MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #331

Plant Pathology

Outline:

Introduction

A plant disease is usually defined as abnormal growth and/or dysfunction of a plant. Diseases are the result of some disturbance in the normal life process of the plant.

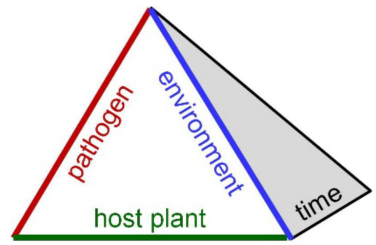
Diseases may be the result of living and/or non-living causes. ***Biotic*** diseases are caused by living organisms (e.g., fungi, bacteria, and viruses). ***Abiotic*** diseases are caused by non-living environmental conditions, (e.g., soil compaction, wind, frost, soil salt damage, and girdling roots).

Plant Disease Pyramid

Specific conditions must be present for biotic disease to develop. There must be a susceptible host plant, the pathogen (fungi, bacteria, viruses, etc.), and environmental conditions conducive to disease development; these must come together in a given point in time. These conditions make up what is called the ***Plant Disease Pyramid***. Biotic disease cannot occur if one of these pieces is missing. [Figure 1]

Environmental Conditions – Weather plays a large role in fungal disease development. Most fungi require free water or specific levels of humidity or moisture for prolonged periods of time to develop. Dry climates are not conducive to their survival. The Rocky Mountain region has fewer fungal diseases than many other parts of the United States due to climatic differences. However, gardens and other microclimates may have conditions ideal for disease development due to poor air circulation, shade, high humidity, and high moisture.

Figure 1. Plant Disease Pyramid



Symptoms

Symptoms of disease are the plant's reaction to the causal agent. Plant symptoms include:

- **Blight –** A rapid discoloration and death of twigs, foliage, or flowers.
- **Canker** – Dead area on bark or stem, often sunken or raised.
- **Chlorosis** – Yellowing – Chlorosis is so generic that without additional details diagnosis is impossible.
- **Decline** – Progressive decrease in plant vigor.
- **Dieback** – Progressive death of shoot, branch, or root starting at the tip.
- **Distortion –** Malformed plant tissue
- **Gall** or **gall-like** – Abnormal localized swelling or enlargement of plant part. It could be caused by insects, mites, diseases, or abiotic disorders.
- **Gummosis** – Exudation of gum or sap.
- **Leaf distortion** – The leaf could be twisted, cupped, rolled, or otherwise deformed.
- **Leaf scorch** – Burning along the leaf margin and into the leaf from the margin.
- **Leaf spot** – A spot or lesion on the leaf.
- **Mosaic –** Varying patterns of light and dark plant tissue
- **Necrosis** – Dead tissue – Necrotic areas are also so generic that without additional details diagnosis is impossible.
- **Stunting –** Lack of growth
- **Wilt** – General wilting of the plant or plant part.
- **Witches broom** – Abnormal broom-like growth of many weak shoots.
- **Insect feeding injury** is also a symptom used in diagnosis, but not a symptom of disease.

Even though a plant has symptoms on a specific part, it does not necessarily mean the damaged tissue contains the organism causing the symptoms. For example, a root rot can cause chlorosis and wilting of stems and leaves, but the disease causal organism is in the roots. It is imperative to examine as much of the plant as possible to determine exactly where the problem is originating.

Signs

Signs are the actual organisms causing the disease. Signs include:

- **Conks –** Woody reproductive structures of fungi
- **Fruiting bodies** – Reproductive structures of fungi; could be in the form of mushrooms, puffballs, pycnidia, rusts, or conks.
- **Mildew–** Whitish growth produced by fungi, composed of mycelium
- **Mushrooms –** Fleshy reproductive structures of fungi
- **Mycelium –** Thread-like vegetative growth of fungi.
- **Rhizomorphs** – Shoestring-like fungal threads found under the bark of stressed and dying trees caused by the *Armillaria* fungi. They may glow!
- **Slime Flux** or **Ooze** – A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.
- **Spore masses –** Masses of spores, the "seeds" of a fungus
- **Insects** and/or their **frass** (excrement) are also signs, although not signs of disease.

Biotic Disease

Biotic causes of disease include fungi, bacteria, viruses, phytoplasmas, nematodes, and parasitic plants.

Fungi

Fungi are organisms that are classified in the kingdom "Fungi". They lack chlorophyll and conductive tissue. Until a few years ago, fungi were considered lower forms of plants, but today are classified as a group by themselves. Because fungi cannot manufacture their own food (due to lack of chlorophyll), they must obtain it from another source as either a **saprophyte** or **parasite**. Most fungi encountered are saprophytic (feed on decaying organic matter). The parasitic fungi, those that derive their sustenance from living plants, are the group of interest in plant health. In dry climates like Colorado, fungi are the most frequent causes of plant diseases.

