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Preventing and Managing Plant Diseases

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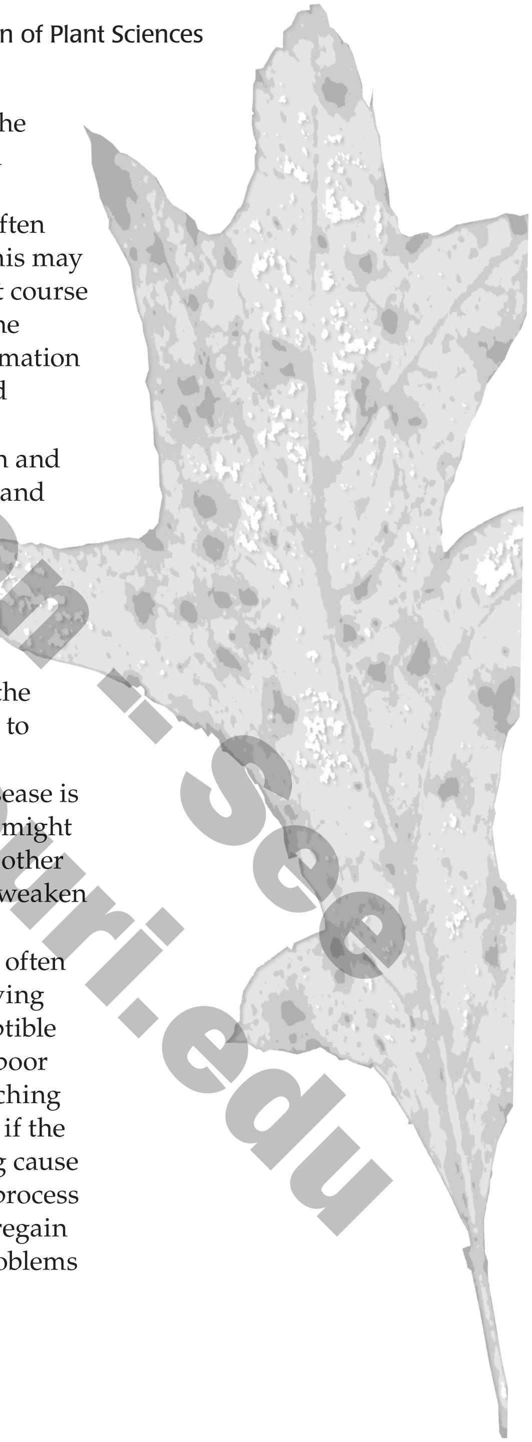


Gardeners' first and best defense against plant diseases is to create the right conditions for vigorous, healthy plants. Thus, preventing and managing plant diseases begins even before planting.

When a plant does not look "normal," or as expected, the gardener often assumes the plant is diseased and that control measures are needed. This may or may not be so. To understand plant problems and determine the best course of action, it helps to have background knowledge about the plant and the typical diseases or other problems to which it is susceptible. Such information can help avoid an inaccurate diagnosis that can lead to wasted time and expense, unnecessary use of pesticides or even damage to the plant.

This publication provides an introduction to help gardeners establish and maintain healthy plants, and it offers a systematic approach to identify and solve the problems that do occur.

Disease is a response

A plant disease is defined as a response to environmental factors or pathogenic, disease-causing organisms that cause negative changes in the plant. A disease may affect the plant's appearance, its ability to yield or to reproduce, or all of these.

It is not always easy to determine if a disease is present. Even if a disease is confirmed, the problems it causes might only be cosmetic. Or a disease might be causing minor yield reductions that do not justify the expense and bother of control measures to eliminate it. In other situations, a disease might weaken a young plant but have little effect on older, well-established plants.

Because a disease is a response, it often provides helpful clues to the underlying problems that made the plant susceptible to the disease. These might include poor siting, water stress or improper mulching or pruning practices. In many cases, if the gardener 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.

Plant disease topics inside

When control measures are called for, the gardener must decide which management techniques are most appropriate. Pesticides are often overused in situations where other controls could be just as effective. When pesticides are needed, the gardener should select a product designed for that specific plant and disease.

It is important to follow the recommended application methods described on a pesticide label. Repeated use of some pesticides can lead the target organisms to develop resistance, which could make future applications less effective. In some cases, pesticides can also cause environmental damage or pose a health threat to pets or humans, or negatively impact populations of nontarget organisms, including birds or beneficial insects that might help keep other plant problems in check.

Plant disease triangle

The image of a triangle is often used to help understand the occurrence of plant diseases that have a biotic, or biological cause (see discussion on page 4). A disease is only likely to occur when three conditions are met, as represented by the three corners of the triangle (Figure 1):

- A pathogen, or disease-causing organism, such as a bacterium or a fungus, is present.
- A susceptible host plant is present.
- Environmental conditions for that disease are favorable.

