Alternatives
A Washington Toxics Coalition Fact Sheet

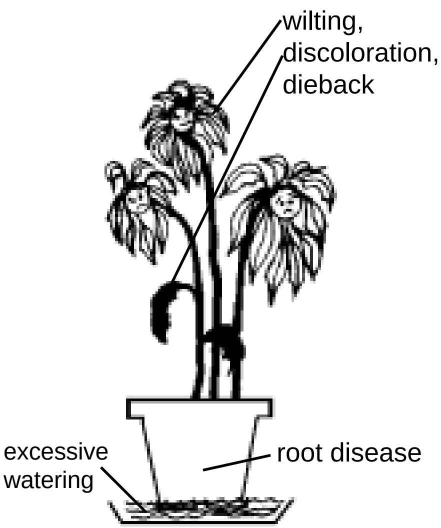
HOME SAFE HOME

Preventing Plant Diseases: Roots

by Doug Collins

The earth's soil is home to a vast array of life as astounding as the immensity of space. Living on the surfaces of weathered rock particles and organic matter and teeming along the roots of every plant are bacteria and fungi. Billions of them can inhabit one teaspoon of soil.

Bacteria and fungi are true alchemists, converting fallen leaves into plant nutrients. The diet of soil microbes is varied, from dead plant material and insects to sugars leaked from plant roots, even to other microbes. There are also organisms that survive by feeding on living plants. Those that interfere with plant function and cause a disease are called plant pathogens. Like other soil inhabitants, most plant pathogens are fungi, water molds, nematodes, and bacteria. No matter what type of plant you are trying to grow, considering the plant pathogens in the soil will help you grow healthy plants.



Symptoms of root diseases are often noticed above ground. Wilting can indicate either insufficient water or root disease. If root disease is the cause, adding more water will make it worse.

Common Soil-Borne Plant Pathogens

Symptoms of root diseases are often noticed above ground as dying branches in a tree, wilting stems and leaves in a tomato plant, or yellowing at leaf tips. Someone may have diagnosed your dying tree or plant as having "root rot." This unpleasant-sounding condition is a generic term used to describe the blackened, dead roots seen when these plants are dug up and examined. Some of the most common soil-borne pathogens commonly associated with root rots are *Phytophthora, Pythium, Rhizoctonia, Armillaria, Fusarium,* and *Verticillium.* Their unique life cycles can make them formidable foes for the home gardener.

Phytophthora and the related pathogen *Pythium* are sometimes called water molds and are not true fungi. They employ a swimming spore, called a zoospore, at some stage of their life cycle. These zoospores can move in the soil when there is sufficient moisture. Under the right conditions, zoospores are produced asexually and are released from infected plants. They do not survive long without a host, but when they contact a root, stem, seed, or fleshy fruit lying in the soil, they will penetrate and begin to absorb nutrients from the plant through a string-like network of cells called mycelia, which can also spread to the roots of adjacent plants.

As in many organisms, sexual reproduction is necessary to produce structures capable of surviving unfavorable cold winter temperatures or periods when the soil is dry. But, in most *Pythium* and *Phytophthora* species, there is no need to find a mate, as a growing filament can produce both a spherical, egg-shaped organ and a penis-like organ for self-fertilization. The thick-walled spores, called oospores, that develop are able to survive in plant tissue and the soil for many years.

Pythium causes seed rots, seedling damping-off, and root rot of all types of plants. Fleshy fruits such as cucumbers, green beans and potatoes that are in contact with the soil can be turned to a soft, watery, rotten mass when infected by *Pythium* species. *Phytophthora* species affect the roots of many plants and also cause some diseases that affect primarily above-ground plant parts. *Phytophthora infestans*, the cause of late blight of potatoes and tomatoes, is the most infamous plant pathogen. The potato famine in Ireland came after devastating losses to the Irish potato crop from late blight in 1845, 1846, and again in 1848.

Rhizoctonia differs most markedly from pathogenic *Pythium* and *Phytophthora* species in its ability to survive as either a pathogen or a saprophyte. Saprophytes are organisms that live off of dead organic material. This dual existence gives *Rhizoctonia* species a competitive advantage as a soil inhabitant, making them especially difficult to control. *Rhizoctonia* species, genetically similar to mushroom-forming fungi, also form structures (called sclerotia) capable of surviving in the soil for many years. Most plant seedlings and roots are susceptible to *Rhizoctonia* and control is difficult. Rotating to a different crop for a period of three to four years and amending with compost or manure allows time for soil microorganisms to compete with saprophytic *Rhizoctonia*, lowering the potential for future infections. Several biological control agents have been developed specifically for their ability to prey on *Rhizoctonia* (see table on the last page).

Armillaria is a mushroom-forming fungus also capable of surviving on both dead organic matter and living plants, with an incredible ability to infect adjacent trees. The largest organism in the world is an "individual" *Armillaria ostoyae* that covers 2,200 acres, growing through the earth and roots of trees in the Malheur National Forest in eastern Oregon. To survive periods of desiccation, cold, and fire, *Armillaria* mycelia produce a thick, almost woody cortex of cells with a shoestring appearance that can be found along the roots of infected trees. When compatible mycelia fuse they may produce fruiting bodies (mushrooms). Millions of spores are released from the gills of the mushrooms, but this is not as significant a mechanism of spread as mycelium. In addition to infecting conifers, *Armillaria* has also been shown to infect apples, peaches, vines, shrubs, and some herbaceous species.