A fungus "body" is a branched filamentous structure known as ***mycelium***. One single thread is called a hypha (hyphae, plural). Most fungi reproduce by spores, which are structures that contain little stored food (unlike seed). Spores are the main dispersal mechanism of fungi and can remain dormant until germination conditions are appropriate. Many fungi over-winter as fruiting structures embedded in dead plant tissue.

When a spore comes into contact with a susceptible plant, it will germinate and enter the host if the proper environmental conditions are present. Hyphae develop from the germinated spore and begin to extract nutrients from host plant cells. The hyphae secrete enzymes to aid in the breakdown of organic materials that are ultimately absorbed through their cell walls. Fungi damage plants by killing cells and/or causing plant stress.

Fungi are spread by wind, water, soil, animals, equipment, and in plant material. They enter plants through natural openings such as stomata and lenticels and through wounds from pruning, hail, and other mechanical damage. Fungi can also produce enzymes that break down the cuticle (the outer protective covering of plants).

Fungi cause a variety of symptoms including leaf spots, leaf curling, galls, rots, wilts, cankers, and stem and root rots. Fungi are responsible for "damping off" symptoms associated with seedlings.

Damping Off

Damping off is the fungal infection of seeds or seedlings that leads to death. When infected with damping off, seeds may fail to germinate. In other situations, seedlings develop but eventually fall over and die. An examination of stems at the soil line reveals a discolored, "pinched in" appearance. Most plants are susceptible to damping off because of the soft immature nature of seedling tissue that is more susceptible to infection.

The best method to manage damping off is to avoid it in the first place. For starting seeds indoors, use pasteurized soil or planting mix and ensure that plants receive optimum light, water, and heat for rapid germination and growth. In home situations, damping off frequently develops due to poor lighting and overwatering. These conditions stress plants and make conditions optimal for the development of the soil-borne organisms that cause damping off.

In the garden, plant seeds at appropriate times (correct soil temperature for rapid germination) for the crop and avoid overwatering for optimal germination and growth. A strong healthy plant is better equipped to fight off infection.

Scientists continue to study the role of hyperparasites (parasites of parasites) in disease management. Several biological pesticides have been developed from naturally occurring hyperparasitic fungi and bacteria. The organisms protect plant roots against invasion by harmful soil pathogens. These biological pesticides must be applied prior to the development of damping off so the beneficial organisms have time to grow and colonize roots. They cannot be used as "rescue" treatments.

Leaf Spots

One of the most common fungal plant symptoms is leaf spotting. Leaf spot symptoms are caused by many different fungi. Generally, fungal leaf spots possess a distinct dark brown or red margin between the interior (dead) and exterior (healthy green) tissue called a *border* or *margin*. (Figure 2).

Fungal fruiting structures (reproductive structures) are usually embedded in the dead interior. Frequently, a "halo" of yellow or red color develops around the border. A halo indicates recently killed tissue that will eventually die. Because of the cycle of killing tissue and creating a border, then killing more tissue and creating another border, many fungal leaf spots take on a target-like appearance.

To confuse matters, a series of drought events can cause damage that exhibits alternating light and dark bands. Additionally, fruiting structures may not be obvious in dry climates like Colorado. To positively identify a fungal leaf spot, it is best to either culture tissue from the sample or look for spores under a compound microscope.

Figure 2. Cedar knot gall rust is a common leaf spot with a colorful border.

Examples of common leaf spot diseases in Colorado include *Marssonia* and *Septoria* leaf spots of cottonwoods and aspen, ink spot of aspen, and early blight of tomatoes and potatoes.

Powdery Mildew

Powdery mildew is one of the most common diseases in dry climates like Colorado. General symptoms include a white or grayish powdery growth on leaves. It thrives in warm dry climates, often explodes in small yards with limited air movement, and in the fall as nighttime humidity rises. [Figure 3]

Figure 3. Powdery Mildew

There are many species of mildew fungi, each being host-specific. In Colorado, for example, it is common on ash, lilac, grapes, roses, turfgrass, vine crops (cucumbers, melons, and squash), peas, euonymus, cherry, apple, crabapple, pear, Virginia creeper, and others.

Management is centered on a variety of cultural techniques. Avoid crowding plants as the lack of air circulation favors powdery mildew. Select resistant varieties where possible. Avoid late-summer application of nitrogen fertilizer as it may push growth of tender young leaves that are more prone to mildew. Avoid overhead irrigation as it raises relative humidity. Remove and destroy infected plant parts. A variety of fungicides found in the home garden trades are effective against powdery mildew.

