Plant Disorders and Diseases

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A plant disorder is defined as any abnormal plant growth or development. The affected plant does not live up to the normal expectations; it is incapable of carrying out its normal physiological functions to the best of its genetic potential. There are almost an unlimited number of factors that can have a negative affect plants. Disorders can be broken down into two main categories, abiotic disorders and biotic disorders. Abiotic disorders are caused by nonliving entities, such as adverse environmental effects or improper cultural practices. Biotic disorders are more correctly called plant diseases and are caused by infectious organisms.

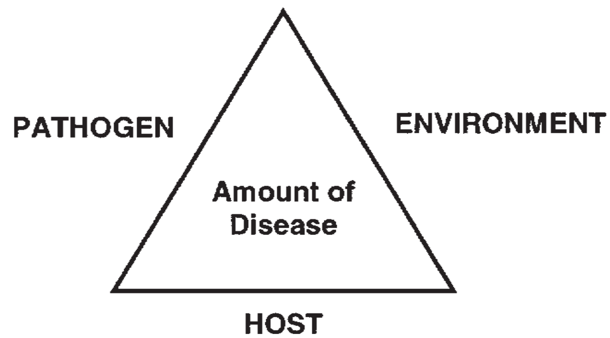

Figure 1. The disease triangle.

Basic Concepts in Plant Pathology

This chapter discusses the basic concepts of plant pathology—the study of plant diseases and disorders.

Causal Agents

Infectious diseases are caused by biotic (living) organisms. The most common plant diseases are caused by fungi, bacteria, phytoplasmas, viruses and viroids, nematodes, and parasitic higher plants.

Abiotic disorders are caused by noninfectious factors. The causal agents of disorders are almost unlimited, but the most common disorders usually are caused by factors, such as temperature extremes, moisture extremes, light extremes, nutrient extremes, poor soil (acidity or alkalinity, salt, texture, hard pans, caliche), pesticide toxicity, air pollution, strong winds, hail, and improper cultural practices.

The Disease Triangle

A disease episode requires the interaction of three components: the host, the pathogen, and the environment. This interaction is known as the disease triangle (fig. 1).

In order for a disease to occur, the host plant must be susceptible to the pathogen (disease organism). First, the plant must be susceptible genetically, meaning that the organism present can cause disease on that plant. In some cases, the host must be at a certain physiological state for disease to occur. For example, some organisms attack only young plants, others take advantage of mature or aging plants, and some organisms are able to take advantage of the plant at any growth stage. In most cases, pathogens take advantage of plants that are stressed. Vigorous, strong-growing, nonstressed plants are less susceptible to disease than plants growing under stress conditions.

Disease only results from the infection by a virulent (aggressive and able to cause disease) pathogen. Most pathogens go through a life cycle in which part of the time the organism is dormant. When a pathogen is dormant, no disease can occur.

Although the disease triangle is illustrated by a triangle with all sides equal, the environment really is the most important part of the interaction. The environment must be conducive (favorable) for disease development. That is the temperature, moisture, nutrients, and wind must all favor the pathogen's growth and development.

Some diseases (notably those caused by viruses) require a vector (transmitting agent) for infection. In these cases, the vector is an additional component of this interaction.

The degree to which these three components interact relates to the disease severity. For example, if the host is highly susceptible, the pathogen is highly virulent, and the environment is highly conducive, then the disease will be very severe. Severity also includes an element of time - the longer the environment remains favorable for disease development, the greater the severity of the disease.

Successful disease management requires the disruption of some part of the disease triangle. For example, many management strategies involve preventing the plant from becoming stressed, such as good water and fertilizer practices. Other strategies target the pathogen, such as using preventative or curative fungicides. Although the environment is difficult to control, some management strategies, such as choice of planting date, try to avoid the environment's negative effects. There are several different strategies for disease management. But, overall, the most successful strategy depends on the integrated use of available control methods. This concept can be termed Integrated Disease Management.

Symptoms and Signs

Plants are considered to have a disease or a disorder when they are not growing up to expected standards. There are two visual keys to identifying "sick" plants—symptoms and signs.

Symptoms

Symptoms are the visual response of the plant to attack by an infectious organism or an abiotic factor. For example, plants exhibiting leaf spots, cholorosis, necrosis, wilting, and stunting are showing symptoms of an abnormality. Symptoms are a very important part of determining the cause of plant problems. However, there are several factors that prevent symptoms from revealing the exact causal agent.

First, symptoms are nonspecific. Many different pathogens and abiotic factors can have the same affect on the plant. For example, any entity that disrupts the movement of water in the plant will cause the plant to wilt. Another factor is that symptoms change over time. Therefore, good symptom descriptions require observing the plant over time and noting the progression of symptom development. Symptoms often develop away from the infection site. For example, aboveground symptoms of water and nutrient stress occur when roots are damaged. Additionally, symptoms will vary due to the pathogen's virulence (aggressiveness), the degree of host susceptibility and the environmental conditions.

Signs

Signs are the visual presence of some structure formed by the pathogen on the host plant. Examples include fungal mycelium, spores, fruiting bodies and bacterial ooze. While symptoms are nonspecific, signs allow for a more specific determination of the causal agent. In some cases, the sign will reveal the exact cause. For example, white powdery growth on plant surfaces are caused by powdery mildew fungi. In other cases, signs will help to narrow down the potential causal agent. For example, mycelium on the surface of turf indicates a fungal disease problem.

Organisms Associated with Plant Tissue

Microorganisms are in constant association with plant tissue. Various fungi and bacteria can be isolated from healthy plant material. These organisms are typically saprophytes, meaning they do not cause any harm to the plant. When plants become diseased, there is typically a primary pathogen associated with the infected tissue. This organism is directly responsible for the disease.

Diseased tissue is colonized quickly by secondary organisms. These organisms are taking advantage of the weakened tissue. In some cases, these secondary organisms may be weak pathogens that cause a further progression of the disease. But in many cases, they are simply saprophytes that feed on the decaying tissue. This movement of organisms on or through the plant is known as organism succession. Organism succession can make identifying the primary pathogen difficult. Diseased plant specimens must be examined relatively quickly after symptoms begin. Otherwise, secondary pathogens or saprophytes are all that can be found associated with the diseased tissue.

Accurate diagnosis of the causal agent is required for effective use of management strategies in general and specifically for effective chemical control. Using an inappropriate chemical will not only be ineffective against the disease agent, but also can lead to additional disease problems by killing beneficial microorganisms in the environment.

Diagnosing Plant Diseases

Diagnosis is the process of determining the cause of a plant disorder. The process requires a blending of science, experience, observation, and art. Diagnosis is a cooperative effort between the grower and the plant expert. Accurate diagnosis depends on routine observation of plants and early detection of problems, examination of good plant specimens, and obtaining accurate information. Additionally, it is important to keep an open mind in evaluating plant problems. Getting a mind-set (deciding what has happened without investigation) is one of the biggest obstacles to an accurate diagnosis. In addition to getting a mind set, factors such as nonspecific symptoms, biotic and abiotic problems occurring simultaneously, multiple infections, and disease complexes complicate the diagnostic process. Multiple infections occur when a plant is infected by more than one pathogen at a time. These pathogens are operating independently from one another. Disease complex refers to the situation where the specific disease problem is caused by more than one organism. In this case, each of the pathogens in the complex must be present for disease to occur. Multiple infections and disease complexes add to difficulty in disease management as identification and control of only one organism may accelerate activity of another organism infecting the plant.

Elements of Diagnosis

A diagnosis is made up of seven parts: identifying the plant species, observing, accurate information, sample collection, identifying the cause, confirming the cause, and recommendations. The grower and consultant (anyone seeing the plant in its environment) are responsible for the first four of these elements. The more accurate this information is and the better the sample submitted, the greater the opportunity for an accurate diagnosis by a laboratory diagnostician. The final three elements are the responsibility of the diagnostician and, in some cases, the consultant aids in the final recommendations.

1. *Identify the plant species.* Identifying the plant species is important, because the plant species establishes the possible host-pathogen interactions. It is best to identify plants by their scientific name (genus, species, and cultivar), however a common name will help if the scientific name isn't known. In a mixed turf stand, identify the species present and which are diseased or not diseased. In the landscape, note if (and what) other types of plants are affected.

2. *Observation.* Accurate diagnosis depends on good, thorough observation of the plant and its surroundings. Develop a description of the symptoms and symptom development or progression. Be as specific and detailed as possible. For example, if the plant's new growth is yellow, don't just say the plant is yellow, because the diagnostician will assume the whole plant is yellow. Photographs are tremendously helpful when the plant cannot be seen in its environment. When describing the problem, be sure to indicate what parts of the plant are affected and how long the plant has been showing symptoms. Other important observations include whether the symptoms appeared suddenly or developed gradually over time, if the symptoms are spreading (on the plant or between plants) or appear to be localized, and if there are other plants of the same or different species in the area that are showing similar symptoms.

   Also include observations of the environmental conditions just prior to and during symptom development. Consideration should be given to day and night temperature, soil temperature, moisture (rain, dew, humidity, sleet, snow), wind (blowing dust), hail, and air quality.

3. *Accurate information.* Information should be obtained on the growing conditions. Determine the soil type, quality, and drainage. Obtain information about the plant's location (indoors, outdoors, in a lawn, greenhouse, raised bed, median). Obtain as much information as possible about where the plant is growing, the exposure (sun, shade, partial shade, morning sun, afternoon sun) and the proximity of the plant to structures (other plants, buildings, sidewalks, driveways, roads, walls). Again, be as descriptive and thorough as possible.

