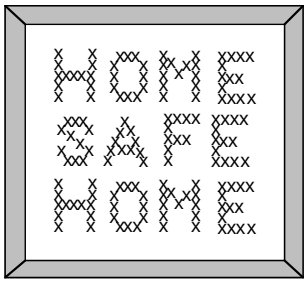
Alternatives
A Washington Toxics Coalition Fact Sheet



Preventing Plant Diseases: Leaves

by Doug Collins

Ambling down the bucolic roads that wind amongst European vineyards, one is naturally tempted to taste the fruit. Pilfering the sweet, easy to reach grapes was apparently a severe problem in 1882 in the Bordeaux region of France. As the grapes would ripen, some growers took to spraying plants along the road with a blue substance made by mixing copper sulfate, lime, and water. Would-be grape thieves were deterred by fear of poisoning. French grape growers were also vexed by the recent arrival in 1878 of a plant pathogen from America, *Plasmopara viticola*. This pathogen caused severe downy mildew on the susceptible grapes grown in France. The disease defoliated grapevines everywhere in the Bordeaux region. Everywhere, that is, except the blue colored vines along the roads. When Alexic Millardet, a local professor of botany, noted this fact, the first foliar applied liquid fungicide, "Bordeaux Mix," was discovered. Today, Bordeaux Mix is used to control a suite of plant pathogens on the leaf surface, including powdery mildew, anthracnose, rust, and bacterial pathogens.

The pathogenic fungi that parasitize the aerial portions of plants are a unique and varied lot. Their variability is due in part to their ability to reproduce many times during a season. Many of these plant pathogens do not depend on sexual reproduction for success; instead they rely on a strategy of rapid asexual reproduction to spread large numbers of spores. As soon as one spore infects a leaf it is on its way to producing thousands more, without needing to find a mate.

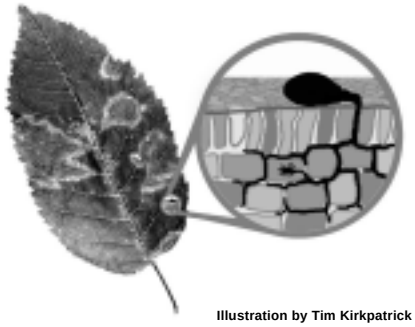


Illustration by Tim Kirkpatrick

A germinating spore sends its hyphal strand into the leaf, where it willl secrete damaging compounds.

The Leaf Surface

Leaf-inhabiting microorganisms exist in a harsh, exposed environment. The surface of plant leaves are often marked by drastic daily changes in temperature, ultraviolet radiation, and moisture, yet a great diversity of bacteria and fungi are found in abundance on leaf surfaces. In soil, the vast majority of microbes are found along the roots of plants, where leakage of sugars provides food. Similarly, leaf-inhabiting organisms accumulate near leaf veins.

The physical surface of leaves reflects the multiple function of leaves. A plant leaf is at once a solar panel, gas exchange system, and sugar production factory. Plant leaf surfaces are pocketed with minute openings through which gases diffuse. Tiny hairs interrupt the leaf surface and some secrete compounds that attract or deter microorganisms and insects. Veins move nutrients and water from the soil to the sugar production cells, then carry sugars to the rest of the plant. The junctions at leaf vein margins and between adjoining epidermal cells form protected valleys. Some sugars are leaked from veins, providing a source of nutrients to bacteria and fungi that colonize leaf surfaces.

The leaf surface is a harsh environment for pathogens and non-pathogens alike. When conditions suit a pathogen, non-resistant hosts will succumb to disease without intervention. Pruning and plant spacing alter the environment in the plant canopy. Increasing air flow and sun exposure can affect the availability of water on the leaf surface, decreasing new infections. Intervention can also occur by application of inhibitory chemicals, specific biological control organisms, and by applying a community of microbes with compost tea.

