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Cooperative Extension Service

Diagnosing Plant Problems

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In this chapter:

Figure 6.1. Some evergreen trees, such as pine, shed older needles during the fall, giving the tree a brown appearance.

For those with a green thumb, growing plants may seem easy. However, when plant problems arise, determining the cause of these issues can be difficult. Developing the skills necessary to determine the cause of a plant problem takes experience and time. The steps involved in the diagnostic process first require analysis of information regarding the history of the symptomatic plant and the surrounding area. Plant symptoms and signs provide additional evidence to aid in determination of a possible cause.

There are numerous potential causes for plant problems. Living factors such as plant pathogens, insects, and wildlife can damage plants. In addition, non-living factors including weather, physiological disorders, mechanical damage, nutrition, and chemical injury may also result in plant damage. Critical thinking is essential to determine which possible causes are the most consistent with the observed damage. While it is not always possible to determine the exact cause of a plant problem, there are numerous resources available to aid in the process. The steps utilized in the diagnostic process are detailed in this chapter.

Data Collection for the Diagnostic Process

Diagnosis of a plant problem begins with the collection of information about the plant and its environment, as well as an evaluation of the symptoms present. After information is gathered, it can be used either to diagnose the issue or to rule out possible causes by process of elimination. The following steps detail this process.

Plant Identification and History

In order to determine whether a problem truly exists, it is important to correctly identify the type of plant. The normal growth of some plants can appear irregular and cause alarm. Time of year should also be considered, as many plants experience alterations in appearance as seasons change. Such is the case with some evergreen trees. For example, pine trees drop older needles in the fall, which can cause distress for those unfamiliar with fall needle drop. However, this process is completely normal for pine trees (Figure 6.1).

Variations in growth and appearance can also be the result of different cultivars or varieties. Keeping accurate records of cultivars can help with the identification of normal growth and appearance of the plant. Many new varieties or cultivars have appearances that vary greatly from those more commonly

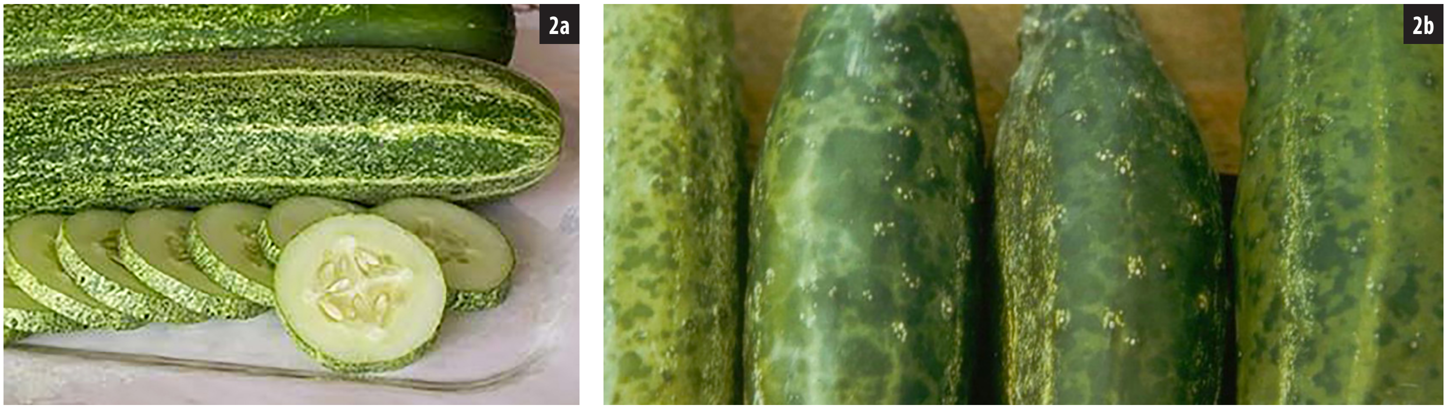


Figure 6.2. The 'Chompers Hybrid' cultivar produces cucumbers with variegation (2a). However, variegation can also be a symptom of a disease such as cucumber mosaic virus (2b).

Figure 6.3. Evaluate the area around a problematic plant to determine whether the damage can result from the topography. When plants are installed into low areas where standing water can collect, plant roots suffocate from lack of available oxygen.

planted. For example, the cucumber variety 'Chompers Hybrid' has a variegated appearance, which may be confused with symptoms from disease or non-living factors (Figure 6.2).

As plants grow and adapt to their environment, appearance may change. It is important to consider the history of plants to determine a possible cause of damage. Keep records of planting dates to determine plant age. Additionally, incorrect planting can stress plants and result in an abnormal appearance. A review of plant care activities, such as frequency and duration of watering and application of nutrients, may help determine possible causes of damage. Consider environmental changes that may have occurred in recent months or years. Severe winters or dry summers can affect plants' appearance and health several months or years after the weather event.

Examine the Site

Examination of the growing site can provide additional information that aids in the diagnostic process. Since growing requirements vary for different plant types and even for different cultivars, it is important to consider the planting site. Plants have specific environmental conditions in which they thrive. When a plant's location provides too much or too little light, water, or drainage, plants exhibit symptoms of damage.

While it may initially appear that only one plant is affected, surrounding plants should be assessed for similar damage. If multiple different types of plants exhibit similar damage, it is likely that the cause of the damage is a non-living factor, such as chemical, environmental, or mechanical injury.

Evaluate the area surrounding the symptomatic plant to identify clues that may establish the cause of a plant problem. Step away from the plant to consider items such as topography (Figure 6.3) and proximity to damage sources, such as wildlife habitats and construction sites. Through an evaluation of the environment surrounding a plant, cause for damage can often be determined.

Figure 6.4. Dieback is a common symptom exhibited by problematic plants (3a). However, the part of the plant where the problem is occurring in this example is the root system (3b).

Inventory of Symptoms and Signs

The type of damage that occurs on plants is important for the diagnostic process. Symptoms are the external response of the plant, which may indicate a problem. Symptoms may include leaf spots, holes in leaves, cankers, fruit spots, holes in fruit, irregular growth, root rots, discoloration, wilting, and dieback, as well as numerous other symptoms. Specific symptoms that can result from diseases, insects, wildlife, and abiotic causes are detailed in the following sections. Symptoms should be documented with as much detail as possible. While diagnostics are not based on symptoms alone, this information can assist in eliminating possible causes, and thereby establishing more likely causes for symptoms or problems.

It is often necessary to examine the whole plant to clearly identify which part or parts are affected. When spots appear on leaves or fruit, it is obvious that these are the parts of the plant that are affected. However, when symptoms such as wilting or dieback are present, the parts of plants affected are less obvious. These symptoms often indicate a problem at the base of the plant or in the root system (Figure 6.4).

Patterns of symptoms can also provide valuable information for the diagnostic process. Take time to assess all plant parts to determine whether damage occurs in uniform or in random patterns. When damage is uniform across all plant parts and/or entire plantings, it often indicates that the cause is abiotic. For example, dieback at the base of shrubs near a road can be the result of salt damage (Figure 6.5). However, when patterns of damage are inconsistent, the cause is more likely to result from disease, insect, or wildlife. Random symptoms may be present on plant parts, whole plants, or groups of similar plants. Damage that results from insect feeding is inconsistent across the leaves of a plant (Figure 6.6). In contrast, diseases usually begin in lower or inner canopies and create gradient patterns.

The timing of symptom appearance and process of change over time can also aid in the diagnosis of plant problems. Damage from wildlife and abiotic factors results in symptoms that appear suddenly and do not spread to other plants over time. Disease and insect damage appears gradually. Over

Figure 6.5. When symptoms such as dieback are evenly distributed along the base of several shrubs near the road, the cause is likely abiotic. In this situation, the cause of the damage is de-icing salt.