Cankers

Cankers are discolored, sunken areas found on plant stems, branches, and trunks. They damage plants by killing the conductive tissue and girdling the plant. Cankers may be caused by fungi, bacteria, virus, and abiotic disorders such as sunscald and hail (Figure 4).

Figure 4. Canker at base of honeylocust

Fungal cankers contain fruiting structures embedded in the discolored canker. Plants with cankers may exhibit branch dieback, leaf loss, and/or poor growth above the damaged area.

Common fungal cankers in Colorado are *Cytospora* (*Cytospora* sp.) and *Thyronectria* (*Thyronectria* sp.). Common bacterial cankers in Colorado include fireblight (*Erwinia amylovora*).

Root Rots

Root rots damage plants by stressing or killing root systems. Two common soil-inhabiting fungi that cause root rots include *Fusarium* sp. and *Rhizoctonia* sp.

Root symptoms of these (and other soil-borne) fungi include darkening, limpness, and mushiness. Rotted roots may break off easily. The cortex (the outer protective covering) of roots sloughs off, leaving behind the thread-like root core.

Leaves, stems, and entire plants may wilt, prompting one to think that the plant simply needs more water. (Unfortunately, additional water often makes the problem worse.)

Generally, the lower, interior leaves turn yellow, then brown and drop off. In addition, plants may be stunted. If enough roots are damaged, the plant eventually dies.

There are no root-rot resistant plants. Management strategies include avoiding overwatering and improving soil drainage. Roots stressed from overwatering or oxygen starvation easily succumb to root rots, because the organisms move through moist soil and water.

Sometimes, a plant with root rot may be salvaged by cutting off damaged roots and replanting in well-drained soil. Biological pesticides containing hyperparasites may help protect against root rot. These products are not designed to “rescue” plants from ongoing damage, but act as preventives.

In the Green Industry, root rots can be managed with a combination of the cultural management strategies and through use of fungicides. Because not all fungicides kill all root rot fungi, it is essential to determine which root rot organism is causing the problem through microscopic examination so the correct product can be recommended.

Bacteria

Bacteria are single-celled microorganisms. They contain no nucleus and reproduce by dividing into two equal parts (fission). As a result, they multiply and mutate rapidly. Bacteria function as either parasites or saprophytes.

Bacteria can infect all plant parts. Unlike fungi, bacteria must find a natural opening for entry. Bacterial cells can move from one plant to another in water, soil, and plant material, just as fungi do. However, bacterial pathogens are more dependent on water. Conditions must be very wet and/or humid for them to cause significant and widespread damage (Figure 5).


Figure 5. Fireblight on crabapple

Bacteria move between plant cells and secrete substances that degrade plant cell walls so the contents can be utilized. Some produce enzymes that break down plant tissue, creating soft rots or water-soaking. Like the fungi, bacteria cause symptoms such as leaf blights and spots, galls, cankers, wilts, and stem rots.

Bacterial leaf spots appear different from fungal leaf spots due to their intercellular movement. Veins often limit the development of a lesion, so they appear angular or irregular, not round.

Bacterial diseases are not common in the Rocky Mountain region due to lack of natural moisture.

It is difficult for beginners to tell fungal and bacterial plant symptoms apart. Table 1 may be used to help distinguish symptoms caused by these pathogens.

Table 1. Comparison of Fungal and Bacterial Leaf Spots

Symptom Description	Fungal	Bacterial
Water-soaked appearance	No	Yes
Texture	Dry, papery	Slimy, sticky
Smell	No	Yes
Pattern	Circular, target-like	Irregular, angular
Disintegration	No	Yes
Color changes	Red, yellow, purple halos	No
Structures of pathogen	Mycelia, spores, fruiting structures	No

Common bacterial diseases in Colorado include bacterial wetwood (slime flux), fireblight (*Erwinia amylovora*), and bacterial leaf spot (*Erwinia* sp.).

Viruses

Viruses are crystalline particles composed of nucleic acid (ribonucleic acid or deoxyribonucleic acid) and protein. They are obligate parasites, meaning they are unable to survive outside of their host. Small virus particles can be found in all plant parts and cannot be seen without an electron microscope.

To move from plant to plant, the particles must be transmitted by vectors and through a wound. The vector is typically an insect, nematode, or human. Insects and nematodes spread viruses between plants as they feed on them. The feeding injury creates the necessary wound. Usually, a plant virus is spread by only one kind of insect vector. Aphids, leafhoppers, and thrips are examples of virus vectors, but not all aphids, leafhoppers, or thrips spread virus.

Humans may spread plant viruses as they work in the garden. Mechanical abrasion from infected tools or touching and abrading plants with infected hands may be all that is needed.