Leaf Infection

When a fungal spore lands on a leaf it usually sticks because spores have a coating that becomes sticky when moistened. When the leaf surface is moist, the spore germinates and a hyphal strand emerges from the spore. Depending on the species of fungus, this special strand either penetrates the cell wall directly or moves over the surface of the plant in search of an opening. The hypha plunges into the plant and begins secreting compounds that break down the plant cells and release nutrients from the host. If the pathogen has invaded a susceptible host, the pathogen spreads, infection progresses, and disease develops.

Harmful bacteria usually enter plants through leaf openings when leaves are wet. Unlike fungi, bacteria do not spread by growing longer and branching but rather by dividing. They reproduce rapidly and are transported through the plants' xylem and phloem vessels. Millions of bacteria ooze from infected plant tissue and are spread by wind, rain, insects, or pruning shears.

Plants have a range of defenses that they use to protect themselves from pathogen attack. Fortunately, many pathogens gain entry into plant leaf cells only to find that they are on the wrong plant or on a resistant plant and disease does not develop. The host "senses" the presence of the pathogen and counterattacks with toxic chemicals. But a susceptible host reacts too slowly. The initial hypha enters cells, begins taking nutrients from the host and branching into more and more hyphae, all the time detoxifying the chemicals secreted by the plant in order to prevent just such an infection.

Diseases Caused by Aerial Pathogens

Some common diseases and symptoms are shown in the table to the right.

Disease Prevention

Aerial pathogens reproduce rapidly. During the growing season asexual reproduction allows for mildews, rusts, and leaf spot pathogens to increase their numbers quickly. Most foliar fungicidal sprays work by protecting plant leaves,

Diagnosing Diseases

Fungal disease (pathogen)	Symptoms
Anthracnose (various) apple, dogwood, maple, oak, sycamore, etc.	Often appears on leaves as brown blotches. Can invade branches causing cankers and girdling. Apples show brown, depressed, circular spots in storage.
Black spot (*Diplocarpon*) rose	Circular, black spots 1/16-1/2" dia. on leaves. Leaf yellowing or leaf drop.
Botrytis blight (*Botrytis cinerea*) blueberry, dahlia, ornamental flowers, rose, rhubarb, etc.	May start as water-soaked brown to tan spots. In high humidity, gray spore mass develops on blossoms, buds, fruit, or petal tips. Can cause twig or cane cankers on blueberry and rose.
Brown rot (*Monilinia fructicola* and *M. laxa*) cherry, peach, plum (stone fruits)	Sudden wilting and browning of flower parts. Dead flowers may be covered by a grayish brown powdery mass of spores. Fruits may mummify on tree.
Downy mildew *(Peronospora* and others) lettuce, grape, onion, cabbage, etc.	Yellow to brown spots on the upper surfaces of leaves. Fuzzy (downy) growth on lower leaf surfaces during humid conditions.
Early blight (*Alternaria tomatophilai, A. solani*) potato, tomato	Small, irregular, blackish brown spots usually on older leaves. Spots enlarge and may show ridged concentric rings. Leaves may become yellow. Fruit (tomatoes) may develop sunken concentric circles.
Late blight (*Phytophthora infestans*) potato, tomato	Water-soaked spots appear on leaves and stems, enlarge rapidly, and turn brown or black.
Leaf curl (*Taphrina deformans*) peach	Leaves turn yellow to red and are thickened, curled, and crisp. Twigs are occasionally distorted and a few fruit may show a reddish growth on the surface.
Leaf spot (*Mycosphaerella arbuticola*) madrone	Affected leaves have numerous small spots.
Leaf spot (*Phyllosticta spp.*) maple, rhododendron	Small, irregularly circular, reddish-brown spots with borders.
Phytophthora canker (*Phytophthora cactorum*) madrone	Cankers occur near base of tree. Have distinct margin, may be brown or blackish and water soaked. Leaves may be stunted or may die.
Powdery mildew (various) apple, cucumber, cantaloupe, hop, pear, raspberry, rhododendron, rose, squash, strawberry	Leaves, stems and flowers covered in a fuzzy, powdery, whitish coating. May be light yellow to purple areas on leaves, especially rhododendrons.
Rust (various) garlic, juniper, rose, etc.	Yellow, orange, or brown spores on infected leaves. Some rusts form cankers or galls on woody hosts.
Scab *(Venturia spp.*) apple, cotoneaster, pear	Affected leaves become twisted or puckered, with black circular, "scabby" spots on their upper surfaces. Scabby spots on fruit.
Stem rot (*Phytophthora syringae*) crabapple, flowering pear, etc.	Cankers on stems of young plants, primarily on lower stems and bases of tree trunks.
Sudden oak death (*Phytophthora ramorum*) Coast live oak, black oak, Shreve oak, and tanoak (symptoms on rhododendron, madrone, etc.)	Leaf spots that can grow into whole-plant infections. Lethal cankers can occur on the trunk of oak trees. Cankers have water-soaked regions of dead bark.
Diseases caused by	**Symptoms**
Bacterial blight (*Pseudomonas spp.*) cotoneaster, poplar, etc.	New growth wilts and turns black in spring. Shoot dieback, cankers with longitudinal cracks.
Bacterial canker cherry, peach, prune, plum	Cankers, gum exudation, and dieback of girdled branches. Dead buds and leaf spots can occur.
Bacterial leaf spot (*Pseudomonas spp.*) maple	Dark brown, sunken spots appear on leaves, flower stalks, and calyx parts.
Fire blight (*Erwinia amylovora*) apple, cotoneaster, pear	Flowers, foliage, and eventually entire branches are blackened and killed