   Information about how the plant is managed also is critical. Determine the irrigation history:

how often the plant is watered and how much water is applied during each watering, how the water is applied, the time of day water is applied, and if and how the watering changes from season to season. Similarly, information should be obtained about the fertilization history: what type of fertilizer is applied, how the fertilizer is applied, how much is applied, and how often it is applied. Determine if and what chemicals may have been used on the plant and/or in the surrounding area. Identify the chemical by name and find out how the material was applied, the application rate, when the material was applied and how often the material has been used. Lastly, obtain any additional information about plant management, such as pruning and sanitation practices.

Additional information about lawn care is helpful when trying to determine the cause of turf disorders. It is important to note the presence of other plants in or near the turf area, and whether or not those plants appear healthy. Also, note the terrain or slope of the lawn, the age of the lawn, how the lawn was established, and the maintenance practices, including mowing, aeration, dethatching, and raking.

4. *Sample collection.* When collecting plant samples for submission to a diagnostic laboratory, it is important for the collector to understand that the diagnostician will see only what you send. Thus, the sample should be as representative of the problem as possible, keeping in mind that aboveground symptoms may be caused by root or soil problems. The best sample is the entire plant, with vegetables and bedding plants, it is best to dig up (do not pull plants out of the ground) and send the whole plant. If possible, collect several plants showing a range of symptoms. When the entire plant can not be collected, for example, trees and shrubs, collect several samples of branches that show the margin between diseased and healthy tissue. Additionally, digging up some of the feeder roots also can be helpful. When collecting diseased turf, cut out a few sections of sod approximately 3-by-3 inches diameter that show both diseased and healthy grass. Be sure the sample includes the blades, thatch, and soil with roots. Keep the sample cool prior to shipping. Use an ice chest to move the sample from one location to another and place the specimen in the refrigerator if it can not be mailed immediately.

Packing the sample also is critical to the overall accuracy of the diagnosis. Every effort should be taken to see that the specimen arrives in as good a condition as possible. Samples should not be allowed to dry out. But they also should not be sealed in plastic bags, because sealed specimens generally rot in transit. Paper bags or plastic bags with air holes may be used. The specimens should be wrapped in newspaper or paper towels before being placed in the bag or box. Do not wet the wrapping material. Whenever possible, it is best to wrap the roots and shoots separately. If the entire plant has been collected, wrap the roots and place them in one bag, and use a second bag to place over the top of the plant. Pack the plant in a box or padded envelop to help protect the specimen from damage during shipping.

Mail the sample and the information (most labs have submission forms that should be filled out completely and included in the package) as quickly as possible. Overnight delivery is recommended. Most importantly, avoid mailing over weekends and holidays. The sooner the sample reaches the diagnostic laboratory, the more accurate the diagnosis will be.

The following are some helpful tips for collecting and sending plant specimens for diagnosis:

1. **Plant diagnosticians are not plant coroners.** Dead, dry or rotten plants are unsuitable for diagnosis. Specimens should show a range of symptoms, but should not be dead.

2. **Don't delay.** Time is critical in diagnosing plant disorders. Collect samples as soon as you suspect you have a disease problem. The longer you wait, the more likely secondary organisms will invade the tissue and interfere with isolating the primary pathogen. Additionally, management methods are more likely to be successful when used early, before the disease is in the advanced stages. Ship samples immediately after collection—use over-night delivery whenever possible.

3. **What you see is what you get.** What the diagnostician sees influences the final diagnosis. Make sure that the sample you submit is representative of the overall problem.

4. **When in doubt, collect more.** It is better to have too much material for diagnosis than not enough.

5. **Pack smart.** If soil and/or water gets on leaves during shipping, it can mask symptoms or result in the growth of organisms that are not responsible for the problem. Try to keep the plant from drying out without keeping it wet. Pack the material as if it is fragile—don't let material get crushed in shipping.

6. **Think.** The more you tell the diagnostician about the problem and the situation, the better the diagnosis will be. Provide complete and detailed information and include photographs whenever possible.

5. *Identification of cause*. The first step to identifying the cause of the problem is to try to determine if it's the result of an abiotic factor, a biotic factor, or both. The information received on symptoms, symptom development, and plant species affected is used to make this determination. Infectious diseases tend to take time to develop and therefore, symptoms typically appear slowly and develop gradually in severity over time. Symptoms will progress on the infected plant and also potentially spread to other plants of like species. Therefore, if the problem appeared suddenly, than it is more likely that the problem is caused by an environmental disorder. There are few exceptions, of course. For instance, drought symptoms usually develop relatively slowly, depending on plant size and overall state of health. Another distinguishing characteristic is the number of different plant species affected. If there are many different types of plants in the area that are showing similar symptoms, it is more likely to be related to an environmental (or abiotic) disorder than a disease. Likewise, if there is only one plant species affected, especially when there are several plants of that species showing symptoms, it is likely that the causal agent is an infectious disease. The sample is then examined using a dissecting microscope.

   If the problem may be caused by an infectious microorganism, one or more techniques will be used to try to isolate fungi and bacteria from the tissue. The two most common techniques for tissue isolation are incubation in a moist chamber and plating on artificial growing medium. Both of these techniques allow microorganisms associated with the tissue to grow. Those associated microorganisms are then identified by using a compound microscope.

   Some organisms, notably viruses, are obligate parasites, meaning they can only grow on living plant tissue. For these organisms, more sophisticated techniques that identify organisms on the cellular (nucleic acid) level are typically used.

   Once the organisms associated with the plant tissue are identified, a determination must be made as to whether or not that organism(s) is responsible for the observed problem. This determination is made using many different resources, including the diagnostician's education, experience, and reference materials (disease compendium, host indexes, Integrated Pest Management guides, extension publications, and other reference books).

6. *Confirmation of cause*. If the organism(s) identified is favored by the prevalent environmental conditions and known to cause disease on the plant infected, typically cause the observed symptoms, and occur in the area, then the diagnosis is made. If the identified organism has not been proven to cause disease on the infected plant, then confirmation of the organism as the causal agent must be completed. This process is known as Koch's postulates or Rules of Proof. This confirmation process involves four steps. Step 1. Constant association of the pathogen with diseased plants. Step 2. Isolation and growth of the pathogen in pure culture (or in the host plant for obligate parasites). Step 3. Inoculation of a healthy plant of same species and cultivar and reproduction of symptoms. Step 4. Reisolation and growth of the same organism in pure culture. Obviously, this process can be time-consuming and requires the right environment. Therefore, this process is used only when an organism that has not been documented as a pathogen is on a particular host, and is constantly associated with the "diseased."

7. *Recommendations*. After the diagnosis is made, recommendations about the course of action should be given. Recommendations should be made by asking several questions. First, the major contributing factors for disease occurrence

and development and the organisms' means of survival and dissemination (spread) should be determined. Next, determine if the damage is sufficient to warrant action. The cost of the action, for both labor and equipment, should be taken into consideration before action is taken. In some cases, the cost of the treatment is more than the damage caused by the disease. It also is important to ask yourself if there is anything that can be done now (or later) to help the plant, or should recommendations be given about how to prevent the problem from occurring again. When making recommendations, it always is important to consider a variety of management strategies, including variety selection, cultural management practices, biological control, and chemical control.

Principles of Plant Disease Control

There are six basic principles of plant disease control: avoidance, exclusion, protection, resistance, therapy, and trap cropping. Avoidance is the act of avoiding disease by planting at a time when or in areas where the pathogen is ineffective, rare, or absent. Exclusion involves reducing, inactivating, eliminating, or destroying the pathogen at the source. Protection prevents infection by use of a toxicant or a barrier between the host and the pathogen. Resistance uses the inherent genetic resistance of tolerance in the host. Therapy attempts to reduce the effect or the pathogen in an already infected plant. Trap cropping can be used when the disease is transmitted by an insect vector. Here, a small amount of a crop that is attractive to the vector is planted around the desired crop. Once the vector has established itself in the "trap crop," the vector and the trap crop are destroyed.

Major Plant Disease Control Methods

The following are examples of management tactics used to control plant diseases. These tactics can be used to try to prevent disease or manage disease within plants, however the key to successful disease management ultimately is prevention.

I. *Resistance or tolerance.* Resistance uses genetic resistance found in some species or varieties. When available, resistance generally is the most effective means of control. In many cases, the "resistance" is really a tolerance, which means that the plant can tolerate the pathogen better than a nonresistant plant. The level of tolerance varies from almost true resistance to weak tolerance, which can be broken down by a very aggressive pathogen or a very heavy pathogen population. Plant resistance must be monitored continually, as pathogens will develop virulence to tolerant plant material. Another complication to using resistance as a management tool is the occurrence of race or strain specificity in some pathogens. A particular cultivar may be resistant to a certain race of a pathogen, but not to another race. Thus, when the pathogen present is of a different race, the resistance doesn't work.

II. *Cultural control.* Good cultural practices that results in strong-growing, vigorous plants are some of the best disease control methods available. They are easy to do and are typically very cost effective. Some of the common cultural practices used for disease management include proper species and cultivar selection, sanitation (proper pruning, removal of debris and diseased plants, sterilizing tools, washing hands), use of disease-free planting material, choice of planting location, time of planting and proper planting techniques, choice of irrigation method and schedule, choice of fertilizer (type, timing, application method, and schedule), good insect and weed management, and crop rotation (for vegetables and annuals).