Viruses overwinter in infected perennial plants or overwintering insects. A small portion of viruses can be transmitted through seeds. Some are transmitted through vegetative propagation.

Viruses cause mottling, spots, mosaic-like patterns, crinkling, and other malformations on leaves and fruits, and may stunt plants. Because viruses are systemic, infected plants must be rogued or discarded (Figure 6).

Viruses are named according to the first plant on which they were found and the type of symptom they cause (i.e., peony ringspot virus, rose mosaic virus).

For example, common virus diseases in Colorado include curly top virus of tomatoes, cucumber mosaic virus of vine crops and tomatoes, tomato spotted wilt virus of tomato, and a variety of greenhouse plant viruses.

Fig. 6. Tomato spotted wilt virus on tomato fruit

Phytoplasmas

Phytoplasmas are bacteria-like organisms; however, they lack a cell wall and can take on a variety of shapes. They are obligate parasites, meaning they can only survive within their hosts. Phytoplasmas live in the phloem of host plants and are vectored by certain phloem-feeding insects, such as leafhoppers. This pathogen causes distortion, yellowing, wilting, and “**witches’ brooms**” (a proliferation of growth). Immature leaf veins may appear clear (called “vein-clearing”). Flower parts may become vegetative and flowers that do develop produce sterile seeds.

Aster Yellows

Aster yellows damages over 300 species of broad-leafed herbaceous plants nationwide. Commonly affected flowering plants include *Echinacea* sp. (purple coneflower), cosmos, marigolds, asters, chrysanthemums, delphiniums, daisies, coreopsis, and zinnias. Vegetables affected include carrots, lettuce, and potatoes. Weeds such as dandelion, ragweed, plantain, wild lettuce, and thistles may also be infected (Figure 7).

Fig 7. Aster yellows on carrot

Aster yellows is spread by the aster (or six-spotted) leafhopper. These insects are small (one-eighth inch long), gray-green, and wedge-shaped. They are called leafhoppers because they move or fly away quickly when plants are disturbed. They feed only on plant sap (phloem tissue) and generally on leaf undersides.

Aster leafhoppers do not overwinter in Colorado due to the cold climate, but are blown in from the Gulf of Mexico in late spring or early summer. Once a leafhopper feeds on an infected plant, about 10 days to 3 weeks must elapse for the insect to become infective. Plant symptoms appear 10 to 40 days after infection. Dry weather can cause increased disease occurrence in the home garden as leafhoppers move from plants in prairies and pastures to irrigated yards. Generally, aster yellows symptoms appear in middle to late summer.

Although aster leafhoppers spread the disease, placing infected plants in the yard can also spread it. Management strategies for aster yellows include planting healthy plants, controlling weeds that may harbor the insects, and removing infected plants. Even though only one part of a plant appears infected, one must assume the phytoplasma is throughout the entire plant.

The pathogen can overwinter in plant crowns and roots. Leaves and stems that develop from this tissue will always be infected and provide a source of inoculum for other susceptible plants. Insecticidal control of aster leafhoppers is very difficult as they are constantly moving in and out of the garden, so it is not recommended.

Parasitic Plants

More than 2,500 species of higher plants are known to live parasitically on other plants. Parasitic plants produce flowers and reproduce by seeds like other plants. The main difference is they cannot produce their own chlorophyll or produce only a small amount of chlorophyll. They must obtain sustenance from a chlorophyll-producing plant to survive. Parasitic plants are spread in various ways including animals, wind, and forcible ejection of their seeds.

Dwarf mistletoe and dodder are two examples of parasitic plants encountered in Colorado. Dwarf mistletoe has chlorophyll but no roots and depends on its host for water and minerals, although it can produce carbohydrates in its green stems and leaves. Dodder cannot produce its own chlorophyll and completely depends on its host for sustenance.

Plants damaged by parasitic plants appear wilted, stunted, distorted, and chlorotic. Some plants, particularly conifers, develop witches' broom symptoms.

Nematodes

Nematodes are microscopic roundworms that live in soil, water, and plant material. They have a spear-like stylet mouthpart, require free water to move about, and reproduce by eggs. They spread in water, infected plant material, soil, and in some cases, insects.

Nematodes cause a variety of symptoms including stunting, yellowing, and wilting of plant tissue. Some infected plants simply appear unthrifty. Some develop strange, knot-like growths on their roots. Many saprophytic and parasitic species exist. Due to cold winters, nematodes as plant pathogens are uncommon problems in Colorado landscape plantings.

Pinewood nematode (*Bursaphelenchus xylophilus*) is a North American native nematode that invades exotic pines such as Austrian, black, and Scots pines.

Pinewood nematode causes pine wilt disease. The symptoms include needle necrosis, branch flagging, and eventual tree death. Trees may decline rapidly; whole tree death can occur in 2 weeks.