Reference: Pacific Northwest Plant Disease Management Handbook

Resistant or Tolerant Varieties

Host	Disease	Resistant or Tolerant Variety
Apple	Scab (*Venturia inaequalis*)	'Akane,' 'Chehalis,' 'Liberty,' 'Prima,' 'Tydeman Red'
	Powdery mildew (*Podosphaera leucotricha*)	'Golden Delicious,' 'Red Delicious,' and 'Delicious' strain
Blueberry	Bacterial canker (*Pseudomonas syringae*)	'Ellio,' 'Rancocas,' 'Weymouth'
Cantaloupe	Powdery mildey (*Erysiphe cichoracearum* and *Sphaerotheca fuliginea*)	Numerous available. Marked with "PM" in catalogues.
Cherry	Bacterial canker (*Pseudomonas syringae*)	'Corum,' 'Sam,' 'Sue'
Cotoneaster	Fire blight (*Erwinia amylovora*)	Cotonester adpressus var. praecos, C. amoenus, C. apiculatus, C. canadensis, C. dammeri var. radicans, C. microphyllus, C. nitens, and C. zabelii
Cucumber	Powdery mildew (*Eryisiphe cichoracearum* and *Sphaerotheca fuliginea*)	Numerous available. Marked with "PM" in catalogues.
Dogwood	Anthracnose (*Discula destructiva*)	Kousa dogwood (Cornus kousa), bunchberry (C. canadensis), cornelian cherry dogwood (C. mas), Japanese cornel dogwood (C. officianalis)
Grape	Botrytis bunch rot (*Botrytis cinerea*)	'Cabernet sauvignon'
Hop	Powdery mildew (*Sphaerotheca macularis*)	'Nugget,' 'Cascade,' 'Mt. Hood'
Peach	Leaf curl (*Taphrina deformans*)	'Muir,' 'Krummel,' 'Red Haven,' 'Rosy Dawn,' 'Frost'
Potato	Late blight (*Phytophthora infestans*)	'Russet Burbank' has moderate resistance
Raspberry	Cane blight (*Leptosphaeria coniothyrium*)	'Boysenberry,' 'Loganberry,' and 'Youngberry'
	Powdery mildew (*Sphaerotheca macularis*)	'Chilcogin,' 'Meeker,' 'Nootka,' 'Sumner,' 'Willamette'
Rhododendron	Powdery mildew (*Microsphaera azaleae*)	none
Rose	Black spot (*Diplocarpon rosae*)	'Electron,' 'Just Joey,' Keepsake,' 'Las Vegas,' 'Silver Jubilee,' 'Voodoo,' 'Love,' 'Europeana,' 'Impatient,' 'Matangi,' 'Play Girl,' 'Playboy,' 'Regensberg,' ' Sarabande,' 'Sexy Rexy,' 'Showbiz,' 'Trumpeter,' 'Viva,' Dortmund,' 'Dublin Bay,' Royal Sunset'
	Powdery mildew (*Sphaerotheca pannosa*)	
	(Varieties listed have shown resistance to both diseases in the maritime Northwest. Resistance may change with location and over time.)	
Strawberry	Red stele (*Phytophthora fragariae var. fragariae*)	'Hood,' 'Totem,' 'Benton'
	Powdery mildew (*Sphaerotheca macularis*)	'Hood,' 'Totem,' 'Benton'
Sycamore	Anthracnose (*Apiognomonia veneta* ; asexual stage *Discula platani*)	'Bloodgood,' 'Columbia,' 'Liberty'
Tomato	Early blight (*Alternaria solani*)	'Early Cascade,' 'JOT-99197,' 'Juliet'
	Late blight (*Phytophthora infestans*)	'Juliet,' 'Legend' is tolerant

