly damaged by brown patch, whereas Kentucky bluegrass is more frequently damaged by Pythium blight or dollar spot. Austrian pine trees are often affected by *Diplodia pinea* (also known as *Sphaeropsis sapinea*), a fungal tip blight that kills needles near the tips of lower branches. Zinnias, lilacs and zucchini are all commonly afflicted by powdery mildew. Red maple trees often display a leaf distortion caused by leaf hoppers. They also frequently suffer from chlorosis, indicated by yellow leaves with green veins, a condition that is frequently due to high-pH soil with little available manganese and iron. Learning these relationships may come from online or library research, discussion with someone at your garden center or plant source, or from the hard teachings of experience.

4. Distinguish between biotic and abiotic factors

Observe carefully to determine whether a plant problem has been caused by a living, biotic, organism or by some type of nonliving, abiotic, factor. By studying the cultural preferences of plants and looking for patterns in the landscape, you may be able to determine the cause of the plant damage.

Other than a characteristic plant symptom or pathogen sign, several clues may help determine if the problem is the result of a plant disease rather than an abiotic disorder (Table 1).

5. Look for symptoms and signs that indicate disease

Understanding symptoms and signs and the differences between them will help with disease diagnosis and allow for discussion with others. Symptoms are the plant's response to infection, or the signals that a plant is not functioning properly. Typical symptoms include leaf lesions, chlorosis, or malformed plant tissues. Signs are the visible parts of the pathogen or pest that caused the symptoms. Signs of a pathogen may include mold on the plant surface; spores; pycnidia, which are small flask-shaped structures that contain spores; or bacterial ooze.

Table 1. Distinguishing between biotic and abiotic factors in plant damage.

Biotic factors	Abiotic factors
Diseases progress over time, often starting small and increasing in size or severity as pathogen inoculum spreads and infects new plant tissue.	Damage often occurs suddenly, such as phytotoxicity from a chemical or storm damage.
Gradual change between damaged and nondamaged plants. Normally, a slight gradient of increasing severity at the margin of diseased areas is present.	Sharp margin of damage between affected and unaffected plants. Chemical spills are a common example.
Symptoms occur randomly on plants of the same species or cultivar throughout the landscape. Diseases do not occur in straight lines.	Damage often follows a uniform or repeated pattern on an individual plant or throughout a planting. Damage occurring solely on a single side of a plant or an area is usually caused by an abiotic disorder. Chemical damage may follow a spreader or sprayer pattern.
Damage occurs to one plant species or cultivar, but rarely to large areas of a mixed planting. Adjacent areas are unaffected.	Often, damage occurs to not just one plant species but to multiple plant species, including weeds.

Consider a typical blue spruce in Missouri. A common disease of this species is *Rhizosphaera* needlecast. To confirm the disease, you would first look for symptoms. Specifically, you would see the dead needles at the lower portions of the branches, because the disease attacks mature needles. Other diseases can also cause older needles of blue spruce to drop, so at this point, you would use a hand lens to further examine the brown or dropped needles, looking for signs of the fungus. Healthy spruce needles have rows of stomata that appear as white dots. In a tree with *Rhizosphaera* needlecast, pycnidia, which appear as small black bumps, emerge from the stomata (Figure 6). Another fungal disease, *Stigmina* needle blight, also produces fungal structures in the pycnidia. However, these two diseases are managed similarly, with pruning and, in severe cases, preventive fungicides.

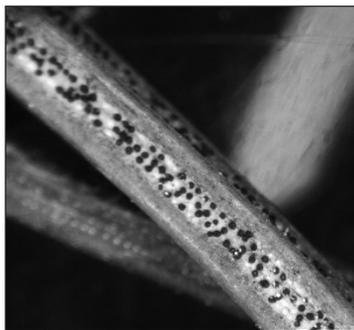


Figure 6. Example of symptoms and signs.

This spruce has browning needles and defoliation (left). The pathogen attacks mature, at least 1-year-old, needles, so the new growth at the tip is unaffected. On close inspection of the needles, numerous pycnidia can be seen emerging from the stomata (right).

Confirming a diagnosis

Using the five steps described above to diagnose plant problems is like putting together a puzzle (Figure 7). If you can find enough pieces and fit them together, you will often see a logical picture emerge. Sometimes this process is called the guess-and-confirm method. With practice and experience, diagnosis becomes progressively easier.