III. *Biological control.* This management strategy uses beneficial microorganisms to manage plant pathogens. Biological control occurs naturally, but often not at levels significant enough to manage serious disease outbreaks. Naturally occurring beneficial microorganisms may be manipulated in the environment by stimulating their growth with soil amendments or other cultural practices. Another means of biological control involves adding laboratory-reared microorganisms to the soil or plant environment.

IV. *Chemical control.* Chemicals can be used to eliminate, reduce, or remove the pathogen at the source (eradication); to prevent disease (protection); or to cure disease (therapy). Chemicals used in plant disease control are fungicides, bactericides, nematicides, and soil fumigants. These chemicals must be less toxic to the plant than to the organism(s) they are designed to control. The most common type of chemicals used are fungicides (in many cases, fungicides also are bactericides). Most fungicides actually are fungistats, which means that the chemical limits the activity of the fungus, but doesn't kill it. The disease will return when the chemical is no longer active and the environment is favorable for disease development. Thus, management of diseases with fungicides often requires repeat applications. Nematicides kill some life stages of nematodes. Typically, the nematode eggs are unaffected, and repeat applications of these materials may also be required. Nematicides are rarely used in home garden situations, because most are restricted-use materials, which means that an individual must have a pesticide licence to purchase and apply the materials. Fumigants are used for commercial crop production and typically help to control insects, nematodes, and weeds in addition to diseases.

Effective chemical use depends on choosing the right chemical and applying the chemical in the right way, at the right time, and in the right concentration. Thus, an accurate diagnosis of the causal agent is required, and the pesticide label must be read, understood, and followed to the letter. Reading and following label instructions is the law and is the responsibility of the person making the application.

Effective Disease Management

Effective disease management requires knowledge of the pathogen—its life cycle, the environmental conditions needed for disease development, where the pathogen comes from, how it spreads, and how it survives between crops. This information helps in applying the best management method at the most effective time.

Living organisms go through a life cycle in which part of the time they are dormant. Most organisms are dormant in winter, and this time in the life cycle is called "overwintering" (a few organisms "oversummer"). The following is a general fungal life cycle, indicating which management principles are most effective at different times.

General Life Cycle

Where Do Pathogens Come From?

Pathogens are ever-present in the environment. Diseases most often originate from infected planting material, such as contaminated seed (exterior), infected seed (interior), and infected cuttings; graft pieces, buds, and transplants. Other sources for plant pathogens include soil, water, and air.

How Do Diseases Spread?

Pathogens have many means of disseminating. One of the most common and important means is by wind-blown propagules. Pathogens can be spread both short and long distances, depending on the type of propagule and the environmental conditions. Water (rain, irrigation, movement of water through soil) is another important means of dissemination. Some host-pathogen interactions require vector transmission. The most common vectors include insects, people (equipment), other animals, fungi, nematodes, mites, and parasitic plants. Other means of spread include fungal hyphae growing between plants, movement of motile spores, forced discharge of spores into air currents, and self-movement of nematodes in soil.

How do pathogens survive?

Plant pathogens typically survive in plant debris, soil (as dormant spores and other resting structures), living hosts (infected perennial hosts or in annual alternate hosts—weeds), and internally in vectors.

Infectious Diseases

Fungi

Fungi are the largest group of plant pathogens. They can be thought of as plants that lack chlorophyll. But they are not plants, they are organisms in their own kingdom. Fungi obtain food from other living organisms or from decaying organic matter. Most produce microscopic spores, which can be compared to seeds of higher plants. The spores develop into threads called hyphae, which grow and branch into mycelium or other specialized structures (fruiting bodies).

Fungi enter plants through wounds, natural openings, or by direct penetration through the plant surface. The fungal mycelium grows through the plant and eventually produces more spores. These spores can then spread the disease to other susceptible plants. Some fungi have complicated life cycles, which require more than one type of spore and/or more than one type of host plant to complete the life cycle.

Fungi are disseminated (spread) by airborne spores (wind currents), soil, water (move in irrigation water or rain splashes), seed, or vectors. Vectors are agents that transmit diseases from one plant to another. Examples of vectors are people, other animals, insects, tools, and other microorganisms (fungi, nematodes, bacteria and parasitic higher plants).

Ornamental Diseases Caused by Fungi

Powdery Mildew. Powdery mildew is the common name for the disease caused by several different fungi that produce a whitish, powdery growth on the surface of infected plants. Powdery mildews are some of the most common diseases worldwide. Almost all plants can be affected by powdery mildew, however each individual fungal species has a somewhat limited host range.

Powdery mildew affects only the aboveground parts of the plants; roots are unaffected. Plants severely infected with powdery mildew, particularly year after year, become weakened over time. These plants are more susceptible to adverse environmental conditions, such as winter injury and other pathogens.

In general, powdery mildew fungi are favored by high humidity in the plant canopy (but are inhibited by water on the leaf surface) and warm temperatures. Cultural practices that increase airflow around plants, thus reducing the humidity in the plant canopy, can help control powdery mildew. Additionally, protective fungicides are available for most plants. However, application timing is important in effective control.

One of the most common mildew diseases is powdery mildew of rose. This disease is caused by *Sphaerotheca pannosa* and is extremely common worldwide. The fungus attacks young, succulent foliage. The symptoms begin as slightly raised, blisterlike, red areas on leaves. Eventually, all infected aboveground plant parts will develop a white powdery fungal growth.

S. pannosa overwinters in infected canes or buds and in fallen leaves. In spring, new shoots become infected from old mycelium, from conidia (asexual spores), or ascospores (sexual spores). Conidia and ascospores are disseminated to other susceptible hosts by air currents. The conidia and ascospores germinate and penetrate the plant directly.

Night temperatures between 58 and 62°F and day temperatures between 65 and 78°F favor the disease. The fungal spores cannot germinate in free water. But they germinate readily when the relative humidity in the plant canopy is high (97-99 percent at night and 40-70 percent during the day).

Powdery mildew is managed with good sanitation practices, including pruning out all infected canes, removing fallen leaves, and destroying all infected plant material. Protective fungicide sprays can be used when weather conditions favor disease development. Plants already infected with the fungus can be treated with systemic fungicides, which should help to reduce the fungus' spread and activity. Be sure to check for registered materials and read and follow the label directions very carefully. In areas where powdery mildew is known to be a severe problem, it is best to plant tolerant varieties.

Other common hosts of powdery mildew fungi include euonymus, photinia, lilac, pecan, verbena, crepe-myrtle, sunflower, Catalpa, Cotoneaster, holly, locust, mesquite, mulberry, privet, Mexican elder, Mexican evening primrose, Mexican bird-of-paradise, apple, pear, phlox, zinnia, stone fruits, tomato, chile, cucurbits and many other vegetables.

Rust Diseases. Rust is the common name for the disease caused by several different fungi that produce dark-colored spore pustules on the surface of infected plants. A wide range of plants can be infected by rust fungi, but most individual rust fungi have a very limited host range. Rust fungi may have up to five different spore stages in their life cycle. Rusts may be autoecious (having only one host) or heteroecious (having two hosts). Heteroecious rusts need both hosts to complete its sexual life cycle, although inoculum can build on one host through asexual reproduction. When two hosts are required to complete the life cycle, one often is considered the "economic host" (the desirable plant) and one is called the "alternate host." In some cases, such as apple-cedar rust, both hosts are "economic hosts."

Like powdery mildews, rust fungi infect only the plant's aboveground parts, and while rust fungi generally do not directly kill their host plants, severe infections ultimately may lead to death by other factors (winter-kill or other diseases).

The presence of spore pustules is a telltale sign of rust infection. Spores produced in rust pustules can be carried by wind currents up to several hundred miles. Spores also are moved short distances by wind, insects, rain, and animals. Additional symptoms of rust diseases include leaf and stem cankers, stunting, yellowing, galls, and a general unsightly appearance of the infected plant.

Rust fungi may be controlled by the integrated use of several different management practices. Removing infected bedding plants or other annuals will help to reduce spread in the garden. Depending on the host, tolerant varieties may be available. Contact and systemic fungicides may help to reduce or prevent disease. Check product labels for appropriate use of these materials.

Black Spot of Rose. Black spot of rose is a fungal disease caused by *Diplocarpon rosea*. The disease develops in moderate temperatures when moisture is present on the leaf surface. General leaf chlorosis and circular, well-defined, black spots on leaves are the most common symptoms. The disease is similar to powdery mildew in that it overwinters in canes and in fallen leaf debris. The fungus germinates in favorable conditions and is spread to susceptible hosts by splashing water or airborne spores.

Sanitation is important in the controlling black spot. Rake and destroy fallen leaves and prune out infected canes. Look for tolerant varieties if black spot is a common problem in your area. Also some fungicides are registered for control of this disease. Check fungicide labels for complete instructions before using any chemicals.

Verticillium and Fusarium Wilt Diseases. *Verticillium* and some *Fusarium* species are common soilborne fungi that cause wilt diseases in a wide variety of plants. While they are two distinctly different fungi, the types of diseases they cause and the plants they infect are similar. Plants infected with these fungi become chlorotic and eventually wilt. In the case of Verticillium wilt, the plants may exhibit wilt or chlorosis on only one side of the plant. Infected plants also may have root rot. A helpful diagnostic symptom of these vascular wilt diseases is the presence of vascular discoloration (brown streaks in the xylem tissue).