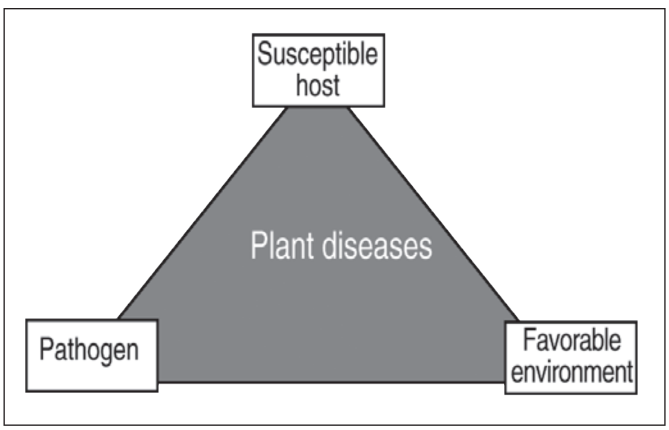


Figure 1. Plant disease occurrence triangle.
A disease that has a biotic cause is only likely to occur when three conditions occur simultaneously.

A disease will only develop when these conditions are present simultaneously. Of course, the pathogen that causes the disease must be present, but there is more to development of a disease. If a host plant is resistant or immune to a disease, it will probably not occur. And environmental conditions must be right. A disease that develops in cool, wet weather is not likely to occur if conditions are warm and dry. A favorable environment is one that promotes a pathogen's growth, or it could be a situation that weakens the plant, thus increasing its susceptibility — such as a sun-loving plant growing in a heavily shaded spot.

The secret is often to manage conditions that represent the corners of the plant disease triangle. Keeping these in mind helps the gardener gain insights into plant diseases and their control.

Disease cycle

The disease cycle is another important concept that describes the chain of events involved in disease development, and its spread and survival (Figure 2). If you can break the disease cycle, you can often manage the disease.

A typical disease cycle includes the following events:

- Production of infectious inoculum (see box).
- Spread of the inoculum.
- Penetration of inoculum into the host plant.
- Infection within the host plant.
- Secondary cycles to produce new inoculum.
- Survival between growing seasons.

Inoculum

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

Depending on the disease, inoculum can be fungal spores, bacterial cells, viral particles or individual nematodes. These could be present in crop residues, in the soil, in weeds or crops, on or in seed, or in wind or water. Inoculum can also be carried on or in vectors (see box).

Pathogens in temperate climates must have a way to survive the winter when their host plants are dormant or absent. It is important to consider how these pathogens overwinter, because this 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 how much inoculum is present in the South influences management decisions farther north.

Vectors

Vectors are agents that carry inoculum of a disease from one host plant to another. They are typically animals such as insects, nematodes and birds. People can also act as vectors; for example, they can carry infectious inoculum on clothes, unwashed hands or dirty tools, spreading it between plants.