often by inhibiting spore germination. Only a few fungicides can stop leaf infections that began 1-4 days earlier, but with few exceptions these are not available to home gardeners. Therefore, disease control is most effective by excluding pathogens, planting resistant varieties, and controlling the environment to deter a disease epidemic.

Exclusion: Exclusion is difficult with foliar pathogens. An obvious measure is to shop carefully for plants, buying healthy plants that do not have visible signs of disease. But due to their rapid and numerous production of spores and their ability to release spores from a high point on a plant, the rusts, mildews, and leaf spot pathogens are pervasive. Since many foliar pathogens reside in infected plant material during the winter months, correct disposal of infected leaves and stems at the end of the season can reduce disease severity in the following year. Infected plant material, be it leaves from a scab infected apple tree or a powdery mildew infected pumpkin, should be removed from the plot and composted in a hot compost pile or at a commercial compost facility.

Certain rust diseases require two hosts to complete their lifecycle. Examples include Amelanchier (Serviceberry) Rust, which must infect a juniper or cedar to complete its lifecycle, and rust of Douglas Fir, which must infect a poplar to complete its lifecycle. Occasionally it is practical to remove the alternate host from the landscape to control the disease.

Resistance: Plants have an intricate defense system that protects them against attack by fungi, bacteria and insects. Many pathogens are capable of infecting only certain species and varieties of plants, but others are more general in their infection capabilities. A pathogen can be defined as an organism capable of evading a host's defenses. Plant breeders select for plants that are able to avoid infection even when the environment is suitable for the pathogen. Resistance is a powerful tool for disease prevention. The table above lists resistant plants for many common pathogens.

Environment: Water on the leaf surface is probably the most important element required for leaf and stem pathogens to succeed. Apple scab, late blight, and most downy mildews and anthracnoses require a film of water on the plant or high relative

humidity in almost every stage of their life cycle. Surprisingly, water deters powdery mildew, which thrives in hot weather and can germinate and infect plants when sufficient humidity is present.

Water on leaf surfaces can be controlled by irrigation method and timing. Drip irrigation and soaker hoses prevent water from landing directly on leaves. Even if these methods are used, however, evaporation of water from wet soil will still increase humidity in the vicinity of the leaves. In some climates, morning dew can deposit enough water for pathogen infection, even if sprinklers are not used. Drip irrigation and soaker hoses eliminate splashing water, a dispersal method for many aerial pathogens that overwinter in soil. Irrigating in the morning allows plant leaves to dry during the day. This is especially important if overhead sprinklers are used.