These fungi survive in soil and crop debris. They are spread by soil, water, wind-blown dust, seed, and infected plant material. *Verticillium* species generally are more active at cooler temperatures than *Fusarium* species.

Both of the fungi exist in many different genetic strains (called races) that vary in their aggressiveness and host range. Thus, a plant can be infected with a mild strain and exhibit chronic, mild to moderate symptoms over a long period. Or, a plant can be infected with a severe strain and be killed within one growing season. Additionally, plants known to be tolerant of the fungus may be tolerant of only one race. When these cultivars are planted where a different race of the pathogen occurs, the tolerance doesn't hold up.

If the plant is infected with a severe strain, there is little that can be done to save the plant. If infected with a mild strain, good water and fertilizer management can help to slow disease development and reduce symptoms. However, the plant is still diseased and will eventually become weakened and should be removed and destroyed.

When replanting an area where a plant has died from this disease, it is best to choose plants that are either nonhosts or are known to be tolerant to the disease. Always replant using disease-free seed and planting material. After planting, avoid injury to roots and crown and maintain good strong growth through proper water and fertilizer management.

Fusarium Wilt of Mimosa. *Fusarium* is a soilborne fungus that invades trees through the roots. The fungus typically enters through wounds but also may enter through direct penetration of the roots or plants weakened by abiotic stress. In addition to the typical symptoms listed above, this fungus causes infected mimosa trees to ooze a frothy liquid from cracks and grow sprouts on trunks. Fungal spores produced on the exterior are easily washed off by rain or irrigation and can be moved long distances in surface water runoff. Control depends on sound cultural practices that help to maintain strong, healthy trees. Mimosa trees should not be planted where trees have died from this disease. Some trees tolerant of this fungus include redbud, honey locust, and New Mexico locust.

Phymatotrichum Root Rot. (Only occurs in the southern New Mexico counties of Hidalgo, Luna, Doña Ana, Sierra, Chaves, Eddy and Lea.) Phymatotrichum root rot (also known as Texas root rot or cotton root rot) is caused by the soilborne fungus *Phymatotrichopsis omnivorum* (Po). The fungus has an extremely wide host range that affects more than 2,300 species of dicotyledonous plants. Monocots are not affected, although the fungus has been found to grow and reproduce on some monocots without causing any disease. Po is limited geographically to parts of the United States (parts of Arizona, New Mexico, and Texas) and Mexico. Even within its geographical boundaries, the fungus is spotty in occurrence. The fungus is found in soils that are high in alkalinity and low in organic matter. Spread of the fungus is limited as it does not produce any viable spores but rather it moves through root grafts between nearby plants.

Symptoms first appear during the summer when air and soil temperatures are high. The first evidence of the disease is a slight yellowing of the leaves. The leaves quickly turn to a bronze color and begin to wilt. Permanent wilting can occur very rapidly—as little as two weeks from the first expression of disease. Plants infected with Po die rapidly with the leaves remaining firmly attached. In some cases, the tree wilts so quickly that there is little color change, though the leaves become dry and brittle. A reddish lesion develops around the crown of trees killed by this fungus.

The fungus also produces signs on or near infected plants. Strands of fungal hyphae are produced on the surface of infected roots. These strands usually are visible with a good hand lens. When strands are viewed under a light microscope, cruciform (cross-shaped) hyphae unique to this fungus can be seen. Another sign is the formation of a white to tan colored spore mat on the soil surface around infected plants. Spore mats develop during periods of high moisture and are not always produced in New Mexico. Spores produced in spore mats have never been germinated and are considered to have no function in survival or infection by this pathogen. Therefore, spore mats do not spread disease but are merely evidence of the fungus' presence.

This disease is very difficult, if not impossible, to control. The fungus survives more than 12 feet deep in the soil, reducing the effectiveness of soil treatments, such as solarization and fumigation. The fungus can be kept inactive by altering the soil environment (reducing alkalinity and increasing organic matter). The following treatment must be applied very quickly after the first sign of disease.

Steps to managing Po:

- Heavily prune back infected trees or shrubs.
- Loosen soil underneath the plant to the drip line.
- Cover ground with 2 inches of composted manure.
- Cover manure with ammonium sulfate (1 pound to 10 square feet).
- Cover ammonium sulfate with soil sulfur (l pound to 10 square feet).
- Soak area with water until water penetrates the soil to a depth of 3–4 feet.

Also, treat any adjacent susceptible trees or shrubs even if there are no symptoms.

Keep in mind that soil is a dynamic medium that will revert to its natural properties. As such, the treatment must be repeated each year in order to prevent the disease from recurring. This treatment is no guarantee of control and is expensive and labor-intensive. Avoiding areas known to be infested with the pathogen is the best control measure.

Fungal Leaf Spots. All plants are susceptible to one or more leaf spotting fungi. *Alternaria, Phoma, Phomopsis, Phyllosticta, Colletotrichum* and *Septoria* are common leaf spotting fungi that can occur in New Mexico. Leaf spots are characterized by brown or black spots randomly scattered on leaves. The spots may develop in concentric rings, be surrounded by a yellow halo, or appear darker in the center (due to the presence of fungal fruiting bodies). Leaf spots are favored by high humidity and/or leaf wetness. Spores are spread by rain and wind. Severe infections may cause premature leaf drop, however the fungi do not become systemic inside the host and do not cause progressive disease. Long-term damage to trees and shrubs typically is minimal, unless severe infections occur for several years in a row.

Leaf spots are managed with good sanitation practices —raking and destroying fallen leaves and pruning out overly thick growth. Good pruning practices increase air circulation and decrease humidity in the plant canopy, reducing the factors that favor disease development. Fungicides can be used, but the damage resulting from the fungi typically doesn't warrant their use. Using of chemicals to manage these diseases is not cost-effective.

Sooty Mold. Sooty mold is a term used to describe the black sooty fungal growth on many trees and shrubs. Several different fungi can cause sooty mold. These fungi are not parasitic to the plants they grow on, but they do grow on honeydew produced by insects (aphids, scale, and mealy bugs). Sooty mold is common in warm, humid weather. The fungi appear on leaves, stems, or fruits as a superficial, black growth. The fungi do not penetrate the host tissue and can be wiped off with a damp cloth. Although sooty mold fungi are not pathogenic, they do create a problem when growth of the fungi becomes dense, reducing the amount of light that reaches the green leaves. This reduced light limits the plant's carbohydrate production and weakens the plant's growth. The most effective means of controlling sooty mold is managing the honeydew-producing insects.

Foliar Turfgrass Diseases Caused by Fungi

Powdery Mildew (caused by *Erysiphe graminis*). The most common turf species affected by powdery mildew are bluegrass and fescue. The disease results in large areas of the turf appearing as if they were dusted with powder. The individual plants are infected with isolated colonies of whitish fungal growth, which rapidly enlarges to cover the entire leaf surface. Infected leaves eventually turn yellow, then tan and brown as they die. Older leaves are more susceptible to attack than the young, succulent growth. Dark fungal fruiting bodies called cleistothecia may form in mycelial mats on the leaves' surface.

The fungus survives as mycelium in living, infected plants or as cleistothecia embedded in plants or plant debris. The fungus is spread by airborne spores that can move great distances in air currents.

The disease generally occurs in the spring and fall and is favored by temperatures between 60 and 72° F, high humidity, and cloudy periods. The disease is most severe in shaded areas with poor air circulation.

Rust (caused by several species of rust fungi). All turfgrass species are susceptible to rust fungi. Turfgrass patches infected with rust are thin and weak and tinted red, brown, or yellow. The individual plants exhibits light yellow flecks on infected leaf blades and stems. The yellowish flecks enlarge and become elongate, parallel with the leaf or stem axis. Rust pustules on the surface of infected plants expose colored spores.

Rust fungi survive as mycelium and spores in infected plants or plant debris. The fungi are spread by airborne spores that move short and long distances in air currents.

The disease occurs from spring through fall on grass that is growing slowly under stressed conditions. Disease development is favored by warm (68-86° F) temperatures, low light intensity, and moist leaf surfaces. After infection, disease spreads rapidly with high light intensity, dry leaf surfaces, and high temperatures (above 85° F).

Snow Molds (caused by several different fungi). All turfgrass species are susceptible to at least one type of snow mold. The symptoms vary somewhat depending on the grass species and the fungus, but typical symptoms include spots on large patches, which are yellow, white, gray, brown, or pink.

Snow mold fungi survive as mycelium or fruiting bodies in infected plants or plant debris. They are spread by leaf-to-leaf contact and usually require wet leaf surfaces for infection.

The disease occurs from winter to early spring. Snow molds are associated with low temperatures, frozen soil, snow cover, or several freeze/thaw cycles during the winter. Snow molds also are favored by moisture from snow, frost, rain, and dew.

Snow molds usually are managed by applying fungicides (labeled for the disease) before the first lasting snow and during periods of snow melt.

Foliar and/or Root Turfgrass Diseases Caused by Fungi

Anthracnose (caused by *Colletotrichum graminicola*). All grass species are susceptible to anthracnose. However the disease is most severe on bluegrass and bentgrass. Symptom development depends greatly on the environment. Scattered chlorosis or irregularly shaped chlorotic patches, ranging from an inch or two to a few feet in size, is characteristic of infected turf. Individual plants have water-soaked lesions on the leaves or stems. The lesions eventually turn reddish brown, and the entire leaf turns yellow, then tan to brown as the leaf dies. Tiny black fruiting bodies may appear on infected stems and leaves.