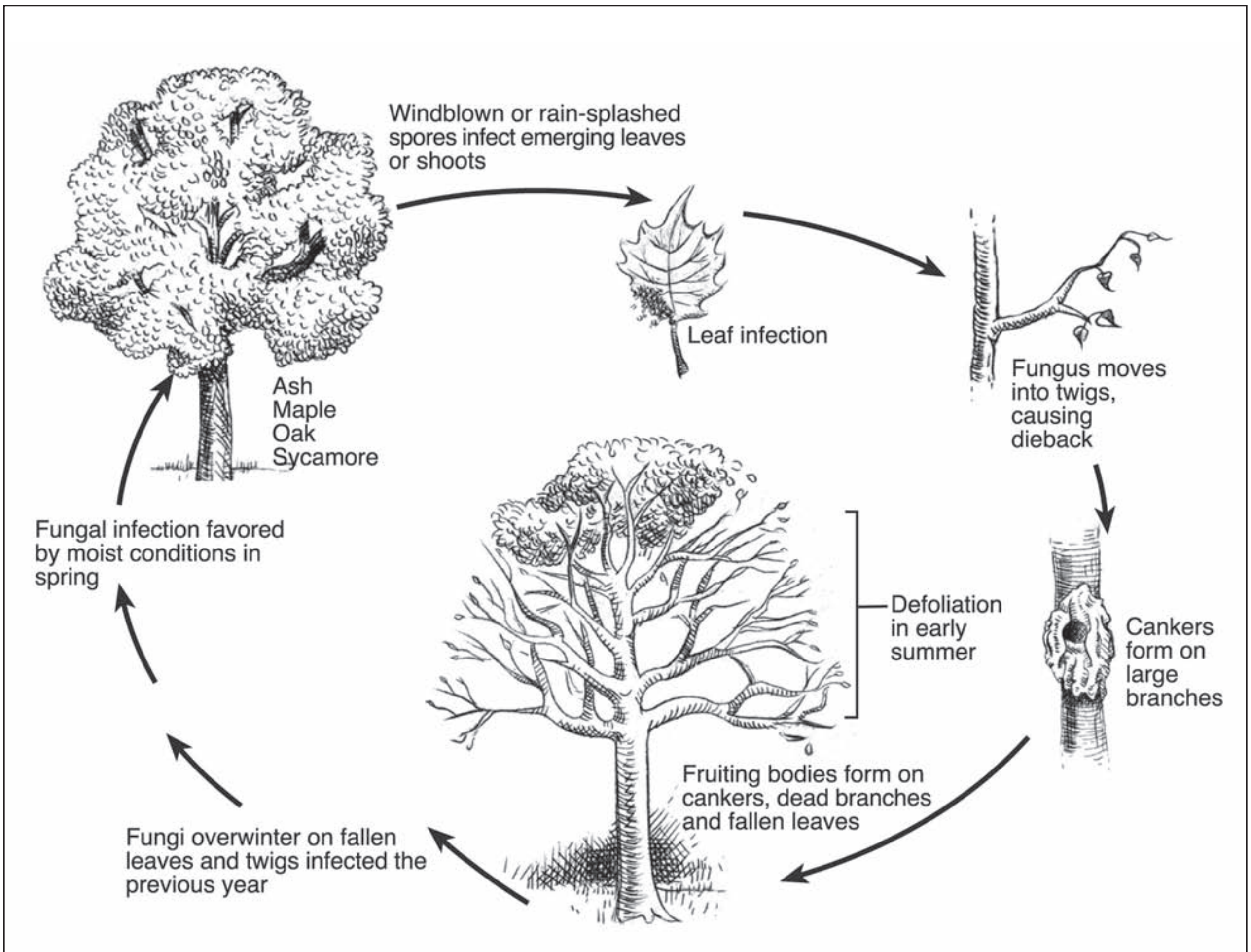


Figure 2. Example of a disease cycle.

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

Insects spread Stewart's bacterial wilt of sweet corn, *Pantoea stewartii*. This disease can survive the winter as bacterial inoculum inside flea beetles. In the spring, when overwintered flea beetles feed on sweet corn, they spread inoculum to new plants. Scientists predict how much of the disease to expect each year based on winter's severity. In mild winters, more flea beetles survive and the level of bacterial wilt will be higher at the beginning of the growing season. After such mild winters, pesticides may be used to reduce flea beetle populations, which will prevent the inoculum from reaching corn plants.

Causal agents of plant disorders

Causes of plant disorders can be characterized as either biotic, living, or abiotic, nonliving. Biotic agents are organisms such as fungi and bacteria. Abiotic agents include improper planting and injury. These two main types of causal agents usually have different symptoms and require different management approaches. However, these two types of problems are often found together because an abiotic factor frequently makes a plant more vulnerable to later attack by a living disease agent.

Biotic causes of plant problems

Fungi

Fungi are the most common biotic cause of plant disease. Microscopic organisms that lack chlorophyll, fungi may be visible as mats of thread-like filaments or "resting structures" that include rhizomorphs and sclerotia. Many fungi reproduce by spores and produce conspicuous fruiting bodies that can aid in identification.

In the diagnostic lab, fungi are often identified by their growth patterns, spores or other structures. Because fungi are not always visible on plant surfaces, a lab can test a sample by placing the affected tissue on a petri plate that contains a nutrient medium. If fungi are present, they will grow and produce structures that are used 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.

Some fungi cause lesions, or dead spots, on leaves. Within the foliar lesions caused by fungi, small black dots may be visible with a hand lens. These are the fruiting bodies that produce fungal reproductive spores. Not all leaf spots require control measures. Gardeners can manage fungal leaf spots by growing resistant cultivars or by using cultural practices that limit the development of disease. If a fungicide is needed, the home gardener generally must hire an arborist or other licensed applicator to make the fungicide injections.

Other fungi cause root and lower stem rots that cause seedlings to wilt and fall over. Commonly known as damping-off, this occurs most frequently in a contaminated growing medium that is too wet. Because moisture promotes fungal growth, the more you water, the more the plants wilt. Home gardeners usually find that careful watering practices, use of sterile pots and uncontaminated, soil-less seedling mixes are the most practical and effective preventives for root and stem rots. (Do not reuse potting soil.)

Some fungi also cause cankers, which are usually visible 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 where the plant tries to protect the damaged area and limit spread of the fungus. If the canker surrounds the stem completely, the stem or branch will die above this point. Canker diseases are difficult to manage. To slow their development and spread, practice good horticultural care to reduce plant injury and stress and remove affected branches.

Some fungi cause vascular wilts. When these fungi grow inside a plant's vascular, fluid-conducting tissues, the tissues die and the leaves no longer receive moisture. Affected branches wilt and die. You can often see dark streaks in a branch under bark where fungi are active. The Dutch elm disease that has wiped out many mature elms in the Midwest over recent decades is an example of vascular wilt. Plants with severe vascular wilt infections usually cannot be saved, but gardeners can sometimes use fungicide injections to protect adjacent plants.