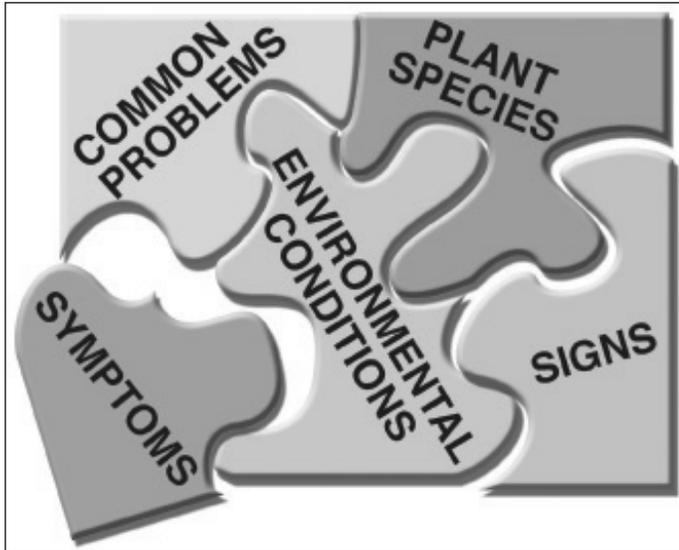


Figure 7. Plant disease puzzle.

To accurately diagnose a plant disease, a gardener must consider many factors that could be causing the disorder.

Using this approach can be time-consuming and incur additional testing fees. Sometimes a lab uses other advanced testing methods or sends a sample for retesting at another plant clinic that specializes in certain techniques or specific pathogens.

Submitting samples

Most states have a university or state plant diagnostic lab. The University of Missouri has the Plant Diagnostic Clinic (see *related websites*). You can obtain the appropriate submission form to submit with a sample on the clinic's website or from your local extension center. The form asks for detailed information. To aid in a quick and accurate diagnosis, fill out the form as completely as possible.

The quality of the sample is crucial. When submitting small plants, it helps to include several samples that show a range of symptoms from the healthy to the severely damaged. When possible, submit an entire plant. If that is not practical, examine the different parts of the plant for all possible symptoms and signs, and submit portions that represent the observed problems. Sometimes the problem is different or more extensive than it first appears to be. For example, an accurate diagnosis of a problem first observed as foliar damage on leaves could result from an impairment of other parts of the plant such as the trunk or roots.

To aid in accurate diagnosis, keep the plant material as fresh as possible during shipping. To prevent decay of the sample, ship samples early in the week to avoid delay over the weekend. Most diagnostic clinics are located on university campuses that do not receive mail on the weekend. If you are collecting a sample over the weekend, store it in a cooler and ship it early the next week. Fresh samples sent through the mail generally arrive in good condition when they are wrapped in dry paper towels or newspaper and

Taxonomy

Taxonomy is the science of classification of plants and animals according to relationships based on morphology, or forms, and to the principles of such classification.

enclosed in a box with packing materials to prevent movement. Do not wrap samples in damp packaging material, as doing so frequently results in a moldy mess by the time the sample reaches the clinic, which wastes time and money for the sender and the recipient alike.

National Plant Diagnostic Network

The National Plant Diagnostic Network was created to address concerns about bioterrorism after the events of Sept. 11, 2001. The goal is to establish a national network of diagnostic laboratories to rapidly and accurately detect and report pathogens, pests and weeds of national interest.

The plant diagnostic clinic at the University of Missouri is part of this network and receives funding and training opportunities to improve detection and identification of pests and pathogens. Every diagnosis made by the clinic, and by the other labs in the network, is collected in a national database. This database allows scientists to quickly determine where a specific pest or pathogen is occurring and how widespread that organism has become.

Managing plant diseases

Integrated pest management, known as IPM, is considered the best approach to maximize the success of management techniques and to minimize costs — including economic, environmental and potentially even health costs. Methods to manage plant disease primarily depend on the biology of the specific pathogen and the host plants.

The gardener who inspects plants frequently and identifies problems when they first begin to develop will often have a wider selection of effective management options. Keep in mind that more than one method may be needed to effectively manage a specific problem.

Common approaches to manage plant diseases include five main types of controls:

- Regulatory
- Genetic
- Cultural
- Biological
- Chemical

Regulatory controls

A regulatory approach to managing plant diseases is often based on exclusion, or using a quarantine to prevent the spread of a disease into new areas. Exotic diseases or pests pose a significant threat to wildlife in a new region. Pathogens and hosts coevolve, meaning as they change over time, each affects the other's evolution. Coevolution allows for some innate immunity in the host population so a disease does not wipe it out. When a new pathogen is brought into an area, the native plants may have no defenses against it. Similarly, an introduced pest does not have natural predators in the new area to keep its population in check. For these two reasons, exotic or invasive pests can have a profound and damaging impact on an ecosystem.