The fungus survives as mycelium in plant debris. It spreads through movement of spores by equipment, people, animals, water, and wind.

The disease occurs any time of the year, but is most severe during the summer months. Disease development is favored by high humidity and leaf wetness. Grass that is under stress, particularly from high temperatures and drought, is particularly susceptible to this disease.

Melting-Out Diseases (*Helminthosporium*-like diseases). Melting-out diseases caused by several different species in the genera *Bipolaris, Curvularia, Drechslera*, and *Exserohilum* are among the most common turf diseases that occur in New Mexico. All turfgrass species are susceptible to one or more of these pathogens. Symptoms of this disease are variable, depending on the fungal species causing the disease. However, some general symptoms include overall thinning or decline of turf followed by irregular patches an inch to a couple of feet in size. It is common for these patches to have many bare spots with exposed soil. The appearance on individual plants can be in the form of brownish green to black lesions; dappled yellow and green patterns on the leaves; or elongated, water-soaked lesions with a yellow halo.

The fungi survive in infected plants or plant debris and are spread through the movement of spores by equipment, people, animals, water, and wind.

The disease occurs from spring through fall. Diseases caused by *Bipolaris* are favored by either wet or dry conditions and temperatures between 68-86° F. *Curvularia* diseases are favored by wet conditions and high temperatures (above 86° F). Drechslera diseases are favored by wet conditions and cool temperatures between 55-65° F.

Fusarium Diseases (caused by *Fusarium* spp.). All turfgrass species are susceptible to disease caused by *Fusarium* species. Diseased turf develops sunken, circular to irregular shaped patches between an inch and 2 feet in size. Patches may develop a "frog's eye" symptom—dead circles with live grass in the center. Individual plants have black to brown "dry rot" of the roots, crowns, rhizomes, and stolens. Infected leaves start out light green in color and rapidly fade to tan. White to pink mycelium develops on infected grass during periods of high temperature and moisture.

The fungi survive as mycelium in infected plants or plant debris. They are spread through movement of spores by equipment, people, animals, water, and wind.

The disease occurs from late spring through summer and is favored by high temperatures and drought stress. Susceptibility increases in grass with excessive nitrogen or unbalanced fertilizer applications.

Pythium Diseases (caused by *Pythium* spp.). All turfgrass species are susceptible to *Pythium* diseases. While the symptoms are somewhat variable, the disease is typified by an overall decline in the turf area. This decline may be gradual or rapid, depending on the environmental conditions. Small areas of declining turf may coalesce to cover large areas. Individual plants have dark, water-soaked lesions. The leaves turn yellow, then tan. Roots of infected plants rot. In the early morning when dew is present, a white, cottony growth may appear on the grass surface.

The fungi survive as oospores in infected plants or plant debris. They are spread by movement of infected plant material by equipment, people, animals, and water. Swimming spores move short distances in water and contribute to the enlargement of individual areas.

The disease occurs anytime during the growing season. Disease development is favored by hot (86-95° F), wet weather with night temperature above 68° F. Susceptibility increases in dense turf and in turf growing in alkaline conditions.

Brown Patch (caused by *Rhizoctonia solani*). This is one of the most common turf diseases in New Mexico. All turfgrass species are susceptible to brown patch. Although the symptoms are highly variable, the disease is characterized by small to large rings or patches of dead grass. Individual plants have small to large, irregularly shaped lesions with a distinct dark brown margin. Infected leaves become chlorotic, then brown with age. Dark brown sclerotia (masses of mycelium with a hard shell) may develop at the base of infected plants.

The fungus survives in soil and in infected plants and plant debris. It is spread by leaf-to-leaf contact and by movement of infected plant material by equipment, people, animals, water, and wind.

The disease occurs from spring through fall and is favored by warm (70-90° F), wet conditions. Dense, highly fertilized, frequently watered grass is more susceptible to the disease.

Root Turfgrass Diseases Caused by Fungi

Summer Patch (caused by *Magnaporthe poae*). Summer patch is common on bluegrass and fescue, but also has been found on ryegrass and bentgrass. It is a common disease on golf greens and is often identified when bluegrass dies and seemingly unaffected bentgrass grows into diseased patches. Before the causal agent, *M. poae*, was identified, the disease was thought to be part of the Fusarium blight complex.

The symptoms first appear as small (1 to 3 inches), circular patches of slow-growing, thinned, or wilted turf. The diseased area may increase in size to 1 to 2 feet in diameter. Affected leaves rapidly fade from grayish green to a light straw color during sustained hot weather. Infected roots, rhizomes, and crowns turn dark brown as they die. Microscopic examination of these tissues reveals a network of sparse, dark brown to black hyphae.

The fungus survives as mycelium in plant debris or perennial host tissue and is spread by aerification and dethatching equipment as well as by transport of infected sod.

Infection occurs in the spring when soil temperatures stabilize between 65 and 68° F. Symptoms develop during hot (86-95° F), rainy, weather or when high temperatures follow periods of heavy rainfall. The disease is more severe when turfgrass is maintained under conditions of low-mowing height and frequent, light irrigation.

Fairy Rings and Slime Molds

Fairy Rings (caused by several species of basidiomycetes). Fairy rings are characterized by circles, rings, or arcs of dark green, faster-growing turf areas. In many cases, the diseased areas die out as the disease progresses, leaving dead areas surrounded by dark green growth. Rings can vary in size during the year and can appear or disappear throughout the growing season. The dark green areas may be surrounded by mushrooms, toadstools, or puffballs that are fruiting bodies of the fungi that cause the disease. These fruiting bodies are excellent signs of the fungi and can be very diagnostic.

The fungi that cause fairy rings live in the soil and decomposing thatch layer. They are spread from one area to another by the movement of infected plant material or infested soil by equipment and wind-blown spores.

The disease occurs from spring to early summer, and the fruiting bodies generally appear in the late summer (during the summer rainy period). The fungi are favored by light-textured soils, low fertility, and drought.

Fairy rings are difficult to control. Fungicides rarely are effective. The affected turf often must be removed, including a significant amount of soil. The area must then be prepared and resodded.

Slime Molds (caused by slime mold fungi). Slime molds are not disease causing agents as they do not penetrate and infect plants. However, they do cause harm to plants by covering the leaf surface and reducing the amount of light reaching the plant surface. Slime molds are pinhead-sized white, gray, or purplish brown fungi, which are slimy in appearance and texture. They appear in patches an inch to 2 feet in diameter during periods of warm, wet weather. They usually disappear within 2 weeks after the favorable conditions are gone. Turf with a thick thatch layer is more susceptible to disease. Slime molds can be washed off plants with a hard stream of water, or swept off with a broom.

Bacteria

Bacteria are single cell microorganisms that lack chlorophyll. They obtain food from living or dead organic matter. Individual bacterial cells are incredibly small and can only be seen using a high powered light microscope. Bacteria reproduce by dividing the cell into two equal parts. Bacteria can divide very rapidly; under the proper environmental conditions one bacterium can produce more than 1 million identical cells in less than 1 hour.

Bacteria enter plants only through wounds or natural openings on the plant surface. Once inside the plant, bacteria multiply rapidly and break down the plant tissue creating a watery mass. Bacteria are only apparent to the naked eye if clumped together to form a colony (bacterial ooze).

Bacteria are spread by splashing rain (waterborne), in soil, in wind-blown dust, by vectors (people, tools, equipment and insects), and infected planting materials (seed, transplants and cuttings). Diseases caused by bacteria generally are favored by high air and soil moisture. Because of this, bacterial diseases are few and somewhat rare in arid regions.

Diseases of Ornamentals and Vegetables Caused by Bacteria

Bacterial Spots and Blights. Bacterial spot and blight diseases affect all aboveground parts of plants: leaves, stems, blossoms, and fruit. A wide variety of ornamentals and vegetables are susceptible to spot and blight diseases. Necrotic, circular or angular-shaped spots characterize spot diseases. In some diseases, the spots are surrounded by a yellow halo and/or dead leaf tissue may fall out of spots leaving holes in the leaf (known as a "shot hole"). Bacterial blights are characterized by a continuous, rapidly advancing death of infected organs.

The bacteria overwinter in infected and healthy tissue, in or on seeds, in plant debris, and in soil. The organism is spread by rain, leaf-to-leaf contact, insects, cultivation, and tools. Water soaking of tissue caused by heavy rains predisposes plants to infection.

Bacterial spots and blights are managed with good sanitation practices—removing and destroying infected plant parts and frequently cleaning tools and other equipment. Copper fungicides and antibiotics can be useful for high-value crops, such as in orchard or nurseries. In vegetable crops, look for tolerant varieties, and rotate crops around the garden.

Fire Blight. Fire blight is a bacterial disease caused by *Erwinia amylovora*. It affects plants in the rosaceae family, most notably apple, pear, rose, pryracantha, photinia and cotoneaster. Infected plants exhibit blighted branch tips that are black and look like they have been scorched by fire. Another symptom is the development of a shepherd's-crook on young, vegetative shoots. The bacterium overwinters in cankers and as symptomless infections in leaf and flower buds. In the spring, the bacterium oozes from infected cankers and is spread by water, pruning tools and insects (primarily bees) to nearby blossoms. Ideal conditions for infection and disease development are rain (or high humidity) and temperatures between 75-85° F.