Blights can also be caused by fungi, leading to death of plant structures such as leaves, flowers and stems. Blight diseases often occur rapidly and can result in 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.

Stomata, hydathodes and nectarthodes

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 nectarthodes 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 clump together to form colonies with unique appearances. Bacterial organisms are often classified according to metabolic types that use different food sources. In the lab, it is possible to narrow the list of bacterial agents that might be causing a problem by growing the bacteria on different kinds of media to see what the bacteria use as a food source. Because bacteria can multiply so quickly, they are often difficult to manage and can rapidly develop resistance to chemical controls.

Tumor-like growths called galls can be caused by bacteria. Crown gall is a common plant disorder that occurs when soil-borne bacteria cause lumpy swellings on roots and the lower stems of many plants. Gardeners often see crown gall of *Euonymus*, grape vines and fruit trees. Cultural practices such as good sanitation and avoidance of wounding can help prevent crown gall and reduce its spread.

Leaf spots are common bacterial diseases that cause mushy or water-soaked lesions; sometimes tissue falls right out of the leaf, which gives it a ragged appearance. Under a microscope, bacterial ooze from a lesion may be evident. This ooze contains millions of bacteria that can easily splash to healthy leaves in water droplets. The bacteria may enter plants through stomata and hydathodes in leaves or damaged tissues (see box).

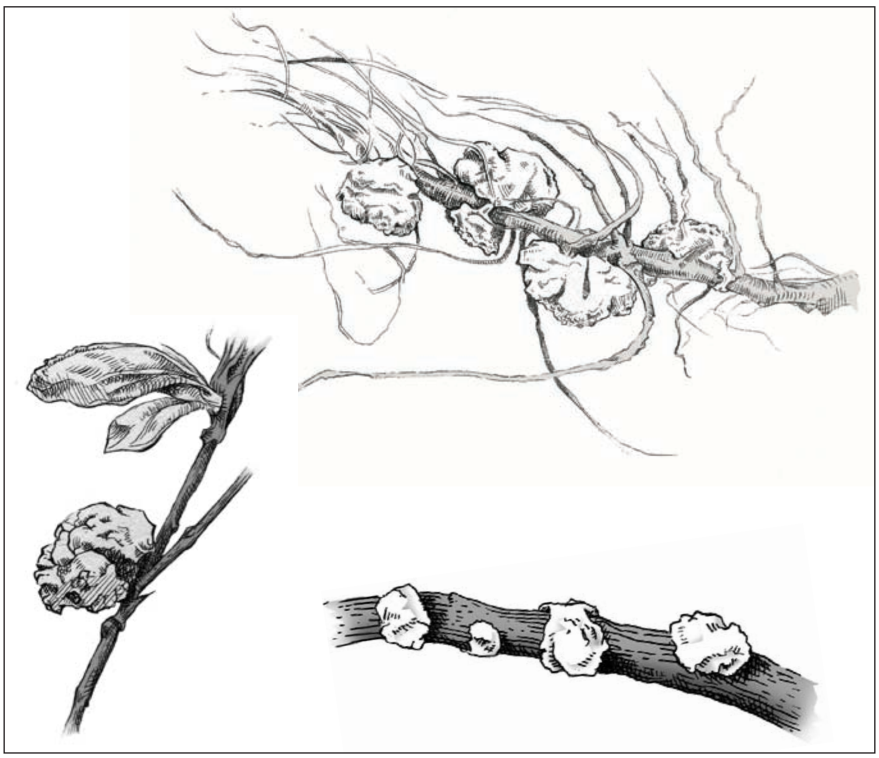


Figure 3. Crown gall symptoms.
Crown gall is caused by *Agrobacterium* and related bacteria. The lumpy swellings typical of the disease are usually seen on roots or lower stems.

Bacteria can be difficult to kill when protected inside the leaf. To protect healthy plants, the gardener can manipulate environmental conditions, remove infected plants and apply chemical protectants or antibiotics. Good sanitation practices are especially important to prevent problems, because a single infected seed can result in an entire tray, or even an entire greenhouse, of diseased plants.

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 over with a characteristic curled, shepherd's crook, or candy cane pattern, and tips turn black as they dry. Fire blight infections are typically most active in the spring when insects spread the infection as they pollinate flowers. The bacteria can enter plants through nectarthodes in blossoms (see box on page 5). Splashing rain and pruning or other wounding events can also spread the disease. Gardeners should use good cultural practices and select resistant cultivars to manage fire blight.

Bacteria also cause soft rots. These can cause rapid decline in the quality of many fruits and vegetables and damage other plants. Affected plants often have a strong odor and mushy tissues that appear melted. Avoid mechanical injury and practice strict sanitation to help reduce the incidence of soft rots.