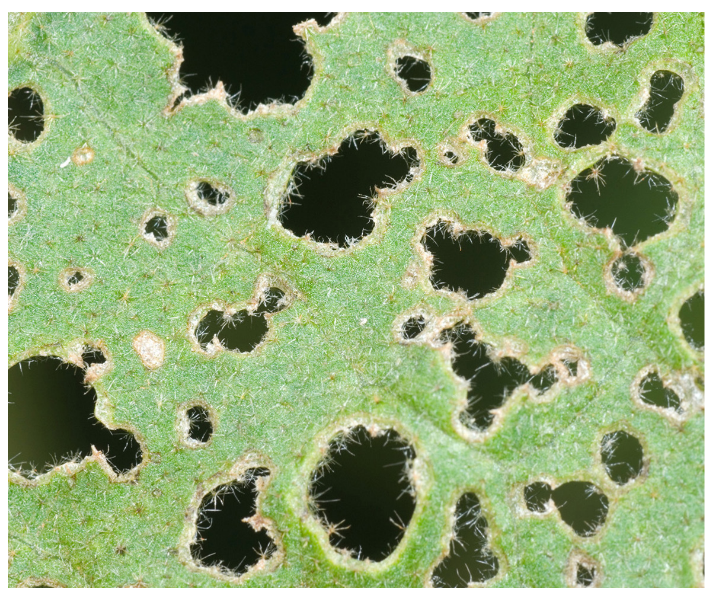


Figure 6.6. Inconsistent patterns are often the result of disease, insect, or wildlife. The damage to this eggplant leaf is the result of flea beetle feeding.

time, the organisms that cause these issues multiply and cause additional damage. Thus, symptoms from diseases and insects worsen over time and move to infect/infest new areas.

Signs are the physical evidence of causal organisms that are responsible for plant damage. Signs indicate the presence of disease-causing pathogens, insects, or wildlife. Signs can include fungal fruiting structures or fungal parts, insects or their frass, and presence of animals or their scat. More details on the types of signs that can be associated with diseases, insects, and wildlife are detailed in the following sections.

While abiotic issues do not produce signs, the lack of observable signs does not necessarily confer that the problem is the result of an abiotic issue. In many cases, visual observation of disease and insect signs requires magnification. Additionally, signs may be limited to specific environmental conditions.

Considerations and Possible Causes of Plant Problems

This critical thinking step is the most challenging portion of the diagnostic process. Determining a possible cause first requires a review of the information that has been collected in the previous steps. This information is then used to either support or eliminate potential causes of injury or damage.

Once information about the plant, site, symptoms, and signs has been gathered, these "clues" may be used to determine a probable cause. Consider all of the known information and possible causes they may indicate. This evidence can also be used to rule out unlikely culprits of the damage. It may be necessary to consult reference materials or additional resources to interpret the collected information. Utilize resources such as university publications, reference books, credible websites, and local county Extension agents.

After review of the material and resources, it may be necessary to gather some additional information. A more thorough inspection of the symptomatic plant may now yield more symptoms not documented before, or a broader view of the site may reveal "clues" not noticed before. This information is then used to continue the process of determining the most likely cause of the plant problem. In order to reach a probable cause for the damage, it may be necessary to repeat this process multiple times.

Disease

Diseases are the observable symptoms that result from infection by plant pathogens. A detailed description of the plant pathogen groups can be found in Chapter 5, Plant Diseases. These organisms can result in a wide range of symptoms. Signs for many plant pathogens are not visible without the aid of a microscope, which increases the difficulty of diagnosing plant disease problems. The following is a description of common symptoms and signs that may be present as a result of infection by specific pathogen groups. A more extensive list of symptoms that can result from each pathogen group can be found in Table 5.1 of Chapter 5. This table presents common symptoms of disease, but other combinations are possible.

Fungi and Water Molds

Fungal and water-mold pathogens are the most common culprits of disease issues. Fungi and water molds have characteristics that make each group unique, but many symptoms are similar. Both are capable of producing a wide range of symptoms on different plant tissues. Leaf and fruit spots are often the first symptoms noticed on symptomatic plants. These spots may be variable in shape, including spots with dark borders and lighter-colored centers or concentric rings (bullseye-like appearance) (Figure 6.7). Spots on plant tissue may expand over time.

Fungi and water molds can also produce stem lesions or cankers (Figure 6.8). Cankers on branches limit the movement of water and nutrients, which may result in symptoms such as wilting, dieback (Figure 6.9), or flagging. When stems or roots become damaged, aboveground symptoms such as wilting, dieback, or plant death may be observed. Rotted plant tissue may appear soft, sunken, discolored, or blackened (Figure 6.10).

Figure 6.7. Leaf spots with concentric rings are often the result of fungal or water-mold diseases. Lesions of early blight of tomato have this appearance.

Figure 6.8. Cankers may appear as cracks or sunken tissue, such as this anthracnose disease on sycamore.

Figure 6.9. Dieback often includes slow decline or canopy thinning and may indicate crown or root disease. Dieback of this catalpa tree was caused by Verticillium wilt.

Figure 6.10. Rotted roots may become brown or black in color, appear thin, and slough off easily. Black root rot is prevalent in both herbaceous and woody plants, including this pansy.

Figure 6.11. A hand lens can be used to magnify plant samples and identify signs.

While most fungal and water-mold signs are only visible with the aid of a microscope, it may be possible to observe some fungal structures with minimal magnification or the naked eye. A hand lens is often used to view symptomatic plant parts with 10, 20, or 40 times magnification (Figure 6.11).

The body of fungi and water molds consists of a mass of threadlike structures (mycelia). These organisms produce sexual and asexual spores, which require magnification to be observed and examined (Figures 6.12 and 6.13). Many fungi produce reproductive structures (fruiting structures such as ascocarps, acervuli, chasmothecia, and pycnidia), which are often visible without magnification. Fruiting structures may appear as small flecks or bumps on infected tissue (Figures 6.14 and 6.15). Overwintering structures that hold numerous spores or fungal tissue for next season's infection, such as chasmothecia and sclerotia, may also appear as small black specks on plant tissue near the end of the growing season (Figure 6.16). Some of these fungal structures can survive for several years in soil (Figure 6.17). One group of fungi produces mushrooms, which are large fruiting structures (Figure 6.18). Some fungi generate spores in abundance, making them visible when they are released from their reproductive structures (Figure 6.19).

Many fungal fruiting structures are only produced under certain conditions; thus the absence of visible signs does not indicate the absence of fungi. Fruiting structures often require conditions such as the presence of moisture (including humidity) and cool to moderate temperatures. It may be possible to induce the development of identifying structures by placing a portion of the symptomatic plant tissue into an incubation chamber (Figure 6.20). This chamber, usually built with a plastic container or bag and a moist paper towel, mimics the ideal environmental conditions that may result in the development of visible mycelium, fruiting structures, and/or spores. Structures typically develop in 24 to 48 hours. Note that not all fungi will develop visible structures with this process.

Figure 6.12. Mycelia can sometimes be observed without the aid of magnification, as is the case with the white mycelial growth of powdery mildew.

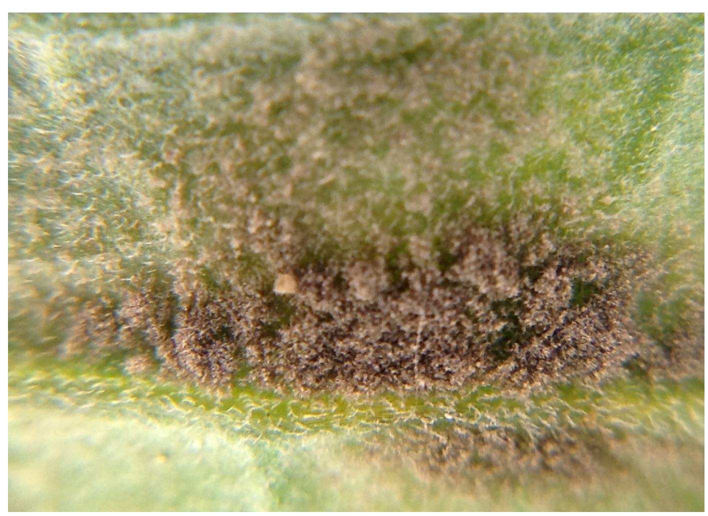


Figure 6.13. Magnification can make clusters of spores visible, as with the brown sporulation of leaf mold on tomato.