Cultural practices can be highly effective in managing fire blight. Infected plant parts should be pruned, cutting at least 6 inches below the disease margin (margin between healthy and diseased tissue), and destroyed. When pruning infected plants, it is advisable to dip pruning shears in a 10 percent bleach solution or 70 percent alcohol, or use fire to sterilize tools in between cuts. Succulent, lush growth is more susceptible to infection, thus it is best to avoid overfertilization (especially with nitrogen) and provide adequate, but not excessive water. Copper fungicides and antibiotics can be effective sprays, however timing is critical and improper use can lead to phytotoxicity (from the copper chemicals) or development of resistance in the bacterial population.

Bacterial Canker. Bacterial canker (also referred to as "gummosis") is caused by several different species of bacteria. It affects stems, branches, twigs, leaves, buds, flowers, and fruit. The disease occurs on a wide range of hosts, including stone fruits, apple, pear, lilac, rose, tomatoes, and small grains. Symptoms include splits in trunks or stems, necrotic areas in the woody tissue, and sunken cankers that may be soft, leathery, or scabby in appearance. Some cankers exude a slimy or gummy substance. The bacteria overwinter in perennial cankers, buds, plant debris and in or on seed. The disease is spread by rain, runoff water, cultivation, tools, and infected plant material.

Bacterial canker is best controlled by good sanitation practices. This includes pruning and destroying infected plant parts and maintaining strong, but not excessively vigorous growth. Avoid planting any material that is suspicious in appearance. Copper fungicides or antibiotics may help reduce spread when many similar plants are in close proximity (home orchards). Caution should be taken in using copper fungicides, because improper use may lead to plant injury and effective use depends on proper application timing.

Crown Gall. Crown gall, caused by the soilborne bacterium *Agrobacterium tumefaciens*, has a wide host range among woody and herbaceous plants. The bacterium enters roots or stems near ground through wounds created by cultural practices and insects. The bacterium also can infect plants above the crown by pruning with infested cutting shears.

Once inside susceptible hosts, the bacterium stimulates host cells to enlarge, causing tumorlike galls to develop. The galls impede water and nutrient movement in the plant. Reduced transport of water and nutrients causes chlorosis, stunting, slow growth, and a general decline in the plant's health. Some plants infected with crown gall will continue to grow seemingly unaffected, while others decline over time until they have to be removed.

Once infected, there is little that can be done to help the plant other than providing adequate water and nutrients. Well-managed trees are less likely to go into a rapid decline. When planting susceptible hosts, use disease-free nursery stock. Avoid injury to roots and crown at planting and during cultivation of turf or other plants nearby.

Slime Flux. Slime flux, also known as bacterial wetwood, is a disease that can be caused by several different species of bacteria. The bacterium enters the plant through wounds or natural growth cracks. Fast- growing trees, like willow, elm and cottonwood, are particularly susceptible. Once inside the tree, the bacteria raise the internal gas pressure in the tree. As a result, the bacteria is forced back out of the tree in the form of an ooze. The ooze flows down the trunk or affected limbs. It first causes the bark to appear moist (thus the name wetwood) and eventually dries to a whitish color. The slime is toxic to the bark and to plants growing under the tree.

Once trees are infected, there is no cure. Proper water and fertilizer will help to reduce the affect of the bacteria and to minimize the amount of slime that is produced. The slime can be washed off the tree, reducing the toxic effects. However, care must be taken to avoid washing the slime onto other plants. These management tactics may slow the activity of the disease, however infected trees become progressively weaker over time and will eventually become hazard trees.

Viruses and Viroids

Viruses consist of nucleic acid, either ribonucleicacid (RNA) or dioxyribonucleicacid (DNA), surrounded by protein (coat protein). Viroids consist only of nucleic acid (RNA only). Both are so tiny they can only be seen with an electron microscope. They do not carry out respiration, digestion, or other metabolic functions, so they are technically not living organisms. Viruses and viroids cannot grow or multiply outside the host cell, but cause the plant to transform host plant components into more virus or viroid particles.

Viruses and viroids are transmitted from one plant to another by vectors (so they are biotic disease agents). Common vectors include people, insects, budding, grafting, nematodes, fungi, seed and/or pollen. The virus or viroid particles enter plants through wounds created by the vector.

Symptoms of these types of diseases are nonspecific and can look like symptoms caused by many other disease agents. General symptoms include stunting, yellowing, curling or twisting of leaves and stems, distorted leaves and fruit, mosaics, mottles, and ring spots.

Diseases of Ornamentals and Vegetables Caused by Viruses

Tobacco Mosaic Virus. Tobacco mosaic virus is one of the most common plant viruses in the world. It has an extremely wide host range, including tobacco, tomato, pepper, potato, cucurbits, lettuce, spinach, bean, pea, grapes, apple, dahlia, salvia, petunia, spruce, and many other ornamentals and weeds. Symptoms are variable, depending on the host plant and include leaf mosaic or mottle, blistering, yellowing, stunting, and overall plant deformity. In some cases, plants are infected, but they show no symptoms. These plants are symptomless carriers of the virus and can be a source of virus spread to healthy plants. Some plants exhibit very mild symptoms, while others become severely deformed. No insect vector has been shown to transmit the virus, but the virus is very easily transmitted by mechanical means (sap transmission). Thus, infected cutting tools and contaminated hands are the two most common ways tobacco mosaic virus is spread from plant to plant. Sanitation is the primary means of controlling the virus. The virus can be transmitted from cigarettes to plants on smokers' hands. Therefore, smokers should thoroughly wash their hands before working with plants and should not smoke while working.

Rose Mosaic Virus. Rose mosaic irus occurs worldwide. The symptoms are highly variable, depending on the variety and the environment. However chlorotic bands or rings, vein clearing, and general mosaics are common. Symptom development on only a portion of a plant is common. Infected plants have decreased vigor, poor flower production, and are more susceptible to winter-kill. The virus is transmitted through vegetative propagation and pollen. There is no control for a plant infected with the virus. Infected plants should be removed and destroyed.

Beet Curly Top Virus. Beet curly top virus is common in arid and semiarid regions on a wide host range, affecting more than 300 plant species. The virus is transmitted (vectored) by the beet leafhopper (*Circulifer tenellus*). Some of the more common hosts include tomatoes, peppers, cucurbits, potatoes, beans, spinach, geranium, nasturtium, petunia, stock, and zinnia. Weeds are important survival hosts for the virus and the vector. Weed hosts include Russian thistle, sow thistle, London rocket, pigweed, purslane, knotweed, and lamb's-quarter.

Symptoms vary somewhat depending on virus strain and host plant, yet there are some common characteristics among infected plants; including overall chlorosis, curling of leaves, thickening of leaves and stems, stunting, deformed fruit, and reduced fruit production. On some hosts, such as tomato and pepper, leaf veins on the underside of the leaves may turn purple. Although viruses usually do not kill their host plants, young seedlings attacked by the virus may die.

Beet leafhoppers are the only means of disease transmission. Leafhoppers feeding on infected plants will rapidly (1 minute) acquire the virus. The virus then circulates through the insect and can be transmitted to a susceptible plant after as little as 4 hours. The leafhopper then remains infective for the rest of its life, although the effectiveness of transmission is decreased when the insects do not continually feed on infected plants. The virus is not passed on to progeny. However, young leafhoppers that develop on infected hosts will quickly become carriers of the virus. As far as is known, the virus has no negative or positive affect on the insect. Leafhoppers overwinter in winter weeds. Mild winters, which allow for significant leafhopper survival, and large winter weed populations are two important factors in beet curly top virus epidemics.

There are no chemicals available for the control of viruses, but several cultural practices can help to reduce or eliminate infections. Good sanitation practices, including weed and insect control and removing infected or suspect plants, are essential to limiting the disease occurrence. Home gardeners also may consider planting susceptible hosts, such as tomatoes and peppers, in a slightly shaded part of the garden, as leafhoppers prefer to feed in sunny locations. However, even shaded plants will become infected when leafhopper populations are high. Placing netted cages over susceptible hosts (particularly when young) may help to prevent infection. The netted material should be small enough to prevent leafhoppers from getting through the material. It also is important that the cages be large enough that the plants do not touch the netting. When plants mature, the cages should be removed. At this stage, the plants are less susceptible to the virus. There is little tolerance known to the virus in commercial varieties. However, this is an active area of research, and new varieties may soon be released that possess a level of resistance to the virus or the leafhopper.

Tomato Spotted Wilt Virus. Tomato spotted wilt virus is an important disease of many vegetables and ornamentals in temperate and subtropical regions of the world. In New Mexico, it is particularly troublesome in greenhouses but can easily move to gardens on infected plant material or be carried by its vector (thrips). The virus has a tremendously wide host range, including tomatoes, peppers, celery, lettuce, spinach, potatoes, peanuts, begonias, geranium, nasturtium, impatiens, petunia, snapdragons, verbena, stock, and statice. Like beet curly top virus, tomato spotted wilt virus has many weed hosts that help it survive from one season to the next. Common weed hosts include curly dock, field bindweed, lamb's-quarters, pigweed, morning glory, jimsonweed, and nightshade.

Symptoms of the virus are numerous and varied. Some fairly characteristic traits of infected plants are bronzing and yellowing of leaves, leaf spots, distorted leaves, and petioles curl downward creating a wiltlike symptom although the plants retains their turgor pressure. Other symptoms include dieback of the growing tips and dark streaking of the terminal stems. Infected plants may develop a one-sided growth habit or may be completely stunted. Infected plants produce little or no fruit. Fruit that is produced exhibits symptoms, such as necrotic streaking, raised bumps, chlorotic spots or ring spots, uneven ripening, and deformation.