Phytoplasmas

Phytoplasmas are essentially very small, 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 can appear 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 (see box). Control measures include removal of the infected plants and nearby weedy hosts, and control of leaf hoppers and other insects that act as vectors for the disease.

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 observed 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 can sometimes be identified by their physical characteristics when viewed at high magnification with an electron microscope. In other cases, "serological" testing of plant sap or more advanced genetic testing techniques can help confirm a diagnosis.

Viruses are spread by insects and nematodes, using infected seed, handling plants or spreading contaminated sap during pruning or propagation, or sometimes by pollinating with infected pollen. The mode of transmission depends on the type of virus. Unfortunately, once a plant has a viral disease, there is no cure. If the virus causes severe symptoms and has potential to

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.

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.

Nematodes

Nematodes are unsegmented, microscopic roundworms that generally have a thread-like form. Not all nematodes harm plants. Some are beneficial and kill plant pests. Others are associated with decaying matter. A parasitic nematode has a needle-like stylet, a tube-like structure that can pierce plant cells to withdraw nutrients.

Some nematodes live inside plants. This is true of the pine wilt nematode that is responsible for the death of many Scots pines across the Midwest. Trees become infected when a beetle that feeds on the tree also brings the nematode. Affected trees quickly turn brown and should be destroyed to prevent infection of 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 the South. 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 range 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 soil on them, can spread nematodes to new areas.

Abiotic causes of plant problems

Abiotic plant problems are not associated with a living organism. An abiotic problem may be physical, environmental or chemical. Many samples of plant disorders received by plant diagnostic centers have problems that are primarily due to abiotic factors. Many others have disease and insect problems that developed due to underlying abiotic issues. For example, many plants have distinct habitat preferences and will easily develop problems if grown in an unsuitable location. In such circumstances, abiotic factors can make a plant more susceptible to the biotic disease organisms discussed in the previous section.

Physical

People, rather than insects or diseases, are often responsible for a plant's problems. Problems caused by people can be categorized as physical or mechanical and include poor planting methods that allow limited area for root growth, improper mulching, construction-related injury or soil compaction, girdling of stems or trunks, or pruning too much or at the wrong time of year. For example, plants should be pruned during dormancy, not during the growing season.

In some cases, physical problems can be alleviated. However, such problems often indicate that the plant was given a bad start. By the time symptoms appear, the gardener may not be able to address the problem's real cause and restore the plant to vigor.

Figure 4. Symptoms of abiotic plant injury.
Injury from nonliving, environmental factors typically occurs on one side or area of a plant or group of plants.

Environmental

Environmental factors are common sources of a plant disorder. Extremes in temperature and moisture are the most common culprits. Drought stress can cause leaf scorch, leaf drop or even branch dieback. Freezing injury in winter can cause leaf burn and dieback of evergreens. When wet conditions saturate the soil for many days during the growing season, plants may develop yellowed foliage due to poor uptake of minerals from the soil by nonfunctional roots.

If decline of whole sections of a plant or a group of plants occurs suddenly, especially if the affected sections are concentrated on one side of the plant or a group of plants, suspect an abiotic, nonliving, factor, such as chemical drift, animal damage or weather.

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 impact 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 will thrive. These plants will have problems if grown in soil that has a nutrient imbalance or an improper pH. For this reason, a soil test can often signal a probable cause for a plant disorder. Pin oak and blueberries, for example, like acidic soils and commonly develop leaf chlorosis when the soil pH is neutral or alkaline. Also, if the gardener fertilizes every year with a complete fertilizer that contains nitrogen (N), phosphorus (P) and potassium (K), the P or K may eventually build up in the soil and interfere with uptake of other minerals such as magnesium, manganese and iron.

Generally, plants have a limited geographic range where they will grow and do 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 not result in good plant health. Selecting plants well suited to the local environment gives them the best chance to thrive and resist disease. Gardeners should be familiar with the plant zone where they are located. See the U.S. Department of Agriculture's Plant Hardiness Zone Map, online at *usna.usda.gov/Hardzone/ushzmap.html* or an updated version from the National Arbor Day Foundation, online at *arborday.org/media/zones.cfm*.

Chemical

Chemicals are also abiotic causes of plant disorders. Symptoms of herbicide injury vary with the product used and tend to cause sudden decline.

The most common symptoms are leaf cupping and distortion caused by drift from pesticide spray or root uptake by ornamentals and vegetables where broadleaf weed killers have been applied to nearby lawns or crop fields. Ice-melting salts that wash into the root zones of trees and shrubs can cause wilting or browning of leaf margins.

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 symptoms that include a characteristic bronzing of leaves.

Five steps to diagnose plant disorders

To accurately diagnose a plant disorder and find its remedy can seem like a daunting task, given the hundreds of plants grown in gardens, landscapes and commercial horticultural operations, and the array of problems that affect them. In some cases, identification may require assistance from a professional plant pathologist, a diagnostician of plant disorders. Before turning to the experts, however, a gardener should attempt to make a diagnosis. Even if the result is not definite, the process is a learning experience that will provide useful information.