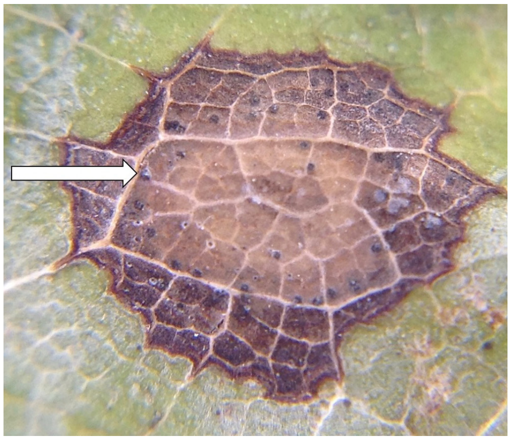


Figure 6.14. Fruiting structures such as the small black bumps (pycnidia) (indicated by the white arrow) are visible with or without magnification.

Figure 6.15. Some fruiting structures may appear as slimy masses, such as the salmon-colored sporodochia of Volutella blight.

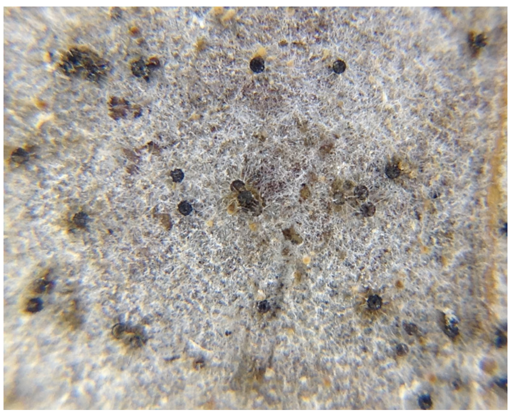


Figure 6.16. Chasmothecia are overwintering structures produced by some powdery mildew fungi at the end of the growing season. They can be observed with or without magnification.

Figure 6.17. Sclerotia (indicated by white arrow) are fungal structures that are visible with the naked eye.

Figure 6.18. Mushrooms are easily-recognizable fruiting structures. They are not always present, even though the fungal body continues to grow below ground.

Figure 6.19. When spores are produced in abundance they may be visible. Puffball fungi produce fruiting structures above ground and release large numbers of spores in a smoke-like manner.

Figure 6.20. When signs are absent, incubation in a bag with a moist paper towel may induce certain fungal structures.

Bacteria

Diseases that result from bacterial pathogens can exhibit a range of symptoms, several of which are similar to those caused by fungal or water-mold pathogens. Bacterial pathogens can result in leaf and fruit spots. These spots may have a yellow halo (Figure 6.21) or water-soaked appearance (Figure 6.22). Symptoms such as cankers, dieback, and wilting may also result from bacterial infections. As bacteria commonly break apart cells when they infect plants, wet rots of fruit (Figure 6.23) or stems are common. Some bacterial pathogens may result in galls, which are tumor-like growths on plant tissue (Figure 6.24).

Due to the small size of bacterial cells, it is uncommon to observe bacterial signs. There are a few bacterial pathogens that accumulate, causing large numbers of cells to ooze from tissue (Figure 6.25). This is considered a sign, even though individual bacterial cells cannot be observed. The lack of visual signs makes the diagnosis of bacterial diseases challenging.

Figure 6.21. Leaf spots that result from bacterial pathogens may have a yellow halo around the lesion, such as with bacterial spot on pepper.

Figure 6.22. Bacterial leaf spots may appear to be oily or water-soaked around the edge of lesions, such as with bacterial blight on beet.

Figure 6.23. Bacterial pathogens can damage plant cells, resulting in rotting of plant tissues. Bacterial soft rot of cabbage results in decay.

Figure 6.24. Galls, or tumor-like growths, can be a symptom of bacterial diseases. Crown gall is prevalent on many different woody plants.

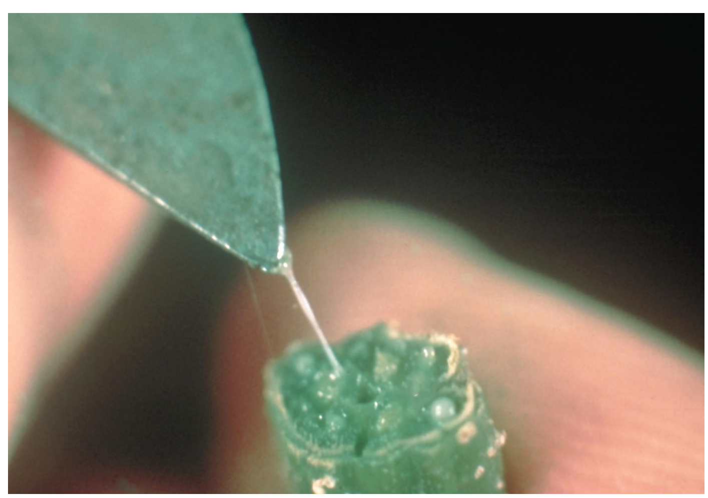


Figure 6.25. Bacterial ooze can be a sign of bacterial infection. Bacterial wilt in cucurbits creates "oozing" signs.

Viruses

Viral diseases result in an extremely wide range of symptoms. Plants infected with viruses may exhibit interruption of a color, known as color breaking (Figure 6.26). Ringspots and line patterns are common symptoms of viral pathogens (Figure 6.27). The leaves and fruit of some plants may display a symptom called mosaic or mottling, in which a lighter green, yellow, or cream color is interspersed with a darker green color. Symptoms such as yellowing of plant tissue (chlorosis), tissue death (necrosis), and dieback may develop as a result of viral pathogens.

Some infected plants may exhibit a stunted or distorted appearance, while others may present a prolific amount of growth (witches' broom) (Figure 6.28). Poor fruit set, flower abortion, and abnormal growth are additional symptoms of viral disease. Many of these symptoms are similar to those that may result from other pathogens or abiotic issues.

Viral pathogens are extremely small and are not visible without the aid of an electron microscope. Thus, it is not possible to visually observe signs in the field. Diagnosis of viral diseases relies heavily on symptomology and elimination of other possible causes. Diagnostic laboratories may confirm virus infection with antibody or molecular diagnostic techniques.

Figure 6.26. Color breaking is the interruption of the primary color pattern by a virus. Tulip color break virus was responsible for "tulipmania" in the 17th century; today color breaking is the result of breeding, not virus infection.

Figure 6.27. Viral pathogens can cause a range of ringspots and line patterns. Tobacco rattle virus on peony may exhibit these symptoms.

Figure 6.28. Witches' broom is the term used for a prolific amount of growth, which can occur as a result of viral pathogens. Rose rosette virus develops a classic witches' broom symptom.

Other Disease Issues (Nematodes, Phytoplasmas, Parasitic Plants)

Nematodes are microscopic, unsegmented worms that infest roots or foliar tissue. When roots become infested, plants commonly appear stunted or lose vigor (Figure 6.29). Nematode feeding on foliar plant parts results in necrosis or leaf blotches (Figure 6.30). Most nematodes are not visible without the aid of a microscope; thus field observation of signs is unlikely.

Infection by phytoplasmas can result in a range of symptoms, including yellowing, stunting, witches' broom, and the production of leaf-like structures in place of flower petals. Plants may also experience virescence, a condition in which chlorophyll (green pigment) develops in tissues where it is normally absent (Figure 6.31). There are no visible signs for phytoplasma pathogens.