Pinewood nematodes are vectored two ways. The primary transmission is by maturation feeding of adult pine sawyer beetles (*Monochamus* sp.) on susceptible trees. Secondary transmission occurs when adult female pine sawyer beetles oviposit (lay eggs) into phloem of susceptible trees. If this disease is suspected as the cause of pine tree death, samples must be sent to a diagnostic laboratory to accurately diagnose pine wilt disease.

Foliar nematodes are found occasionally in irrigated Colorado landscapes. They have a broad host range and can infect many plant species but especially anemone and chrysanthemum.

General Management of Biotic Plant Disease

Plant disease is best managed through an integrated approach, which includes a combination of cultural, mechanical, biological, and chemical practices.

Cultural management includes appropriate plant selection**.** Utilize plants that perform well in the local climate. Use disease-resistant varieties when possible. Plant certified seed or seed pieces.

Place plants in the appropriate environment for optimum growth. For example, grow shade-loving plants in the shade, not hot sun. Prepare soil before planting to improve root growth, reduce compaction in clay soils, and improve water holding of sandy soils. Apply fertilizer and water according to plant needs. Prune correctly, as needed, and at the correct time of year.

Mechanical management techniques include rototilling in the fall, which exposes pathogens, insect eggs, and weed seeds to cold winter temperatures. This action also speeds the decomposition of crop residues, improving soil organic matter. Clean up or prune out infested plant materials to reduce the source of inoculum on the property.

Rotate crops when possible to starve pathogens. For example, avoid planting solanaceous crops in the same area as pathogens specific to this group may build up in soil and infect new crops.

Apply mulch in gardens. Not only does this keep soil moister and cooler (helping roots thrive), it also creates a splash barrier against soil pathogens or pathogens on plant debris in the soil. Use soil solarization to reduce soil pathogens and weed seeds. Pull weeds and volunteer seedlings that hog precious water but also serve as a reservoir for pathogens and insects. Core-aerate turf once or twice yearly.

Biological controls include the use of compost, compost teas, and hyperparasite products, which may reduce pathogens by introducing beneficial microbes. Encourage beneficial insects by planting flowering plants attractive to all stages of development. Avoid blanket applications of pesticides, which may kill beneficials in addition to harmful insects. Spot treat pest problems instead.

Chemical control refers to the use of fungicides, insecticides, and herbicides to manage a problem. Always identify the cause of a plant problem first, then select and use a product appropriate for the problem and follow label directions. Apply it at the correct time using the recommended method. Always spot treat.

Abiotic Disorders

Abiotic agents of disease are non-living factors such as soil compaction, spring frosts, hail, and lawnmower damage to tree trunks. Abiotic agents are noninfectious and non-transmissible. Plant diseases deriving from these agents have been referred to as physiological diseases or environmental diseases.

Water Management

One of the major causes of abiotic plant disorders is improper water application. Too much water can be just as damaging as not enough water, as both kill roots. Examples of abiotic disorders related to water are leaf scorch, winter desiccation, and oxygen starvation (Figure 8).

Figure 8. Water stress on trees often appears from the top down.

Leaf Scorch

Symptoms of leaf scorch include necrosis (browning) of leaf edges and/or between the veins. These are naturally the least hydrated areas of a deciduous leaf, so when moisture is lost, symptoms appear there first. Scorch symptoms on needled evergreens appear as necrosis from the needle tips downward in a uniform pattern. The initial reaction to these symptoms is to provide more water, but that may only exacerbate the situation depending on what is causing scorch in the first place (Figure 9).

Figure 9. Leaf scorch on linden caused by hardscaping over the root zone.

There are several causes of leaf scorch. There may not be enough water in the soil for root absorption. This occurs during drought periods as Colorado experienced in the early 2000s and during winters when soil water is frozen.

Water may be lost faster than it can be replaced. Warm, windy, and sunny weather during winter months causes rapid transpiration at a time when soil moisture may be frozen. During summer, sunny, hot, and windy weather causes such rapid transpiration that roots cannot physically keep up with the water loss.

Soil water may be available, but roots may not be functioning properly to absorb it. What causes roots to function poorly? Soil may be so compacted that roots cannot adequately explore soil for nutrients and moisture. Roots may be severed or otherwise damaged from construction activities or garden cultivation. Planting too deep limits oxygen availability for roots and stresses or kills them. A thick layer of mulch or black plastic covering root systems also injures them due to oxygen deprivation.