When diagnosing plant problems, a gardener should pay close attention to detail when collecting information. Items that can be helpful include a hand lens, trowel, pruning shears, pocketknife, flashlight, digital camera and a notebook and pencil. Establish a location to keep records and reference materials.

It is often possible to rule out many causes of a plant's problems and to 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 identify the source of a problem. Consider the plant's preferences for soil and climatic factors of pH, nutrient levels, soil type, moisture level, light intensity and temperature.

If a plant's identity is uncertain, gardeners can consult references such as those suggested at the back of this guide, or any available gardening or landscape records. Garden stores can usually help identify a plant if they have a stem with several leaves. Local extension offices or the University of Missouri Plant Diagnostic Clinic, online at *soilplantlab.missouri.edu/plant*, can also help. Most other states provide similar services.

References can help 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, it is likely to develop leaf scorch and damage from dogwood borers attracted to the stressed tree. Such symptoms often result from an unsuitable planting site. When this happens, the gardener can only expect limited results from pesticides or other treatments.

2. Determine what is normal

Read plant descriptions and observe other plants of the species, variety or cultivar to learn what is normal for the plant in question. Sometimes a symptom is just a natural feature. For example, someone unfamiliar with '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. If unfamiliar with paperbark maple, the gardener might be alarmed to see sheets of bark peeling from the trunk of a specimen, though it is a normal process for this plant. However, 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 at 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 two- or three-year-old leaves.

Some plants have longer life spans 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, the gardener can only do so much to restore it to a flourishing condition.

3. Learn the common problems 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 disorders, and their related symptoms and signs (see step 5 on the next page).

A diagnostician learns to look for indications of disorders that commonly affect certain species. Austrian pine trees are often affected by *Diplodia pinea* (also known as *Sphaeropsis)*, a fungal tip blight that kills needles near the tips of lower branches. Leaves of hawthorn trees are often attacked by a rust disease and an insect called lacebug. Zinnias, lilacs and garden phlox 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.

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, the gardener may be able to determine the cause of a disorder.

Clues to biotic factors

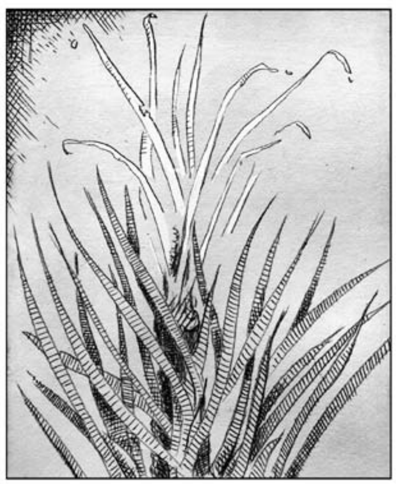
Many types of living organisms can cause plant disorders, including fungi, bacteria, viruses, nematodes, phytoplasmas, insects, mites and parasitic plants and animals. These diseases and insects tend to show up somewhat randomly in the landscape, but they are usually host specific. They often start in one location on a particular plant species and then spread gradually to the entire plant and possibly to nearby plants of the same type.

Clues to abiotic factors

If patterns of damage on the individual plant, or throughout a planting, are uniform and repeated, especially if they are concentrated on one side of a plant or an area, a nonliving factor is the probable cause (see Figure 4 on page 8). Abiotic factors commonly affect multiple species in the landscape or garden over a defined area. Additional clues can often help determine whether the nonliving damage is due to mechanical, physical or chemical sources.

Close visual examination can show if the damage pattern coincides with a cultural practice, such as pruning, mulching or watering. Are stems or trunks broken or girdled, or roots exposed and damaged? Weather records and patterns provide information to help identify other possible physical or environmental factors. For example, heat damage is most likely to show up on the southwest side of a plant canopy because the highest leaf temperatures of the day occur during early to midafternoon when the sun is in the southwest quadrant of the sky. Cold damage occurs on less hardy plants and will be most severe on the least hardy tissues of those specific plants.

Contact chemicals can cause symptoms that occur over the general plant canopy. If a toxic chemical is applied directly to the above-ground parts of a plant, the pattern of application may be detected, such as the extent and size of spray droplets or more severe damage on the portion of the plant exposed to the greatest amount of the chemical. If an aerial pollutant is involved, areas between the leaf veins and along the leaf margin will be the first to show damage. Toxic contact chemicals in the root zone, including excess fertilizer, result in poor root development. These symptoms tend to be localized where the chemical contacts the root, but produce general symptoms in the plant. Roots are injured and root tips may die, which will result in the plant being stunted. Shoots may show water and nutrient stress symptoms, because the roots will not take up water properly. Wilting can occur even though the soil is wet.