For example, if you have ever flown to a location such as California or Hawaii, you may have noticed measures taken at airports to prohibit transport of fruit and other agricultural or horticultural products that could harbor pests and diseases. So far, successful quarantine efforts have kept an aggressive strain of the bacterial wilt pathogen *Ralstonia solanacearum* from entering the United States. This disease could severely impact the country's production of solanaceous crops, including tomatoes and potatoes. Bacterial wilt inoculum was accidentally brought into the U.S. on flower cuttings

IPM considers options

Integrated pest management (IPM) involves the selection, integration and use of pest management techniques based on predicted economic, aesthetic, sociological and ecological consequences. IPM seeks to maximize the use of biological and naturally occurring pest management tools.

The IPM concept does not prohibit use of chemical-based pesticides. Rather, it considers their use as one of many components of a comprehensive pest management program.

shipped from Kenya and Guatemala, but the disease was quickly detected and eradicated before it could begin to become established here.

Another current quarantine aims to check the spread of sudden oak death, a new disease on the West Coast that has been damaging forests in California. In addition to killing oaks, it causes a blight of many other trees and shrubs, and it has infected nursery stock. Whenever infected stock is found, the plants must be destroyed and nearby plants must be isolated and watched for symptoms. If the disease should arrive in the Midwest, it could severely damage our landscapes.

Genetic controls

Breeding for disease resistance uses genetics to prevent disease. Resistance refers to an ability to exclude or overcome infection by a particular pathogen. Many crops and ornamental plant species are bred for disease resistance, creating a new cultivar or variety that provides better performance. Gardeners can select varieties that can resist common diseases, such as roses with black spot resistance or crab apples with resistance to apple scab.

Keep in mind, however, that a plant considered resistant to one disease might be highly susceptible to other diseases or pest problems. For example, certain roses that are highly resistant to the common fungal leaf disease black spot are often still susceptible to other leaf spotting diseases, viruses and other problems.

Also, a disease resistant plant may still be infected if a genetic variant, or race, of the pathogen is present. Plant resistance may also break down if environmental stresses are present that limit the plant's defense mechanism. For example, tomato varieties resistant to Fusarium wilt may still develop the disease under highly favorable environmental conditions or when another race of the fungus is present in the soil.

Although the interactions may be complex, host resistance is the most long-lasting and environmentally responsible method of disease control, and therefore one to strive for. Proper plant selection, whether it be a different variety within a species, or a completely different plant species altogether, can save management or replacement costs in the long run. Before planting, do research to determine the best plant to establish, weighing the potential environment, disease and pest pressures that may be placed on it.

Cultural controls

Cultural disease management strategies are long-practiced methods that prevent the conditions for diseases and other pests to become established. These practices, based on good sanitation and husbandry, often rely on a general knowledge of plants and their problems. Combining a variety of cultural control techniques often works better than using a single method.

Abiotic disorders are caused by the environment, and therefore cultural practices that mitigate or remove that stress should be employed. For example, if a lawn is being scalped or stressed by low mowing, raise the mower deck.

Controlling plant diseases with cultural practices involves a combination of preventing the conducive environment for pathogen growth and improving the growing conditions for maximum plant health. In most cases, gardeners should employ a multitude of cultural practices to produce healthy, disease-free plants that grow vigorously. A few examples are noted below.

- In the garden, rotating vegetables to a different spot each year is a popular cultural control used to disrupt year-to-year pest cycles, as is removing and destroying old plants at the end of the growing season.
- Waiting to plant warm-season crops, such as green beans, until the soil has warmed can avoid seed rots.
- Planting a mix of plant species may reduce or slow the spread of disease if resistant plants are planted among more susceptible plants.

- Watering lawns and gardens early in the morning so the plants can dry quickly and remain dry through the night is an effective cultural practice for some fungal or bacterial diseases.
- Watering ornamentals at the base of the plant, as opposed to using overhead irrigation, will minimize leaf wetness duration and prevent foliar diseases.
- Fertilize plants at the correct time of year. Tall fescue and Kentucky bluegrass fertilized with nitrogen too late in the spring or during the summer are more susceptible to brown patch or Pythium blight.
- Pruning and training plants in ways that promote air circulation around leaves and that allow more light penetration creates a healthy environment that discourages infection.
- Planting a tree or shrub correctly and in the right type of location gives the plant a better chance of resisting diseases and other problems. Diagnostic clinics often see plants that died simply as a result of improper planting.