Mechanical damage on lower stems or trunks from mowing equipment, improper planting, improper staking, animal chewing, or boring insects may also prevent or slow water uptake. ***The bottom line is that more water is lost than can easily be replaced.***

Oxygen Starvation

Oxygen starvation occurs when excess water in the soil drives out oxygen, in effect “suffocating” roots. Plants respond by dropping lower leaves that are usually yellowed or necrotic. Leaf loss is most noticeable from the inside of the plant out and the bottom up. In addition, leaves may be smaller than normal, growth increments may be small, and the plant may have an overall unthrifty appearance.

While oxygen starvation causes root damage, the first clue that something is wrong appears on the canopy, stems, and branches. These parts are the furthest from the water source, so the symptoms appear there first.

To control problems caused by water management issues, identify the likely causes and correct them if possible. This will require some detective work to determine which factor or (usually) combination of factors is causing the problem.

Management strategies are based on good horticultural practices. For example, add organic matter to vegetable and flower gardens before planting to improve drainage as well as water-holding capacity. Cut back on irrigation frequency or adjust the quantity of the water applied. Core aerate turf, which will also benefit tree roots growing in it. Apply and maintain mulch at levels appropriate for the material used. Remove any black plastic in the landscape.

Weather

Winter desiccation is caused by dry winter winds that result in leaf water loss. Water cannot be replaced in the plant because the soil is too cold for root function. Symptoms of winter desiccation include necrotic leaf or needle tissue (typically from the tips inward), discoloration of needle or leaf tissue, and patchy damage distribution on individual plants in windy locations. Plants may not exhibit symptoms until the following summer when droughty summer conditions ensue (Figure 10).

Figure 10. Winter dehydration on pine appears on needle tips.

To deter winter desiccation, fall water plants after they go dormant. Roots are still active and can absorb water until soil temperatures drop below 40°F. When the ground is not frozen, additional irrigation may be helpful monthly during the winter in the absence of snow cover or sufficient snowmelt or rainfall.

Temperature

Temperatures below optimal plant growth cause plant damage. The amount and type of damage depends on how quickly temperatures drop, the lowest temperature reached, and how long cold temperatures are sustained. Freeze injury may be caused by frost crystals that form in the freezing water outside of plant tissues or by freezing water inside plant cells. Damage from the latter is much more severe and resembles herbicide phytotoxicity, bacterial blight, and branch flagging due to insect borer activity (Figure 11).

Spring freezes damage exterior buds first, as these are the first to deharden. Fall freezes affect interior buds first as these are the last to harden. Damage of tissues is uniform. For example, newly developing conifer needles may be killed completely or from the tips inward.

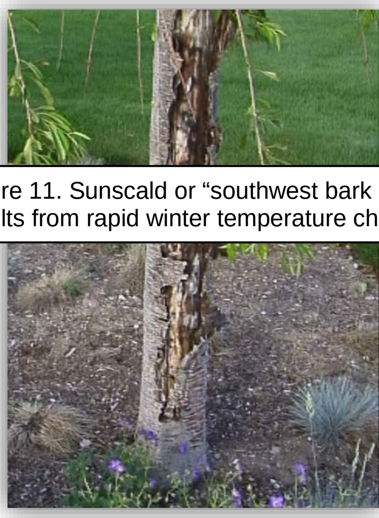


Figure 11. Sunscald or "southwest bark injury" results from rapid winter temperature changes.

Temperatures above optimal growth cause plant damage as well. The most severe injury occurs on leaves that are exposed to the sun and tissue that is furthest away from water such as outer branch tips, leaf margins, and between leaf veins.

Chemical Injury

Chemical injury is plant damage caused by pesticides, fertilizers, de-icing salts, and other products.

Herbicides

Herbicides (weed killers) damage plant tissues by causing symptoms such as chlorosis, necrosis, distortion, and elongated growth. Glyphosate, dicamba, and 2,4-D are examples of common herbicides that cause chemical injury to desirable plants when used incorrectly.

Herbicides that behave like plant growth regulators, such as dicamba and 2,4-D,translocate through both the xylem and phloem. They stimulate growth such as cell division, elongation, and fruit and flower production (Figure 12).

Figure 12. Damage on grapes from 2,4-D. Notice the distortion in leaf vein pattern.

Excessive concentrations of these chemicals cause twisting and curling of stems, stem swelling, weakened cell walls, rapid cell growth, and cellular and vascular damage and death. Grasses are not affected by plant growth regulators apparently due to a different arrangement of vascular bundles (xylem and phloem).

Glyphosate is an amino acid inhibitor that interferes with synthesis of certain amino acids needed to build proteins. Glyphosate moves through the phloem to the new growth of shoots and roots. Injury symptoms include chlorosis, shortened internodes (compact growth or stunting), stem proliferation, and mimics damage caused by 2,4-D and other plant growth regulators, viruses, phytoplasmas, eriophyid mites, and environmental factors.