Diseased needles at end of twig

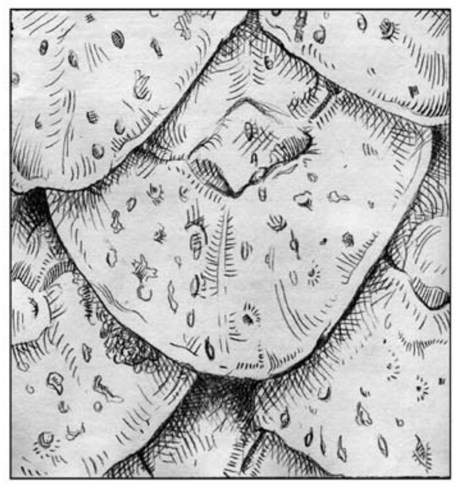

Diseased scales on pine cone

Figure 5. Symptoms and signs of Diplodia (or Sphaeropsis) tip blight.
Symptoms of this disease include browning and stunting of new needles at branch tips. A close look will also show fungal signs — small black bumps that are the reproductive fruiting bodies — on dead needles, twigs and cones.

5. Look for symptoms and signs

Understand symptoms and signs, and the differences between them, to help diagnose a plant's problem or to discuss a sample with others. Symptoms are the plant's response to infection. They are what you see that signals the plant is not functioning normally. Typical symptoms include brown spots on leaves, yellowing or crinkling of leaves, discoloration or mushy plant tissues. Signs are visible structures made by the pathogen or the disease agent (or insect) that caused the symptoms. Signs include mold on the plant surface, mushrooms, droplets of bacterial ooze or dark-colored bumps on a leaf.

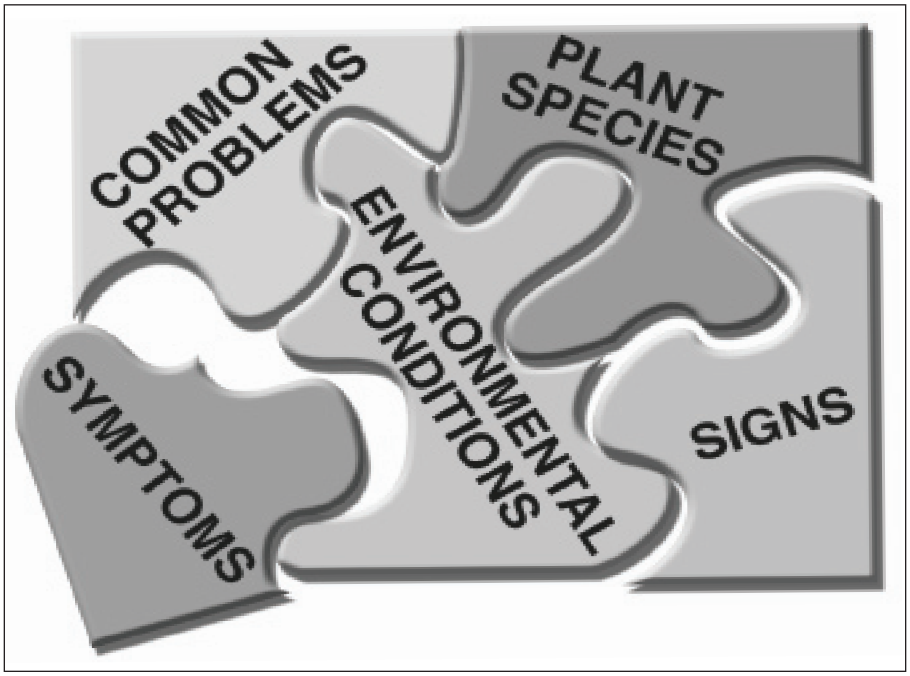


Figure 6. Plant disease puzzle.

Diagnosing a plant disease accurately requires the gardener to consider many different factors that might be causing the disorder.

Consider a typical Austrian pine in Missouri. A common disease of this species is called Diplodia tip blight. To confirm the disease, you would first look for symptoms. Specifically, you would see the dead needles at the tips of the branches. At this point, if you use a hand lens to further examine the brown branch tips, you could see signs of the fungus causing the disease: small black bumps or specks that are the fruiting bodies. Symptoms of Diplodia tip blight are similar to pine tip moth damage, but the signs are different. In the case of the moth damage, the fungal fruiting bodies are not present, and moth larvae and tunneling in the shoots will be evident.

Confirming a diagnosis

Using the five steps described above to diagnose plant problems is like putting together a puzzle. 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.

Take a lesson from professional plant diagnosticians: Good reference materials can be a great help in the process. Sources of information and pictures include Web sites, textbooks, extension publications and professional and trade journals. Related MU Extension publications are listed at the end of this publication.