The virus is transmitted from infected to healthy plants by at least nine thrips species. Thrips transmit the virus in a persistent manner, which means that once the insect acquires the virus it can transmit the virus for the remainder of its life. The virus is not passed from adult to egg. However, progeny that develop on infected plants will quickly pick up the virus and become effective disease vectors.

Controlling the disease is difficult. The wide host range, which includes perennial ornamentals and weeds, enables the virus to successfully overwinter from year to year. In landscape situations, controlling thrips does not translate into reduced disease. This is probably due to the fact that large populations of thrips may fly or be blown into treated areas from nontreated areas nearby. Controlling thrips is somewhat more effective as a disease control measure in greenhouses. Control may be with pyrethroids, carbamates, chlorinated hydrocarbons, organophosphates, and insecticidal soaps. However, great care should be taken to avoid repeated use of any one chemical, as thrips in the treated population may rapidly build resistance to the material. Rotating the insecticide class is the best approach to insect control. Pesticide registrations are changing constantly, so it is important to read the label for legal uses and follow all label instructions carefully. In greenhouses, thrips populations may be reduced by covering all openings (doors, vents) with a fine mesh (400 mesh) screen.

While eliminating the disease may not be possible, the incidence and severity of the disease may be reduced by several cultural practices. It is important to start with virus-free plants. Do not purchase or plant anything that exhibits symptoms such as described above. Remove any infected or suspect plants from the greenhouse, garden, or landscape. Control weeds. Efforts are underway to breed cultivars with good horticultural characteristics that also exhibit tolerance to the virus.

Nematodes

Nematodes are microscopic, nonsegmented worms. They are filamentous in shape. However, females in some species may become swollen at maturity and exhibit round or pear-shaped bodies. Plant parasitic nematodes have a hollow stylet that penetrates plants cells. This stylet is visible under a light microscope and sometimes under a dissecting scope. Nematodes have well-developed digestive and reproductive systems.

Nematodes are placed into different classifications based on how they live their lives. For example, ectoparasitic nematodes live freely in soil, do not enter plant tissue, and feed superficially on roots. Migratory endoparasitic nematodes live freely in soil, enter plants and move through plant tissue feeding internally. Sedentary endoparasitic nematodes have a free-living juvenile stage, but as adults they attach to the root and feed in one location.

All nematodes live at least part of their life cycle in soil. Nematodes can move slowly in moisture film surrounding roots and soil particles, but long distance spread is achieved by the movement of soil. Thus, soil in irrigation water, on animals, on equipment, and plant material can spread nematodes from one location to another.

Diseases of Ornamentals, Vegetables and Turfgrass Caused by Nematodes

Root-Knot Nematode. Root-knot nematodes (*Meloidogyne incognita*) can be a serious pest in home gardens and field-grown crops. The pest is most serious in warm, light soils. Root-knot nematodes have an extremely wide host range (more than 2,000 species) that includes most vegetables, many cereals and field crops, some trees, and weeds.

The severity of symptoms depends on the host, the nematode and the age at which the plant was infected. Younger plants are more severely damaged than mature plants. Aboveground symptoms are not unique, and in fact may be reminiscent of diseases caused by many other pathogens and abiotic disorders. Common aboveground symptoms include stunting, chlorosis, wilting (particularly during the heat of the day), and reduced yield. Roots of infected plants exhibit characteristic galls and may be distorted. These galls usually are visible with the unaided eye, and can clearly be seen with a hand lens or dissecting microscope. The size and number of galls depends on the type of host, the age of infection, and the nematode population. Because nematodes are sensitive to soil type, damage may be "spotty" rather than uniform across a field or garden.

Root-knot nematodes live in soil as eggs and juveniles, and in plants as adults. Juvenile nematodes invade roots of susceptible hosts. Once inside the host root, the nematodes swell and become pear-shaped, disrupting the developing root tissue. As the nematodes feed on root cells, the cells enlarge creating what are called "giant cells." It is the formation of giant cells and the presence of the nematodes in the roots that creates the characteristic root galls. Female nematodes lay their eggs (200-500 per female) in a gelatinous matrix on the outside of the root. Eggs hatch in the soil, and new juvenile nematodes invade other roots. During favorable conditions, the life cycle of this pest is completed in about one month, so there may be up to four or five generations per season. Therefore, populations can build up in soils very rapidly.

Several management practices can be used to reduce nematode populations. Never plant transplants that exhibit nematode galling (remember that legumes form root nodules for nitrogen fixations which may look similar to small nematode galls). Avoid areas known to be heavily infested with nematodes. Crop rotation may be helpful, but the wide host range of the pest limits its effectiveness. There are registered chemicals that can be used to control nematodes. However most are soil fumigants that can only be used prior to planting and are "Restricted Use Materials," which means they must be purchased and applied by a licensed pesticide applicator. Some success controlling nematodes has been had in relatively small areas by incorporating soil amendments that contain crushed seashells. The seashells are made of chitin, which is the same protein that makes up the nematodes exoskeleton. The adding of chitin to the soil stimulates beneficial soil microbes that degrade chitin. This increase in beneficial organisms helps to reduce the nematode population by destroying the nematodes' cell wall. Additionally, one year of weed-free fallow may reduce nematode populations significantly. The key is that the ground must be kept weed-free, as many weeds are important alternate hosts for the nematode.

Turfgrass Nematodes. Plant parasitic and saprophytic nematodes are components of every turfgrass ecosystem. The importance of these microscopic worms in the overall health of the turf varies, depending on the type of nematode, the nematode population, and the environment. While some nematodes can be beneficial in controlling some pests, others can cause serious diseases in turf. Nematodes are more likely to cause disease in warm temperate or subtropical regions, although disease can occur in cooler regions as well.

Nematode injury might appear as areas of low fertility, even when adequate fertilizers have been applied. Symptoms will be slight to severe chlorosis, declining growth, gradual thinning, wilting, and in severe cases, death. Turf that is under stress, particularly from high heat, drought, low fertility, or excessive thatch, is more susceptible to nematode injury.

Chemical treatment with a nematicide is available to professional sod growers, nursery operators, and professional pesticide applicators.

Parasitic Higher Plants

Parasitic higher plants are flowering plants that live off other plants. True and dwarf mistletoes and dodder are examples of parasitic plants.

Mistletoes have chlorophyll but no roots and, thus, rely on host plants for water and nutrients. True mistletoes parasitize hardwood trees, such as cottonwoods, elms, oaks, and locusts. This pathogen is disseminated by birds, which feed on the seed-baring mistletoe berries. Dwarf mistletoes attack conifers and are important pathogens in conifer forests. Dwarf mistletoes forcibly discharge, their seeds and are disseminated by wind currents.

Dodder has no chlorophyll and no true roots. It depends on a host for water, nutrients, and carbohydrates. Dodder is a soilborne, vinelike plant that twines around its host. It is mostly a problem in agricultural fields but can be troublesome in home gardens and landscapes, particularly in newly developed areas that were once used for agriculture.

Abiotic Disorders (Noninfectious Agents)

Nutrient Deficiencies

Nutrient deficiencies occur when essential elements are not available in the required amount. The effect on plants depends on the host plant and the element(s) that is deficient. Some general symptoms include stunting, chlorosis, small leaves, malformed leaves, poor root growth, weak plant growth, and poor turfgrass stand establishment. The following are some common nutrient deficiency descriptions:

- **Nitrogen**: slow growth, stunted plants, and chlorosis (particularly older leaves).
- **Phosphorus**: slow growth, stunted plants, purplish foliage coloration on some plants, dark green coloration with tips of leaves, delayed maturity, poor fruit or seed development.
- **Potassium**: leaf tips and margins "burn," starting with the older leaves, weak stalks, small fruit, and slow growth.
- **Iron**: interveinal chlorosis of young leaves (veins remain green except in severe cases), twig dieback.
- **Zinc**: decrease in stem length, rosetting of terminal leaves, reduced bud formation, interveinal chlorosis, dieback of twigs (if deficiency lasts more than one year).
- **Magnesium**: interveinal chlorosis in older leaves, curling of leaves upward along margins, marginal yellowing with green "Christmas tree" area along midrib of leaf.
- **Calcium**: death of growing points (terminal buds and root tips), abnormal dark green, premature shedding of blossoms and buds, and weak stems.
- **Sulfur**: light green color of (mostly) young leaves, small and spindly plants, slow growth, delayed maturity.
- **Manganese**: interveinal chlorosis of young leaves—

gradation of pale green coloration with darker color next to veins. No sharp distinction between veins and interveinal areas as with iron deficiency.

- **Boron**: death to terminal buds, thickened, curled, wilted and chlorotic leaves, reduced flowering, and improper fertilization.

Soil availability of nutrients is influenced by soil characteristics. The pH of the soil has a profound effect on nutrient availability. For example, iron, though plentiful in the soil, is mostly unavailable to plants in alkaline soils (pH above 7.5). Likewise, phosphorus, manganese, copper, and zinc also are less available in alkaline soils. Boron, which is needed by plants in very small amounts, is almost completely unavailable at pH between 7.5 and 8.5. A soil pH between 6.5 and 7.5 gives a maximum availability of the primary nutrients (nitrogen, phosphorus and potassium) and a relatively high degree of availability of the other essential elements. Unfortunately, much of the soil in the Southwest is alkaline.