Fertilizers

An excess or shortage of the 17 essential elements required for plant growth and development may cause plant damage. Excess amounts of fertilizers can “burn” plants due to the level of salts in fertilizers.

Symptoms of fertilizer damage include leaf margin necrosis (similar to drought stress in appearance), leaf discoloration, soft rapid growth, and vegetative growth at the expense of flower and fruit production.

Nutrient deficiencies include chlorosis, interveinal chlorosis, blossom-end rot, stunting, and purpling. Symptoms of nutrient excesses and deficiencies may be confused with disease, insect, mite, or other environmental problems. If a soil nutritional problem or salt injury is suspected, have the soil tested.

When excess fertilizer has been applied, apply water in an effort to leach salts from the root zone. Quick release fertilizers are more prone to “burn” plants. Follow label directions when applying fertilizers to avoid plant damage.

Salts

It is common practice in Colorado to use de-icing salts to remove snow and ice from roadways and sidewalks. Salts injure plants from 1) salt burn on foliage, 2) root burn of salts, or 3) soil buildup that deteriorates soil structure, interfering with drainage and root growth.

Symptoms of salt spray on leaves include stem and leaf deformities, witches' brooms, and twig dieback of deciduous plants. Conifers exhibit needle browning at the tips of branches. Salt spray damage is only noticeable on the plant side adjacent to a road.

Symptoms of salt accumulation in soils are different from salt spray and include marginal leaf scorch, stunting, and twig dieback. Leaf scorch may not appear until later in the season or in following seasons.

To reduce salt burn, avoid de-icing salts, add organic matter and charcoal to the soil, leach with water, or protect plants using a barrier that will keep salt-laden snow away from plant material.

Compost and other soil amendments can be high in salt when made with manure or biosolids. Symptoms of salt burn include marginal burning of leaves, stunting, root dieback, and death of plants. For additional information, refer to Colorado Master Gardener GardenNotes #241, *Soil Amendments* (Figure 13).

Figure 13. Salt damage on bean leaf " burns" the margin of the leaf. This was caused by using compost high in salts.

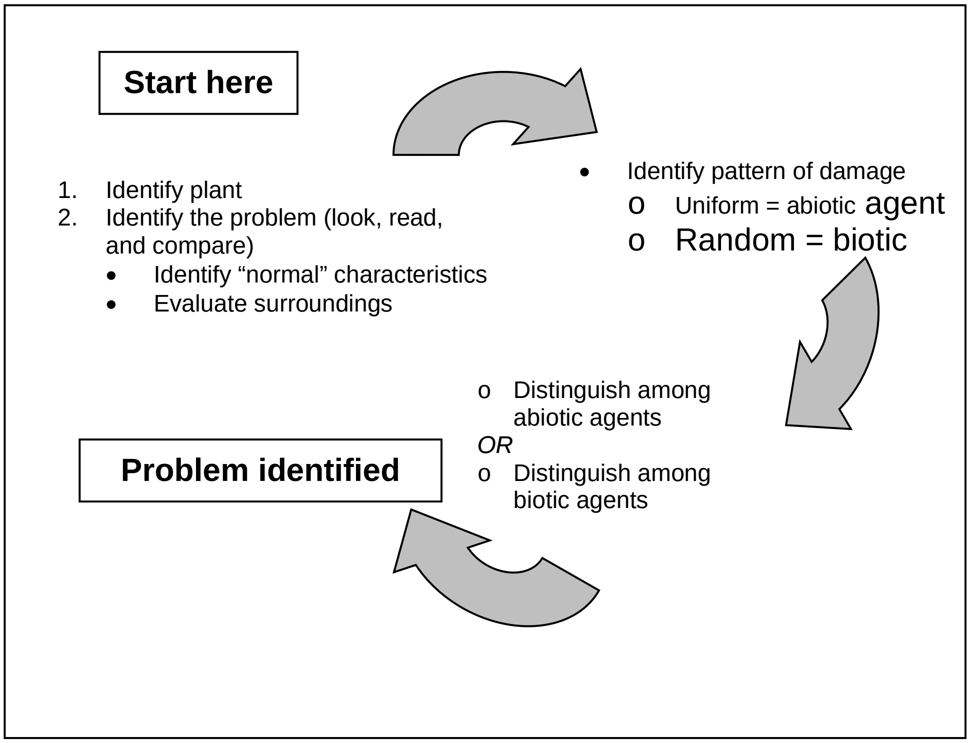
Plant Disease Diagnosis

General steps in the diagnostic process include the following:

1. Identify the plant.
2. Identify the problem(s).
   a. LOOK – Define the problem by describing the signs and symptoms.
      1) Identify "normal" characteristics of the plant
      2) A systematic evaluation of the plant helps organize questions in a methodical process.
   b. READ – Distinguish between possible causes by comparing signs and symptoms with details in reference materials.
   c. COMPARE – Determine probable cause(s) through comparison and elimination.
3. Evaluate if management efforts are warranted.
   a. What type of damage/stress does this disorder/pest cause?
   b. Under what situations would management efforts be warranted?
   c. Are management efforts warranted for this situation?
4. Evaluate management options effective for this disorder/pest and when they are applied.