Call on the experts

If a plant disease problem still has you stumped after following the steps to diagnosis, you might decide to call on the experts. You could take a sample to a local garden store or to your county extension office where a quick consultation might answer your questions. You could also send a sample to a higher authority — a plant diagnostic laboratory.

To identify plant disorders, diagnostic labs use a variety of techniques, the choice of which depends on the sample. In many cases, diagnosis will be relatively simple because the lab is familiar with the problem, having previously seen many plants with the same disease.

With a more challenging sample, or when identifying an unfamiliar disease, a diagnostician may use a taxonomic approach that includes the main steps of isolating the suspect pathogen, identifying it and then confirming it (see box). Using this approach can be time-consuming and expensive. For example, to confirm a potential diagnosis, a technician might inoculate a healthy plant with a pathogen from the sample to see if the healthy plant

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.

develops the same symptoms. 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. At the University of Missouri, information about the plant diagnostic clinic, how to submit samples, associated fees and other information can be found at *soilplantlab.missouri.edu/plant*. You can download forms to submit with a sample or obtain them at an extension office. The form asks for detailed information that is important to fill out as completely as possible to aid in a quick and accurate diagnosis.

The quality of the sample is critical. 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 might first appear. 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 assist in accurate diagnosis, keep the plant material as fresh as possible during shipping. To prevent decay of the sample in the mail over a weekend, you should wait to collect the sample or store it in a cooler over the weekend to ship 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 enclosed in a padded envelope or plastic bag and then boxed. Do not wrap samples in damp packaging material. This 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 functional national network of existing diagnostic laboratories to rapidly and accurately detect and report pathogens, pests and weeds of national interest. More information about the network is online at *npdn.org*.

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

So far, the network has probably been most useful to facilitate quick identification of accidental introduction of new pests and pathogens brought into the United States as a result of the global economy. For example, a bacterial wilt disease accidentally introduced on geranium cuttings from tropical areas was quickly identified and eradicated before it could become established.

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 is often a quarantine to prevent the spread of a disease into new areas. 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 accidentally came into the country on flower cuttings shipped from Kenya and Guatemala, but the disease was quickly detected and eradicated before it could begin to become established here.

Another 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 also 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 disease-causing organism. Many crops and ornamental plants are bred to be disease resistant. Gardeners frequently use this method when they select varieties and cultivars that can resist common diseases, such as roses with black spot resistance or crab apples with resistance to apple scab.

A plant considered disease resistant is able to resist a specific disease, but it can still be highly susceptible to other diseases. For example, certain roses that are highly resistant to the common fungal leaf disease black spot are often susceptible to other leaf spotting diseases, viruses and other problems.

IPM considers options

Integrated pest management, often referred to as 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.

Also, a plant that is resistant to a specific disease could still develop the infection, especially if a different genetic variant of the pathogen is present. For example, tomato varieties resistant to Fusarium wilt can develop the disease under highly favorable environmental conditions or when another race of the fungus is present in the soil.

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 associated disorders. Combining a variety of cultural control techniques often works better than using a single method.

In the garden, rotating tomatoes 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 different plant species also may reduce or slow the spread of disease if resistant plants are planted among more susceptible plants. Watering early in the morning so the plants can dry quickly and remain dry through the night is another effective cultural practice for some fungal or bacterial diseases. 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. In general, gardeners should strive to plant healthy, disease-free plants and maintain them in a vigorous condition.

Biological controls

Biological control agents are known as a way to manage harmful insect populations by the use of beneficial organisms such as lady beetles. There are also biological controls for some plant diseases. For example, formulations of beneficial fungi or bacteria are widely used as a spray or dust to coat plant surfaces and help prevent attack by more harmful disease-causing organisms.

Chemical controls

Finally, chemicals such as fungicides, bactericides or nematicides are used to control plant diseases. Chemical controls can be effective, but it is important to properly identify the problem and determine that the method is suited to the situation. For example, a fungicide will not cure a problem caused by insect damage, poor drainage or bacterial disease.

Samples are often submitted to the diagnostic clinic after chemical control has failed. In some cases, plant damage is the result of a burn from chemicals applied to treat a different plant problem. Effective, proper use of chemical controls can save the gardener money and can also prevent application of chemicals that could harm the environment or potentially even compound pest problems.

Always read chemical labels 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. The National Pesticide Information Center, online at *npic.orst.edu*, and cosponsored by Oregon State University and the U.S. Environmental Protection Agency, is an up-to-date source of information on a range of technical, regulatory and pest control topics. A good reference for information on pesticides currently labeled for use in Missouri is online at *kellysolutions.com/mo*, which is linked to the Missouri Department of Agriculture Web site.

For further information

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

MU publications at *extension.missouri.edu/explore/*

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

Related reading and Web sites

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National Pesticide Information Center (NPIC), online at *npic.orst.edu*

University of Missouri Plant Diagnostic Clinic, online at *soilplantlab.missouri.edu/plant/diseases*

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