Biological controls

Biological control is based on the premise of using nature against itself. The most common biological control for harmful insect populations is the use of predators, for example, lady beetles being used to control aphids. Few biological controls are currently available for the control of plant diseases in the lawn and garden, and the scope of disease control they provide is limited. These formulations of beneficial fungi or bacteria that suppress plant pathogen growth do not provide complete control but can be used as one component of an IPM program.

Chemical controls

Finally, chemicals such as fungicides, bactericides or nematicides are sometimes necessary to control problematic plant diseases. Chemical controls can be an effective and necessary part of an IPM program, but it is important to properly identify the problem and determine if a pesticide is warranted and, if so, to use it correctly. For example, fungicides will not cure a problem caused by insect damage, poor drainage or bacterial disease.

Samples are often submitted to a diagnostic clinic after chemical control has failed due to incorrect diagnosis of the problem, which often turns out to have been an abiotic disorder. A plant problem should be properly diagnosed before any fungicide is applied, so as to avoid the unnecessary cost and the potential harm to the applicator or environment. Even when warranted, a fungicide application is not a long-term solution for control, as the disease will recur after the fungicide activity has worn off and environmental conditions are conducive. Fungicides are a short-term fix, and the need for them indicates a longer-term and multipronged management approach is necessary.

When using chemicals, always read and follow the label carefully. Apply compounds properly, and respect environmental health and safety information indicated on labels. This information can include special directions for mixing and application, limits to application on windy days or before predicted rain events, or buffer areas needed between application areas and wells or watercourses.

Although older diagnostic references can be valuable resources, they might recommend chemical control measures that are outdated or no longer legal. Visit the National Pesticide Information Center's (NPIC) website for up-to-date information on a range of technical, regulatory and pest control topics. NPIC is cosponsored by Oregon State University and the U.S. Environmental Protection Agency. For information on pesticides currently labeled for use in Missouri, see the Missouri Department of Agriculture's online Pesticide Registration Database (see "pesticide information" under *related websites*).

For further information

If you have questions that this publication or other references do not answer, contact your local extension center.

MU Extension publications at <http://extension.missouri.edu>

G6010	<i>Fruit Spray Schedules for the Homeowner</i>
G6020	<i>Fire Blight</i>
G6026	<i>Disease-Resistant Apple Cultivars</i>
G6202	<i>Disease Prevention in Home Vegetable Gardens</i>
G6203	<i>Common Diseases in the Home Garden</i>
G6204	<i>Managing Nematodes in Gardens</i>
IPM1029	<i>Identification and Management of Turfgrass Diseases</i>
MP604	<i>Plant Disease Identification Form</i>
MX342–344	<i>Disease of Trees, I–III</i>
MX858	<i>Pine Wilt: A Fatal Disease of Exotic Pines in the Midwest</i>

Related reading

- Agrios, George. 2005. *Plant Pathology* (5th ed.). Boston: Elsevier Academic Press.
- Gilkeson, Linda, Pam Pierce and Miranda Smith. 1996. *Rodale's Pest and Disease Problem Solver*. Emmaus, Pa.: Rodale Press.
- Reader's Digest. 2000. *Garden Problem Solver*. Pleasantville, N.Y.: Reader's Digest Association.
- Schrock, Denny. 2004. *Ortho Problem Solver*. Des Moines, Iowa: Meredith Books.
- Sinclair, Wayne A., and H.H. Lyon. 2005. *Diseases of Trees and Shrubs* (2nd ed.). Ithaca, N.Y.: Comstock Publishing.
- University of Illinois Extension. 2004. *Home, Yard and Garden Pest Guide*. Champaign.

Related websites

Pesticide information:

National Pesticide Information Center (NPIC): <http://npic.orst.edu>

Missouri Department of Agriculture Pesticide Control: <http://agriculture.mo.gov/plants/pesticides> and click on Pesticide Registration Database

Plant hardiness zone maps:

U.S. Department of Agriculture, 2012: <http://planthardiness.ars.usda.gov>

National Arbor Day Foundation, 2015: <http://arborday.org/media/zones.cfm>

University of Missouri Plant Diagnostic Clinic: <http://plantclinic.missouri.edu>