Parasitic plants utilize host plants to obtain nutrients and water. As a result, parasitized plants may appear less vigorous or exhibit dieback (Figure 6.32). Parasitic plants can be easily observed, which simplifies diagnosis of disease issues of this type.

Figure 6.29. Roots infested by nematodes may cause the plant canopy to decline or appear stunted. Root-knot nematode infestation has resulted in the stunted appearance of these squash plants.

Figure 6.30. Leaf necrosis or blotches may be a symptom of foliar nematodes. Foliar nematodes can infect a range of leafy plants, including ferns.

Figure 6.31. Some plants infected by phytoplasmas display virescence. Aster yellows is a common disease caused by a phytoplasma.

Figure 6.32. Mistletoe is a common parasitic plant that may result in dieback of the host plant when populations are high.

Insects and Mites

Feeding damage is the most common way to identify a potential insect or mite problem. Caterpillars, aphids, and mites may remain on the foliage for days or weeks after initial infestation. Consequently, infestations can be discovered early by regular examination. However, if pests have completed their development and left, only plant damage may remain. In addition, mobile or intermittent feeders are often missed because they move frequently. Thus, plant damage may be the only observable clue.

Most plant-feeding pests have some type of chewing or sucking mouthparts. Tissue removal by chewing insects is obvious, in contrast with the subtle effects of sap feeders. Beetles, caterpillars, and tree crickets eat portions of leaves, sometimes leaving distinctive damage patterns. The needle-like sucking mouth parts of aphids, leafhoppers, and mites remove plant sap, while the saliva of other insects can break down plant tissues as they feed. Symptoms of insect infestation may be holes, wilting, discoloration, or spotting. Some sap feeders excrete large volumes of nutrient-rich honeydew. An accumulation of honeydew makes leaves, stems, or branches shiny and sticky. Black sooty mold may thrive on the deposits. Finally, thrips tear at flowers and foliage with file-like rasping mouthparts that leave fine scratches.

Consider the following when evaluating possible pest damage to plants:

- Document the range of plant species affected. General feeders, such as Japanese beetles or fall webworms feed on many plant species; damage by specialist pests is confined to closely related species.
- Determine season or activity period. Some pests have relatively well-defined activity periods that can help narrow the list of potential culprits. For example, bagworms begin to feed in early summer. Aphids are cool-season pests, while most mite species are favored by hot, dry weather.
- Consider type of tissue affected or damaged. Some plant feeders prefer buds or expanding leaves, while others target older foliage.

Chewing Insects

Some chewing insects leave characteristic feeding damage. This damage may help identify the type and age of the insect. For example, newly hatched individuals may not be able to chew tough tissue or veins, thus damage is limited to surface "window pane" feeding (Figure 6.33). Older insects can consume tougher tissue and may leave little behind. Table 6.1 presents examples of common feeding damage patterns by chewing insects.

Figure 6.33. Some chewing insects may consume only surface tissue, leaving a "window pane" appearance.

Table 6.1. Characteristic damage by common chewing insects.

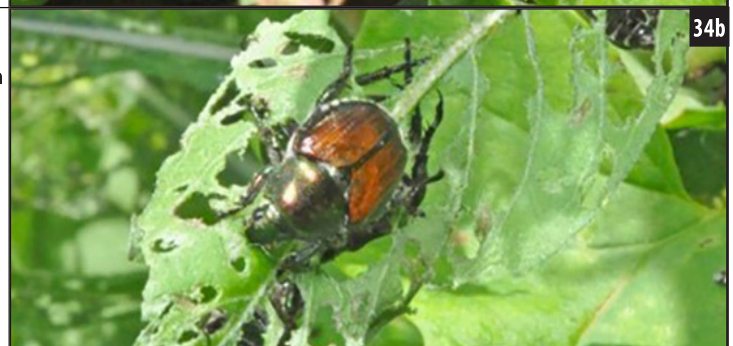
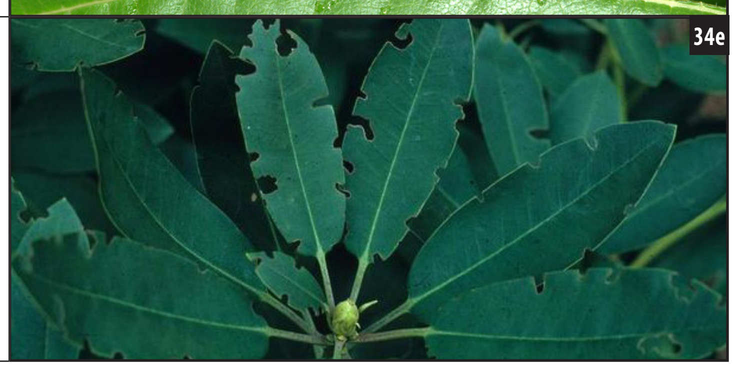
Type of Insect	**Illustration of Damage**
Many flea beetles chew scattered, rounded "shotholes" in leaves. Other chewing insects such as tree crickets and katydids, chew similar but larger holes. (Figure 34a)	
Some insects feed on soft plant tissue but do not chew through veins. This "skeletonizing" is characteristic of Japanese beetles. Some newly hatched caterpillars (bagworms) and sawfly larvae produce this pattern of injury. Slugs feed on low foliage in shaded, humid areas. They rasp tissue, causing similar damage. Look for their slime trails on foliage and surrounding soil. (Figure 34b)	
Many beetles and larger caterpillars may consume most of the leaf, leaving only the midrib or large veins. (Figure 34c)	
Grasshoppers and some caterpillars hang on to the edges of leaves and feed from the side. Others may feed evenly around the perimeter so the leaf becomes gradually smaller but keeps its general shape. (Figure 34d)	
Weevils chew uneven notches in the sides of leaves as they feed. (Figure 34e)	

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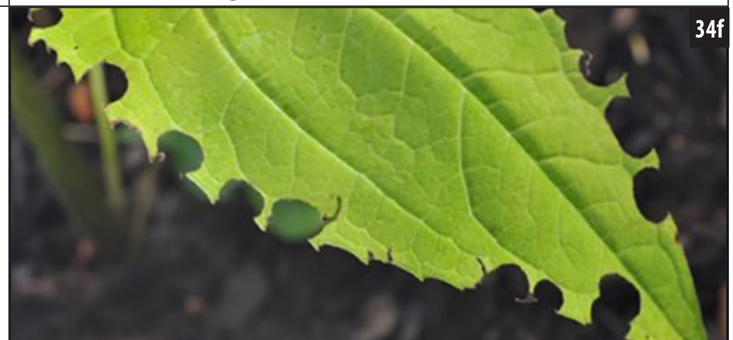
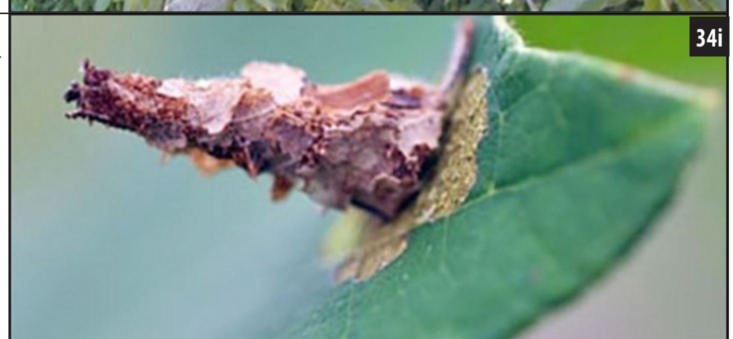
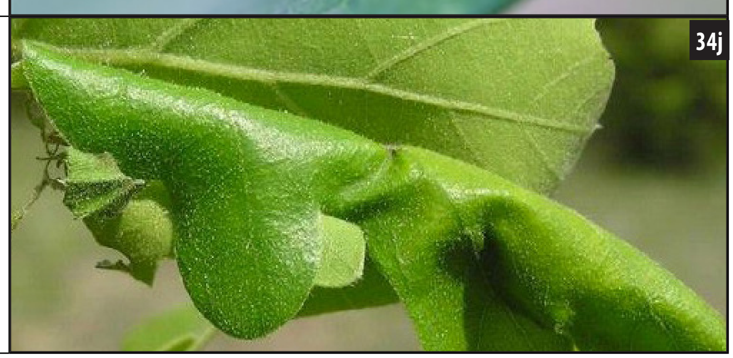
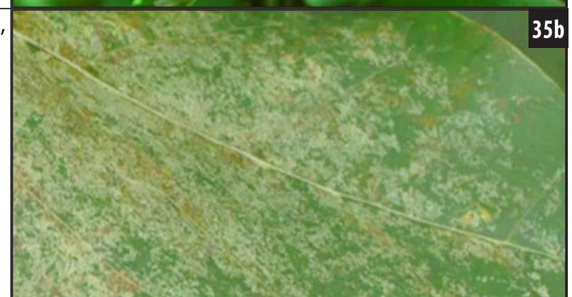
Table 6.1. Characteristic damage by common chewing insects.