Determining the causal agent of plant damage can be a tumultuous endeavor, so let us expand on content around Step 2, Identify the problem(s). Use a systematic approach when diagnosing plant damage and determination will become easier (see Chart 1). The probability of correctly diagnosing plant damage based on one or two symptoms is low. In contrast, probability of correctly diagnosing plant damage based on many symptoms and factors is high. Therefore, using investigative skills and asking many questions is imperative to arriving at a correct diagnosis. [Chart 1]

Chart 1. A flow chart displaying the systematic approach to determining causal agents of plant damage.



Sample Questions

Accurate diagnosis is absolutely dependent on accurate observation. When making observations we must ask the following questions:

1. What symptoms is the plant expressing?
2. How many plants are affected?
3. Is there a pattern associated with the problem (i.e. is the problem located in one area; such as a low area, on the north side, south side, etc.)?
4. Are there any differences in susceptibility of varieties or species (i.e. is it just the tomatoes or are other plants also affected)?
5. Ask about obvious causes first, such as animals, frost, flooding, or mechanical damage.
6. Determine which part of the plant is actually damaged. Wilts, for instance, frequently are only a response to some damage to the roots. Dieback of branches is sometimes caused by cankers or mechanical damage further down the stem.
7. Are the roots healthy appearing (not black or mushy) and moist? Note: You may not be able to diagnose the problem without roots.
8. What about the texture and wetness of the soil? Is it too heavy, sandy, or compacted? Is salt crusting evident?

9. What is the weed population? (Weeds may indicate a particular soil problem.)
10. Find out as much as possible about the previous history: fertilizer, pesticides, land leveling, cultivation methods, irrigation schedules, and climatic conditions.
11. There are many other questions that you may think to ask based on the specific sample in question. ***Remember, we can never ask enough questions. The more thorough you are, the better the diagnosis.***

Determine what the "normal" plant would look like during that time of year. Describe the damage using terms like "gall", "witches broom", and "chlorotic." Establish the location on the plant where initial damage occurred. For example, there are leaf spots with fruiting structures on the underside of leaves, but these symptoms are not what caused tree death. Cankers along the branches and trunk are what killed the tree.

Distinguishing the factor that caused plant death from other symptoms and signs can be tricky. In turfgrass, many times sclerotia, fruiting bodies, and conidia are spotted in necrotic and problematic areas. However, these disease-causing structures may not be related to turfgrass death.

Identify Pattern of Plant Damage

Uniform damage patterns on individual plants and on many different plants in a specific area are typically characteristic of nonliving or abiotic factors. Abiotic factors include mechanical, physical, or chemical factors.

Random damage patterns on individual plants or on a specific family or genus of plants typically indicates a living or biotic agent of disease. Biotic factors include fungi, bacteria, or nematodes.

> Important note: You may come to a diagnosis based on the answers a client provided, but when double-checking the diagnosis, you may realize the diagnosis does not seem quite right. Keep an open mind, go back through your questions, and take a different diagnostic avenue.

Distinguish Between Biotic and Abiotic Factors

Signs of biotic pathogen activity will always be present. It is a matter of whether the sign is observed. First, closely study plant damage. Mentally identify possible causal agents. Then look for signs that would accompany such damage. Signs of disease include fruiting structures, overwintering structures, mycelium, insect frass or carcasses, and ooze. Because some diseases are vectored by insects, signs that the vectors are present are equally as important as finding signs of the disease. In addition, some types of disease symptoms mimic symptoms of insect or vertebrate damage. It is critical, therefore, to distinguish between insect and pathogen damage using observed or unobserved signs of both insects and pathogens.

If no signs are observed, abiotic activity should be considered. Ask questions regarding mechanical, physical, and chemical factors affecting the damaged plant. Mechanical factors include string trimmer damage to tree trunks, improper pruning cuts, injury during transportation of plant material and guy wire damage. Physical factors include temperature extremes, light differentials, and extreme changes in oxygen and moisture levels. Chemical factors include pesticide damage, fertilizer damage, nutritional disorders, and pollutants.

Author: Mary Small, Colorado State University Extension. Artwork by David Whiting; used by permission. Figures 2,3, 6 and 10 by Mary Small and Figure 10 by Curtis Utley, both of Colorado State University Extension.

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