Some elements, such as nitrogen, are readily leached through the soil and therefore need more frequent application for an adequate supply. Additionally, the relative amounts of different elements affect nutrient availability. The excesses of certain nutrients may result in the plants' inability to take up another essential element.

Soil tests are needed to determine the base nutrient content and other important soil characteristics. The results of a soil test will help determine the type and amount of fertilizers needed for different plants. Nutrient toxicities can occur with overfertilization or with improper fertilizer application. In most cases, applying a balanced fertilizer with essential micronutrients is beneficial to plant growth. In some areas, additional foliar applications of some micronutrients, such as iron, might be needed to keep plants green.

Pesticide Injury

All pesticides, if used inappropriately, can be toxic to plants. In most cases, damage results from improper application or from pesticide drift. Failure to thoroughly clean spray equipment also can result in injury to nontarget plants.

Common symptoms of pesticide injury include leaf burn, leaf distortion, chlorosis, flattened or enlarged stems and roots, and plant death. Symptom type and severity depend on the type of pesticide and the concentration of the chemical. In turf situations, damage appears in patterns associated with the chemical application.

When any pesticide is used, it is imperative that the material be applied carefully and in accordance with the pesticide label. It also is important to avoid spraying on windy and/or hot days.

Temperature Extremes

Temperature extremes, both high and low, can cause injury to plants. High temperature results in excess transpiration, wilting, heat stress, and sunscald. The plants are unable to cool themselves by evapotranspiration. In turf, heat stress is intensified by objects covering blades, high humidity, dry soil, and lightning strikes.

Low temperature injury causes leaf epidermal cells to separate from underlying tissue, giving the affected tissue a silvery appearance. The affected herbaceous tissue will wilt and turn black. On trees, frost or freeze damage results in splits and cracks in trunks branches and twigs, eventually causing cankers to develop. These cankers become entry sites for secondary organisms, such as fungi and bacteria.

Salt Injury

Salt injury occurs when the plant takes up excessive salts from either the soil or the irrigation water. Damage results from a loss of feeder roots. Symptoms include marginal necrosis; and leaf, stem, and twig necrosis. Salt injury often is seen in association with heat and water stress.

Light Extremes

Light affects germination, growth, and shape of plants. Lack of light causes etiolation (elongation) between nodes and results in poor color. Excess light can result in sunburned foliage or fruit.

Water Excess

Excess soil moisture results from excess irrigation, rainfall, or poor soil drainage. These soils have reduced oxygen levels, which inhibit plant growth.

Plants may be chlorotic, have small or thin foliage, and have numerous dead or dying roots. Roots may die from a lack of oxygen or from soilborne fungi favored by high soil moisture. The final result may be plant death. Chronically wet soils may become black in appearance and have a foul odor.

Water-soaked, aboveground plant parts are predisposed to many diseases. Additionally, excessive moisture on the foliage favors many foliar diseases that require either free water or high humidity for germination and infection.

Drought Injury

Drought injury results from a chronic lack of water. Affected grasses turn bluish and the leaves curl before turning brown. Shrubs and trees wilt in the afternoon and recover at night until they wilt permanently. New foliage is small and pale in color. Plant growth is restricted, and plants are more susceptible to heat stress.

Wind and Sand Injury

Wind injury results from excess air movement. Damage is more severe if temperatures are high. Plants become desiccated and may become radically altered in shape due to the winds directional force. Leaves become tattered either from the force of the wind whipping the foliage around or from wind-blown sand. Wind may lead to problems associated with wind-blown pathogens.

Hail Damage

Hail causes necrotic spots on foliage and fruit. Severe hail may cause holes in leaves or leaves to become tattered. Hail striking the crown of young plants can cause plants to fall over and die.

Air Pollution

Air pollution, which results from a lack of sufficient air currents, can cause problems on many different types of plants. Combustion of fuels, auto exhaust, coal burning, and the interaction of sunlight and nitrogen oxides create different air pollutants. The common major pollutants are nitrogen oxides, ozone, hydrocarbons, peroxyacetyl-nitrate (PAN), and sulfur dioxide.

Symptoms of air pollution vary somewhat depending on the type of pollutant. However, common symptoms include flecking of upper leaf surface, bronzing of the lower leaf surface, and interveinal bleaching. Damage may be invisible.

Improper Cultural Practices

Management Practices that Impact the Health of Ornamentals

Planting. One of the keys to growing and maintaining healthy plants is to get the plants off to a good start. Gardeners should start with disease-free planting material that is strong and vigorous. The plants should then be planted in a good location, according to the needs of the plant. For example, sun-loving plants should not be planted in the shade and vice versa. Other important factors, which impact the initial health of the plant, include planting at the right time of year; preparing the soil, planting hole, and root ball properly; and then planting the plant at the right depth. Improper planting can result in plant death, but the plants can die anywhere from shortly after planting to several years later.

Irrigation. Water is the most important component for growing plants. All plants need water. But there is a line between adequate water and too much water. Ironically, the symptoms and damage to the plant are the same for drought and excess water. Some important considerations with respect to irrigation include the timing and frequency of application, the amount applied, the application method, and the water quality.

Fertilization. Fertilizer is important in maintaining strong, vigorous plants. Plants need to be fertilized according to their needs. One of the most important factors is the selecting the proper fertilizer. Consider the macronutirent ratio, the presence or absence of micronutrients, and the formulation (water-soluble, granular, slow-release, foliar sprays). Timing and application frequency are also important factors.

Cultural Practices. Other cultural practices that impact overall plant health include pruning, sanitation (removal of debris, clean tools, etc.), weed and insect control, staking, mulching, and cultivation.

Cultural Management of Turfgrass

Turf diseases are best controlled with good management of the turfgrass. For maximum disease control, turfgrass should be maintained at a moderate growth rate. Turf that is very lush or under stress is more susceptible to disease than turf that is grown at a moderate pace. Management practices include irrigation, fertilization, mowing, and dethatching (aeration).

Water. Turfgrass is best watered in the early morning. This allows for efficient use of the water and for the grass blades to dry before nightfall. Water thoroughly so that water penetrates several inches into the soil. It is better to water less frequently and for longer periods than to water frequently for short periods.

The amount of water needed will vary depending on the time of year and the weather conditions. You can determine the amount of water to apply with each irrigation by placing a few empty food cans in various locations on the lawn. Turn on the sprinklers for a designated amount of time. After irrigation, measure the amount of water that has accumulated in the cans. This shows how much water in inches that were applied in that specified amount of time. You can then adjust the duration of irrigation to provide the desired amount of water.

Fertilizer. Using slow-release nitrogen fertilizers can help reduce the rapid flush of lush growth after fertilization. Slow-release fertilizers release nitrogen slowly over a long period of time. This avoids disease problems that may by associated with large amounts of nitrogen available all at one time. Fertilization is best applied in split applications during the growing season.

Mowing. The practice of mowing creates problems with diseases by damaging the turf (the cut) and by altering the carbon/nitrogen ratio in the plant. However, mowing is an important practice in turf maintenance. Thus, efforts should be made to lessen the impact of mowing on the grass. Grass should be mowed as high as is practical for the use of the turf. Low mowed or scalped grass plants are more susceptible to diseases. Be sure that your mower blades are sharp and that they are making nice clean cuts on the grass blades. Dull mowers tear or shred leaf blades, leaving the jagged tips of injured leaves straw colored. Overall appearance of turf is ragged and grayish in color. In addition to poor appearance, the jagged cuts made by dull blades are more attractive to many disease organisms. Scalping injury (mowing grass so short that yellow or brown stem tissue is exposed) is caused by infrequent mowing, weedy grass areas, and uneven areas. Scalping weakens turf plants, making them more susceptible to diseases.

When grass is mowed properly, the clippings can be left on the lawn surface. This helps with the overall balance of nutrients and microorganisms in the thatch and soil. If grass is mowed infrequently, clippings should be removed because the large amount of clippings will mat on the surface of the lawn reducing the amount of water and air penetration to the soil and causing heat stress to the grass immediately under the clippings.

Dethatching and Aerification. Thatch is the layer just below the grass blades and above the soil. It is made up of decomposing grass plants—leaves, shoots, rhizomes and roots. A small amount of thatch is desirable. However, if more than 3/4 inch of thatch accumulates, it impedes water penetration and can cause detrimental effects to the grass. Roots tend to grow in the thatch layer instead of the soil, increasing risk of drought or high temperature damage. Excessive thatch is caused by keeping turf too wet or too dry, high soil acidity or alkalinity, high nitrogen fertilization, and repeated pesticide applications.

Thatch accumulation is controlled by periodically aerating of the grass. Aeration is achieved by poking holes in the lawn, vertical mulching, slicing, or power raking. Lawns should be aerated at least once a year, twice a year for turf exposed to heavy traffic.

Benefits of aeration include improved exchange of air and water, reduced water runoff, water penetration/retention in the soil, increased root/shoot growth, improved drainage, reduced thatch, and disease and insect control.

Fungicides for Turf Disease Control. Several broad-spectrum and disease-specific fungicides are available to help manage turf diseases. It is important that the disease be identified as best as possible to help in selecting the proper chemical. Only use registered fungicides and only when absolutely necessary, because repeated fungicide application will reduce the chemical's effectiveness as the fungal population may become resistant. Keep in mind that fungicides typically do not kill the fungus, they stop the activity of the fungus and allow the turf to get a head start on filling in the diseased areas. However, if conditions that initiated the disease problem reoccur, repeat treatment may be necessary.

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