Type of Insect	Illustration of Damage
Leafcutter bees remove smooth, rounded sections. (Figure 34f)	 34f
Blotch and serpentine leafminers feed on tissue inside the leaf, creating hollow areas that may be swollen or discolored. Insects or accumulated waste may be visible by holding damaged leaves up to the light. Leaf miners commonly infest holly and boxwood. Heavily mined leaves may drop prematurely. (Figure 34g)	 34g
Fall webworms (FWW) build tents on the ends of branches, whereas Eastern tent caterpillars (ETC) build tents in the crotches of tree branches. ETC and FWW use silk to create communal nests. ETC feed on wild cherry and related species from March through April. Two generations of FWW spin tents on the ends of branches of many tree species in June and August. (Figure 34h)	 34h
Bagworms spin silk coverings with pieces of host plant foliage attached. The structure provides protection from desiccation and predators. Skeletonized feeding damage by this small caterpillar is visible on the leaf surface. The camouflaged bagworms are often undetected until damage becomes severe. (Figure 34i)	 34i
Leaftier and leaf roller caterpillars use silk to fold or roll leaves and create individual shelters on foliage in which they feed. (Figure 34j)	 34j

Sap Feeders

General decline of an entire plant or plant part can appear as yellowed or wilted foliage, general loss of vigor, or dieback. These general symptoms can indicate many problems, including sap-feeding insects. Many sap feeders are small and feed on the undersides of leaves, so they are easily overlooked. Often, the effects are subtle and symptoms are slow to develop. Table 6.2 presents examples of common damage that may result from sap feeders.

Table 6.2. Characteristic damage by common sap-feeding insects.

Type of Insect	Illustration of Damage
Saliva injected during feeding by some insects can cause distorted growth or discoloration. Injury may be mistaken for chemical injury or disease. Examine the undersides of the leaves for presence of insects. Normal new growth may indicate that the injury occurred some time ago. (Figure 35a)	
Fine spotting (stippling) on leaves may be caused by leafhoppers, plant bugs, lace bugs, or mites. Saliva injected during feeding destroys chlorophyll at the feeding site, but the toxins do not diffuse throughout the leaf. Continued feeding by increasing numbers of pests can cause the entire leaf to lose color and drop prematurely. If stippling symptoms are present on the newest growth, then the infestation may still be active. Look for pests on undersides of leaves. (Figure 35b)	
Thrips tear at leaf tissue to puncture cells and feed on their contents. Injury appears as thin scratches or flecking of the leaves. Thrips can produce distorted growth by feeding in buds or along veins in developing foliage. Black varnish-like spots of waste accumulate on the lower leaf surface where these insects feed. (Figure 35c)	
Scale insects are destructive pests of landscape trees and shrubs. They resemble growths on plant leaves or bark, but they can be scraped off with a fingernail. Armored scales live under crusty, waxy coverings that resemble rough spots on bark. They spend their lives on woody tissue. Soft scales resemble larger bumps, so they are much easier to detect. In addition, they produce large amounts of nutritious excrement called "honeydew." Over time, buildup of honeydew supports the growth of the dark sooty mold fungus. Sap removal by scale insects gives heavily infested plants the appearance of drought stress. (Figure 35d)	

Gall Makers

Galls are abnormal growths that may be found on most plant parts, from catkins to leaves (Figure 6.36). Most are caused by tiny wasps, aphids, flies, or mites. Unlike scale insects, they cannot be easily scraped off.

Many gall makers attack woody plant species, resulting in galls on twigs or branches (Figure 6.37). However, most insect galls do not affect plant health. The number of galls on a plant can fluctuate naturally from season to season.

Borers and Girdlers

Plant decline or foliar wilt along a single branch can mean infestation by borers or girdling insects.

Borers tunnel into woody tissues, often disrupting plants' ability to move water and nutrients. Damage produced by borers varies with the type of insect. Borer damage is often apparent as holes or splits on the outside of woody tissue. Longitudinal slits with splintered margins that form along finger-sized branches are typical of periodical cicada egg-laying damage (Figure 6.38). Significant damage can occur after brood emergence in an area. Many borers produce exit holes. These insects usually attack trees that are injured, dying, or suffering from transplant shock. However, some can infest healthy trees. Multiple exit holes are typical of the adult stage of an insect leaving the tree after completing its development. Several beetle families produce small holes while entering the tree to lay eggs. Exit holes of roundheaded borers are typically one-eighth to three-eighths of an inch wide and scattered randomly on branches or trunks. Scattered small holes are emergence sites of shothole borers or bark beetles, while D-shaped emergence holes, such as those made by the emerald ash borer, are characteristic of flatheaded borers (Figure 6.39). Tunneling insect larvae such as the petiole borer can cause sudden, premature leaf drop. Petioles generally turn black, and a small, white worm can be found in the leaf stem.

Girdlers are beetles that chew around a twig so that it breaks easily (Figure 6.40). The beetle's eggs are laid in the portion of the twig that falls to the ground. This damage increases stress to the tree and creates sites for potential disease development.

Figure 6.36. Some insects can cause gall formation on leaves.

Figure 6.37. The horned oak gall represents an example of insect galls on woody tissue.

Figure 6.38. Longitudinal slits along finger-sized diameter branches are typical of periodical cicada egg-laying damage.

Figure 6.39. D-shaped emergence holes are characteristic of flatheaded borers.

Figure 6.40. Girdling insects chew around twigs or branches and increase the likelihood of breakage.

Wildlife

Determining what wildlife species is causing a problem can be difficult. Wildlife species can cause a wide range of damage to plants, through feeding or other activities. Wildlife damage can be broken into two broad categories: aboveground damage from feeding, trampling, or antler rubbing and belowground issues. The following sections discuss various types of wildlife damage. Use any and all observations including plant damage and the types of habitat located around the damaged plant to help determine the species responsible.

Damage Type

Aboveground Damage from Feeding

Each group of wildlife species referenced in this section is divided by feeding behaviors and resulting damage.

Small mammals (rodents): Chewed bark and cambium tissue on small trees and shrubs are most frequently caused by mice, rabbits, squirrels, muskrats, or beavers. Look for teeth marks. These will be clean cuts, and plant tissue will not appear. torn (Figures 6.41 and 6.42). Frequently, teeth marks will be left in the plant material. These teeth marks can help gauge the size of the animal that caused the damage. Water sources close by may indicate issues from muskrats or beavers. Beaver damage is unique and easily identifiable due to their ability to chew into large trees and cause extensive damage to plants near ponds or streams. Other damage common from this group includes damage and removal of berries, fruits, or vegetables. Teeth marks left in berries or vegetables may help to gauge the size of the culprit, when there are no tracks or scat to aid in identification.