Temperature can either enhance or discourage a plant disease. Both plants and pathogens have an optimum temperature for growth, as well as minimum and maximum temperatures, beyond which they will not grow well. Pathogens are promoted when the temperature is near the pathogen's optimum but is too hot or cold for the host to grow well. Some diseases, such as Late Blight, are more common in cooler temperatures while others, such as Early Blight, are favored by hotter temperatures (75-84° F).

Though there is little one can do about the weather, the microclimate of a leaf surface can be influenced by the distance between plants and by pruning strategies. Wider plant spacing and effective pruning increase air circulation, decreasing the drying time for morning dew or water from a sprinkler. Directions for best plant spacing are given on seed packets. Thinning seedlings early in the season will prevent a dense canopy of foliage and potential disease problems later in the season. Prune and train vines to keep their leaves away from the ground or splashing soil particles that may carry pathogen spores. Also, remove plants that are heavily diseased or prune diseased branches of perennials.

Plants grown in healthy, fertile soil are more capable of avoiding infection by both above-ground and below-ground pathogens. Stress due to lack of nutrients or water weakens plants and increases susceptibility to infection. A diverse community of microbes in the soil can activate plants' defenses, making them more resistant to attack by foliar pathogens. See our companion fact sheet *Preventing Plant Diseases: Roots* for tips about encouraging a healthy soil environment.

If resistant varieties are not available or disease pressure is severe, a protective, foliar-applied spray can be effective in preventing pathogen infection. Compost tea (see sidebar) can be an effective disease prevention tool, though results vary due to the quality of compost. There are also a few biological control agents available for leaf pathogens (see table at the right). If you are considering using a chemical fungicide, get a proper diagnosis first. Send a root sample to the lab as well because root pathogens often cause leaf symptoms or weaken plants, making them susceptible to infection by foliar pathogens that may only be a secondary problem to the root disease. ■

Plant Disease Clinics and Labs

Plant Disease Clinic; Cordley Hall, Room 1089, Oregon State University, Corvallis, OR 97331-2903; Tel: 541-737-3472; putnamm@bcc.orst.edu

Washington State University Plant & Insect Diagnostic Lab, 7612 Pioneer Way East, Puyallup, WA 98371-4998; Tel: 253-445-4582; e-mail to: glass@puyallup.wsu.edu or www.puyallup.wsu.edu/

Ribeiro Plant Lab, Inc. 10744 NE Manitou Beach Drive, Bainbridge Island, WA 98110; Tel: 206-842-1157; fungispore@aol.com or www.ribeiroplantlab.com

Compost Tea

Like a stiff brew of Earl Grey, compost tea is made by steeping dry material in water to extract the soluble elements. In the steeping process, soluble nutrients are dissolved and microbes are dislodged from compost particles and suspended in the water. This mix is then sprayed or poured onto soil or leaves.

Compost tea is made in many different ways, from using a burlap sack filled with compost in a 5-gallon bucket of water to 500 gallon tanks with air pumps that keep the water aerated and circulating. Both methods can produce quality compost tea if made with quality compost. Here is a simple method for producing compost tea used by Lisa Taylor, Seattle Tilth Children's Garden coordinator:

1. Fill a 50 gallon barrel with water. Let sit for 1 hour or overnight to let the chlorine in the water dissipate.
2. Fill a 25-pound burlap sac with quality compost and tie it off tightly.
3. Drop the compost "tea bag" in the water and let sit for 2 days to 2 weeks, depending on the temperature. In the middle of the summer, 2 days is sufficient, during cooler weather in spring and fall the brew can be left for up to 2 weeks.
4. The mixture can be sprayed directly on leaf tissue or drenched into the root zone of plants.

Foliar Biological Control Agents

Product	Labeled for
Serenade	Gray mold, powdery mildews
AQ10	Powdery mildew, etc.
BlightBan A506	Frost injury, fire blight
TopShield	Botrytis blight, powdery mildew
Messenger	Many