Medium-sized mammals: This group includes species like raccoons, skunks, opossums, armadillos, foxes, coyotes, and groundhogs. These species can range in size from several pounds up to the size of a medium-sized dog. (Coyotes can reach about 40 pounds.) Unfortunately, this is the most wide-ranging group in terms of the damage they can cause to plants or landscaping. Fruit-bearing trees, gardens, or landscapes may all be affected. Damage to plants may result when these mammals dig holes in the ground when searching for food or establishing dens. Some species may directly remove seeds, bulbs, fruits, or vegetables.

Large mammals: Deer, elk, black bears, cattle, and horses may tear and cut branches, leaves, or the whole plants of sprouting fruits and vegetables. Livestock culprits aren't actually considered wildlife but can cause damage similar to deer and elk. Large mammals are usually easier to identify because of their size and the amount of "evidence" they leave in the area. Tracks and/or scat are often present within the area, as well as extensive damage to plants that occurs in a very short period of time. Deer and elk are capable of consuming large quantities of hundreds of species of plants year-round. Damage will occur more frequently on plants or sections of plants where new growth is occurring. Bud damage occurs most frequently during winter months by both deer and elk, which can cause severe damage and potential death for the plants.

Figure 6.41. Clean cuts from a larger mammal, the beaver.

Figure 6.42. Clean cuts on a pine seedling caused by a rabbit.

Birds: Birds can cause damage to plants by either tissue removal or pecking damage. The removal of edible plant material such as fruits is the most common (Figure 6.43). Berries may have tears or damage from pecking. Tooth marks will not be present in this type of damage. Other types of birds, such as woodpeckers, may damage plants by pecking bark material. Sapsuckers, often confused with woodpeckers, create horizontal lines of holes in tree bark (Figure 6.44). These birds remove sap from holes to use as a food source during winter months.

Turtles: Damage from turtles is uncommon, but box turtles can feed in vegetable gardens. Look for damage close to the ground, with torn pieces of plant material or dime-sized or larger chunks missing out of vegetables.

Figure 6.43. Berry damage from birds (indicated by the white arrow).

Belowground Issues

Damage to plants can be directly or indirectly caused by wildlife. This is especially true when damage occurs below the soil surface. These issues are harder to diagnose as they are often out of sight. Roots of trees and bushes may be girdled by vole feeding during winter, when vegetative material is scarce. This belowground damage often goes unnoticed until the following spring, when plants show decline or poor vigor. In order to determine whether voles are active in the area during winter, monitor vole burrows.

Mole tunnels may disturb plant roots, but tunneling is usually only aesthetic and is not directly harmful to plants. Moles can be beneficial by managing grubs in lawns and increasing soil aeration. Checking for tunnels or soil mounds will indicate whether there are moles present within the area. Expect any plant damage to occur within close proximity to these tunnels.

Tools for Identifying the Cause of the Problem

Tracks and Scat

One of the easiest ways to determine potential species causing plant damage is to look for tracks or scat near the damage. This will help narrow down the possibilities of what may be causing the damage, but presence of tracks or scat does not mean the animal that left them is causing the damage. It is just a tool to help determine what species are in the area, and this information is added to the list of other "clues" to help narrow down the potential list of causative species.

When trying to determine the species that left a track, pay close attention to the size of the track, the number and position of fingers and toes, whether claws are visible, and, if there are multiple sets of tracks, the spacing between prints (Figure 6.45). Apply this information to a mammal or bird field guide, which will have a section on tracks. Alternatively, there are several good resources for track identification online including the Internet Center for Wildlife Damage (refer to Additional Resources section for link).

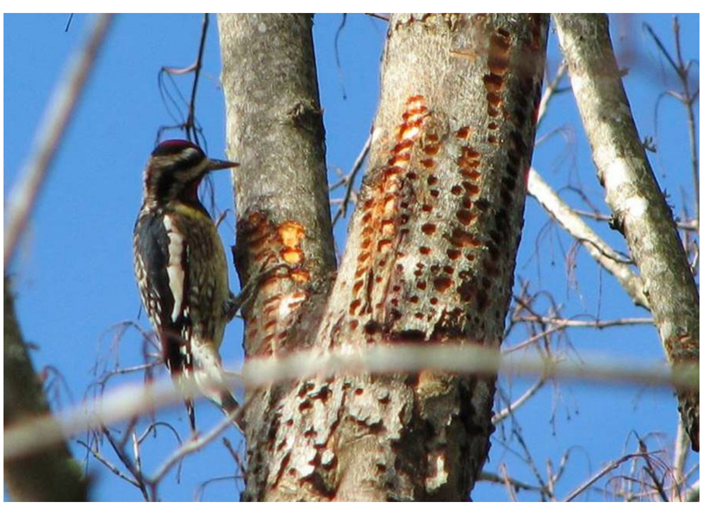


Figure 6.44. Sapsuckers damage trees by making lines of holes.

Figure 6.45. Example of tracks that may be left as evidence.

Scat is the fecal matter or droppings of wild animals and is a reliable sign that wildlife has been present in the area. When examining scat, avoid touching or wear rubber gloves to protect against potential diseases. Take note of scat size, width, and shape (Figure 6.46). Characteristics, such as a tubular or rounded shape, flat or pointed ends, and singular or multiple droppings, will help guide the identification of the species. See "Scat Identify Key" resource in the Additional Resources section to help identify scat.

Trail Cameras

Trail cameras offer an affordable and easily implemented option to determine causes of wildlife damage. Cost of cameras can be as little as $25 depending on features and brand. In most situations, the cheaper versions are capable of taking the quality pictures needed to identify wildlife culprits. Set the camera up in a manner that maximizes the chances of the nuisance wildlife triggering the device. Place a camera in the area that is experiencing the issue, preferably close to the plant(s) being damaged. Cameras should be placed at an appropriate height for the size of animal thought to be causing the problem. For example, if squirrels or rabbits are suspected, direct the camera to focus closer to the ground. With deer or elk, cameras should be placed about hip height. Even though a certain species is captured in a picture, this may not be the species that is causing the problem. Use pictures to help narrow down the potential list of causative species.

Resources and Reference Material

References can be helpful when attempting to identify wildlife species and damage. These resources include field guides and internet sources like the Internet Center for Wildlife Damage.

Abiotic Causes

Abiotic plant injury may be caused by environmental or physical conditions. These problems are noninfectious, meaning they are not caused by living organisms. In many cases, vigorous plants are healthier than those under stress. Thus, it is important to consider the age-old horticulture recommendation of "the right plant for the right place." For plants to thrive, they must have light, water, and nutrients in the proper amounts and temperatures within a range that supports growth. Plants grown in a location similar to their native habitat, especially in areas with minimal disruptions, will generally suffer less abiotic injury than those introduced from more exotic locations or those planted in areas with human-impacted habitats. While plants differ greatly with regard to optimal environmental conditions, the injuries observed when conditions are not met also vary greatly. Besides natural causes, plants sometimes suffer injury from chemicals or constraints humans bring into their growing space, such as herbicides, deicing salts, and synthetic materials around stems and roots. All of these noninfectious factors may contribute to plant injury.

Weather

Several aspects of weather may affect plant growth, including temperature, sunlight, and rainfall. Damage that results from weather conditions may be exhibited as a wide range of symptoms.

Late-summer fertilization (especially nitrogen) and abundant soil moisture encourage perennials to continue to grow well into autumn and delay cold acclimation. Plants that fail to adjust to cooler temperatures may exhibit winter damage to buds or stems. This damage appears as partial dieback to stems as growth resumes in spring or as lack of vegetative and/or flower bud growth.

Figure 6.46. Raccoon scat is dark and tubular.

Figure 6.47. Broad-leaf evergreens such as magnolia may exhibit leaf burn as a result of winter injury.

Broad-leaf evergreens (such as holly, magnolia, cherry laurel, and boxwood) may exhibit another type of winter damage called leaf burn or leaf scorch (Figure 6.47). On sunny days, these plants photosynthesize with open stomata. Cold, winter winds, combined with low water availability due to frozen soils, cause desiccation of leaves via rapid loss of water through stomata. In severe cases, this leaf burn may affect a large portion of the plant's canopy, causing deformity or even death. Fleshy stems with little bark coverage may also be affected. Milder cases of leaf burn may be expressed only on the leaf margins and may only cause temporary unsightly brown leaves that are replaced in spring with new growth. It is important to keep evergreens well-watered in late fall and winter as long as soils are thawed. A layer of mulch helps retain soil moisture.

Frost damage is another type of cold-temperature problem that can occur in spring as plants begin regrowth or as temperature-sensitive annuals are planted. Frost may occur when temperatures drop a few degrees or more below freezing. Sensitive plants exposed to frost may display blackening of young growing tips, leaves, flowers, or buds. Annual plants whose growing tips are damaged may be completely lost. Perennial plants usually regrow, but sensitive flower buds may be damaged, resulting in reduced flower and fruit production. Plants may be protected from frost by covering with light cotton or synthetic fabric material to catch warmth from the ground and hold it close to the plant. It is important that such material not only cover the plant, but also stretch down to the ground. Sometimes small plants are covered with solid objects such as flower pots or buckets; these objects should be removed to allow ventilation as temperatures warm. Coverings offer protection from light frost but are not effective when temperatures drop below 25°F.

Another aspect of cold-temperature damage may occur on tropical houseplants or certain vegetables. These plants are accustomed to growing under warm conditions, and as a result, low, non-freezing temperatures (40°F-50°F) may cause damage. Common houseplants such as peace lily, philodendron, and certain orchids, exhibit wilting and even death with prolonged exposure to low, non-freezing temperatures. Cold damage occurs with certain vegetables after prolonged storage under refrigerated conditions. Cucumbers, tomatoes, peppers, and watermelon may exhibit water-soaked tissue when refrigerated for long periods.

Hot temperatures, usually coupled with bright sunlight, may also cause damage to plants. For example, hot temperatures increase water demand in plants, causing them to release more water through their stomata than can be supplied by the root system. This results in temporary wilting, but plants usually recover overnight if there is sufficient soil moisture. Nevertheless, some scorching of leaves may result (Figure 6.48).

Plants are naturally adapted to certain light conditions (sun, part-sun, or shade). For example, shade-adapted plants will show symptoms such as yellowing, scorch, burn, or death when grown under sunny conditions. Plants germinated and grown

Figure 6.48. High temperatures can result in drought stress, which may be observed as leaf scorching.

Figure 6.49. Plants subjected to high soil moisture or flooding may exhibit a variety of symptoms, including yellowing of new growth and defoliation.

in one environment (greenhouse, house windowsill, nursery holding area) and then transplanted outdoors may scorch or burn when suddenly exposed to brighter light. It is important to gradually expose these plants to higher light conditions (called hardening off) before permanently planting them in a brighter location. Even houseplants abruptly moved to a bright window may exhibit some damage to leaves accustomed to lower-light conditions. Conversely, plants that are grown in high-light conditions and then moved to shade usually exhibit stunted growth and defoliation. New leaves produced in shade conditions are larger and thinner, and plants generally produce fewer flowers than similar plants growing in sun.

Figure 6.50. Decline refers to a decrease in plant vigor and can result from numerous abiotic issues.

Extremes in rainfall may also result in abiotic damage to plants. Severe low-moisture conditions or drought may cause symptoms such as wilting, yellowing, marginal leaf burn, and premature fall coloration of leaves. Insufficient rainfall is best remedied by irrigation. However, spotty or shallow irrigation may fail to meet plants' needs. A weekly, relatively deep irrigation equivalent to one inch of rain (wetting the soil to six to eight inches deep) is usually more beneficial to plants that frequent shallow irrigation. Newly transplanted plants with limited root systems may benefit from frequent shallow irrigation until roots are established. Too much rainfall or irrigation may also cause damage to plants. Plants under high soil-moisture or flooded conditions may exhibit wilting, yellowing of new growth, and defoliation due to damage to roots caused by low oxygen (Figure 6.49). Ensure that soils are well drained and aerated by incorporating organic matter; elevate soil in mounds or raised beds in areas of poor drainage.

Physiological Disorders

Physiological disorders are often characterized by gradual decline over time. Symptoms of decline include reduced growth, premature leaf coloration, winter injury, whole-plant dieback, water sprout production on woody plants, and increased susceptibility to insects and disease. Decline may be caused by a number of abiotic issues (Figure 6.50). Soils may lose structure and become compacted due to traffic, which impacts root health and subsequently foliage health. Packaging material, such as synthetic burlap or galvanized wire baskets, often constricts root systems, leading to decline.

Improper planting techniques may also result in decline or death of a plant. Prior to planting, all potentially girdling roots should be removed, so they do not wrap around the base of the plant. Plants should be installed at an appropriate depth and then maintained correctly. Improper maintenance, such as excess mulch or exposed roots, can lead to increased plant stress and an increased risk of decline. Symptoms of improper planting practices may appear within the first few years after planting. However, other symptoms may take five or more years to become visible.

Inappropriate temperature, rainfall, or sunlight may also result in decline, particularly if these conditions are mild or otherwise not extreme. This situation results in delayed symptom development but compromises plant health over time. Decline is best managed by good cultural practices. Proper fertilization, irrigation during drought, mulching, and proper pruning may help to slow or reverse decline. It is important to closely monitor pest situations on stressed plants, as they often develop compromised natural pest resistance.

Mechanical Damage

Plants often suffer physical damage from devices used in managing the landscape. Synthetic material left on plant roots may eventually constrict the root system. Synthetic burlap or twine should be completely removed from the root system before planting. It is common to stake trees after planting to prevent them from blowing over during strong winds. Trees staked too tightly are slower to establish new root systems than those that are allowed to sway slightly. The material used to secure the tree to the stake may also be problematic. Bare wires or twine tightly secured to the trunk or branches may be quickly overgrown by the plant, making it difficult to remove later and eventually causing constriction and girdling of the branch or trunk (Figure 6.51). Covering the section of twine or wire that touches the tree with flexible garden water hose or coarse fabric will delay growth around the fastener. In most instances, staking material should be removed after one growing season.

Mechanical damage may also be caused by wind, ice, or snow load. For woody plants, proper pruning, especially when plants are young, helps to develop strong trunks and branch angles that are better able to withstand weight and force. A discussion of proper pruning techniques is provided in Chapter 17, Care of Woody Plants.

Figure 6.51. Wires or other materials used to secure plants should be removed at the appropriate time to avoid constriction and girdling of the plant.

Another cause of decline is damage to the lower trunk by string trimmers or landscape equipment. Plants' phloem vessels are located just under the bark and can be easily damaged, especially on young trees. If damage occurs, photosynthates from the leaves fail to be transported to the root system. A weakened root system results in decline, and in severe cases, plants may fail to leaf out in spring. While it may seem logical to cover the base of the trunk with protective material, this practice also presents problems. Protective covers or wraps may retain moisture and invite decay. The best practice is to maintain a wide layer of mulch around the tree, making it unnecessary to trim or mow close to the trunk. However, mulch itself can be damaging when it is applied too deeply or too closely around the trunk.

Nutrition

There are 16 nutrients that are necessary for plant growth. Deficiencies or excess of any of these nutrients may cause symptoms such as discoloration (Figure 6.52), stunting, distortion, or burning. Sometimes, nutrients are present in adequate amounts but soil pH, when too acidic or too alkaline, limits the availability of nutrients to plants. Plant roots that are compromised by poor drainage, compacted soils, low soil moisture, or pest issues may also result in nutrient deficiencies due to the plant's inability to uptake nutrients. Symptoms of nutrient deficiency or toxicity are characterized in Chapter 1, Basic Botany. When nutritional issues are suspected, the first step is to complete a soil test (see Chapter 4, Soils and Fertility). Testing the soil will determine the level of important nutrients in the soil, as well as the soil pH. Recommendations from a soil test may help remedy the nutritional issue or, in rare cases, suggest the need for further analysis.

Figure 6.52. Nutritional deficiencies may result in a wide range of symptoms, including discoloration of plant tissue.

Figure 6.53. Chemical damage may be observed as chlorotic or necrotic spotting on leaf surfaces.

Chemical Damage

Patterns of chemical injury on individual plants differ, depending primarily on whether a chemical causes damage directly on contact or whether it is absorbed and moved throughout the plant. Direct-contact damage can occur on foliage, stems, and roots. Symptoms from shoot-contact chemicals occur over the general plant canopy. The injury does not spread with time or move to previously undamaged plants. Injury is characterized by chlorotic or necrotic spotting (Figure 6.53). Spots are usually uniform in size and evenly distributed over all or most plant surfaces, with a distinct margin between affected and healthy tissue.

If a chemical is applied directly to aboveground parts, the application pattern may be observed. For example, the pattern of spray droplets may be visible, or areas where spray accumulated along leaf edges may show the most damage. In the case of a toxic gas (volatile chemical), areas between leaf veins and along leaf margins, where water concentration in lowest, develop damage first. Examples of shoot/foliage contact chemicals are foliar-applied fertilizers; the agricultural herbicides paraquat, acifluorfen, and dinoseb; and herbicidal oils. (Very few, if any, contact herbicides are available to home gardeners.)

Toxic contact chemicals in the root zone, including excess fertilizer, can result in damaged roots or poor root development. Roots can be injured and root tips may be killed. Damaged roots are unable to obtain water; thus aboveground symptoms such as reduced growth, wilting, or chlorosis may be observed. In severe cases, wilting can occur even when the soil is wet. Lower leaves generally wilt first, followed by the drying of leaf margins (leaf scorch). Herbicides that inhibit root growth include the agricultural herbicides dinitroanilines, DCPA (Dacthal), and diphenamid. Excess nitrogen fertilizer can have the same results. Keep in mind that many other factors also injure roots or inhibit their growth, including nematodes, disease-causing pathogens, soil compaction, cold weather, salinity, and nutritional deficiencies or excesses.

Some chemicals can move throughout a plant after being absorbed. The effects of these mobile chemicals depend upon whether they are transported in the xylem or the phloem. Toxic chemicals transported in the xylem primarily cause symptoms in older plant foliage as they move upward from the crown. Examples of xylem-transported chemicals include urea fertilizer and the agricultural herbicides triazine, alachlor, and metolachlor. Chemicals transported through the phloem may move in many directions from the point of absorption; for example, it may move from the shoots to the roots or vice versa. Symptoms caused by phloem-transported chemicals occur primarily in the plant's new growth and meristematic regions. Affected young tissue is discolored or deformed, and injury may persist for several sets of new leaves. Examples of phloem-transported chemicals include the common garden herbicides 2,4D, dicamba, and glyphosate.

Diagnostic Assistance

In many cases, it may not be possible to determine the cause of a plant problem without additional assistance. Numerous resources are available to aid in this process. County-based Extension agents are local resources that can be utilized to assist homeowners with identification of the cause of a plant problem, as well as to provide recommendations regarding management of problems. In Kentucky, at least one agriculture and natural resources and/or horticulture agent is located in each of the 120 counties. Agents possess a broad range of knowledge on a variety of agricultural and horticultural topics. These individuals may provide various services to diagnose plant problems, including consultation, sample assessment, and/or site visits. Contact the local Cooperative Extension office for more information on services provided. To locate a local Extension office, visit https://extension.ca.uky.edu/county.

Diagnosis of a specific plant problem may require a specialist to assist in the identification process. The University of Kentucky and Kentucky State University both employ specialists that focus on specific areas of plant health. Specialists in the departments of plant pathology (diseases), entomology (insects), forestry (wildlife), and horticulture (abiotic) partner with Extension agents to provide homeowners and commercial growers with diagnoses and management recommendations for the wide array of plant problems. These specialists are accessible through local county Extension agents.

A wide range of diagnostic services are available to assist residents of Kentucky in determining the causes of plant problems and growing healthy plants. A county Extension agent can assist in determining which, if any, of these services are needed. Homeowners should work with the county Extension agent to submit samples. This ensures that appropriate samples are provided, improving response time and reducing the risk of an insufficient sample submission.

Plant Disease Diagnostic Laboratory: When a plant problem has been determined to be the result of disease, a sample of the affected tissue may be sent to one of the two University of Kentucky Plant Disease Diagnostic Laboratories. Diagnosticians review samples using microscopy, culturing, and/or molecular methods. Diagnosticians provide identification and management information. The University of Kentucky plant pathology fact sheet *Submitting Plant Specimens for Disease Diagnosis* (PPFS-GEN-09) provides helpful information for collecting appropriate samples.

Insect Sample Submissions: When insects have been determined to be the issue, plants with suspected insect injury, photos, or vials containing an insect sample can be submitted directly to the University of Kentucky Department of Entomology. Specialists review these samples and provide correct identification and management information.

Weed Identification: Extension weed specialists at the University of Kentucky Department of Plant and Soil Sciences are able to provide species identification, as well as weed management information. When herbicide injury is suspected, specialists in this program review samples to determine whether the problem is consistent with herbicide contact. However, the University of Kentucky does not provide herbicide residue testing.

Plant Identification: The Herbarium at the University of Kentucky Department of Forestry can provide identification of woody plants and wildflowers.

Soil Tests: The University of Kentucky Division of Regulatory Services provides soil testing for a minimal fee. Soil samples can be submitted through a county Extension office. Once soil is analyzed, a report is provided that includes recommendations to improve soil health.

Plant Tissue Analysis for Nutrients: Several private laboratories can provide an analysis of the nutrient composition of plant tissue for a fee. A county Extension agent can determine if this service is needed and provide additional information on submitting a sample.

Summary

The process of diagnosing plant problems can be a challenging exercise in critical thinking. Information about the problematic plant is collected by considering the identity of the plant and its history. Examination of the site may also provide additional information that may aid in the process. A thorough analysis of symptoms and signs is important for the diagnostic process. After collection, this information is used to determine whether the problem is the result of a living factor (disease, insect, or wildlife) or a non-living cause. It may be necessary to consult a variety of resources in order to draw conclusions from the information collected. If a probable cause cannot be determined after a review of the information collected, numerous services are available to assist in the diagnosis of a plant problem.

Appendix

Appendix A: Considerations for Diagnosis of Ornamentals in the Landscape

Additional Resources

University of Kentucky Department of Plant Pathology Publications https://plantpathology.ca.uky.edu/extension/publications

University of Kentucky Department of Entomology Publications https://entomology.ca.uky.edu/entfacts/

University of Kentucky Department of Forestry Wildlife Publications https://forestry.ca.uky.edu/wildlife-pubs

University of Kentucky Wildlife Damage Website https://forestry.ca.uky.edu/wildlifedamage

Internet Center for Wildlife Damage http://icwdm.org/

Scat ID Key https://icwdm.org/identification/feces/scat-id/

University of Kentucky Department of Horticulture Residential Publications http://www.uky.edu/hort/home-horticulture

University of Kentucky Cooperative Extension Service https://extension.ca.uky.edu/

Kentucky State University Cooperative Extension Service https://www.kysu.edu/academics/college-acs/school-of-ace/co-op/index.php

Considerations for Diagnosis of Ornamentals in the Landscape https://plantpathology.ca.uky.edu/files/ppfs-gen-15.pdf

Kentucky Cooperative Extension Service County Office Information http://extension.ca.uky.edu/county

Submitting Plant Specimens for Disease Diagnosis https://plantpathology.ca.uky.edu/files/ppfs-gen-09.pdf

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