Fusarium pathogens cause wilts in important crops such as tomatoes, spinach, and sweet potatoes. Many greenhouse flowers and seedlings are subject to lethal attack by this prolific pathogen, whose mycelia and spores block xylem vessels and prevent the movement of water from the roots to the leaves so that plant leaves wilt and die. The entire plant usually dies, only to be invaded in its entirety by this aggressive pathogen. Using the energy stored in the dead or dying plant, the organism sporulates profusely and wind, water, insects, or hapless gardeners can then spread its spores. The fungus can also produce overwintering spores that may remain viable for years and, like *Rhizoctonia*, *Fusarium* can colonize dead organic matter and live as a saprophyte. Fortunately, each host is attacked by a different strain of *Fusarium*, so crop rotation is very useful in managing the disease.

Verticillium is another important soil-borne pathogen that causes wilting similar to *Fusarium*. Verticillium wilt is common on maples, and other hosts include tomato, eggplant, pepper, potato, peppermint, chrysanthemum, fruit trees, strawberries, raspberries, roses, alfalfa, and elm. The fungus survives in infected plant tissue but also forms resilient structures called microsclerotia that can survive for many years.

Pathogen Exclusion, Resistance, and a Healthy Soil Environment

The presence of these formidable pathogens in your soil does not guarantee that disease will occur. Three factors must come together for a plant disease to develop: 1) a pathogen capable of averting a plant's defenses and infecting the plant, 2) a susceptible host, and 3) environmental conditions conducive to the pathogen's growth. The best disease-prevention strategies address all three of these factors.

■ **Exclusion**: Choosing disease-free seeds, planting only healthy starts, and discarding sick plants are all methods that attempt to exclude pathogens from the growing space. Pick starts carefully and do not introduce weak or diseased plants into the garden. If possible, buy guaranteed disease-free seeds. When a pathogen does make it into a garden, as many will, choosing disease-resistant varieties and controlling the soil environment can prevent the disease or delay development and reduce losses.

■ **Resistance:** Plant roots are constantly under attack by microorganisms in the soil. Over millions of years, this barrage has favored plant traits capable of preventing pathogens' entry into the plants. Disease resistance, the ability of a plant to remain healthy in the presence of a pathogen and an environment conducive to it, is an important trait that breeders select for. As a gardener, it is worth choosing a disease-resistant variety

Resistance to *Phytophthora*

Plants Commonly Infected
Resistant/Tolerant Variety†

Apple
Seedlings: 'Antonovka', 'McIntosh' and 'Wealthy'; rootstocks: M9

Dogwood

Juniper
Juniperus horizontalis 'Bar Harbor' has intermediate resistance

Potato
'Russet Burbank', 'Russian Banana', 'Kennebec'

Rhododendron*
R. davidsonianum, R. pseudochrysanthum, R. delavayi; 'Caroline', 'Red Head', 'Professor Hugo de Vries', 'Caronin', 'Serenade', 'Martha Isaacson', 'Pink Trumpet'
*Most commercially available Rhododendron cultivars are highly susceptible. The above are not resistant to Powdery Mildew or Root Weevil.

Raspberry
'Chilliwack', 'Meeker', 'Sumner', and 'Summit' are moderately resistant

Strawberry
'Olympus', 'Hood', 'Totem', 'Rainier', 'Shuksan'

Tomato
'Legend', 'Tommy Toe', 'New Hampshire Surecrop'

True fir

Plants not commonly infected:
Sargent crabapple, Hall crabapple, Douglas Fir

Varieties resistant to *Pythium*, *Rhizoctonia*, and *Armillaria* are not generally available.

†References

Pacific Northwest Plant Disease Management Handbook. Ed. J. M. Pscheidt and C. M. Ocamb. 2002.

Verticillium Wilt of Maples. WSU Extension Bulletin EB0983.

Johnny's Seed Catalog

Territorial Seed Catlog

Resistance to various *Fusarium* species

Plants commonly infected
Resistant/Tolerant Variety†

Asparagus
‘Jersey King’
Bean
Cucumber
Iris
Onion
Melons
‘Athena’, ‘Rayyan’, ‘Savor’, ‘Sweetie No. 6’, ‘Angel’, ‘Pulsar’, ‘Earlydew’
Potato
Spinach
‘St. Helens’, ‘Jade’, ‘Chinook II’ and ‘Skookum’
Tomato
Numerous varieties available. Marked with “F” in seed catalogs.
Tulip

Resistance to *Verticillium*

Plants commonly infected
Resistant/Tolerant Variety†

Cucumber
Eggplant
Maples
‘Jade Glen’ and ‘Parkway’ cultivars of Norway maple are tolerant
Melons
Oak
Quercus alba (white oak), *Q. falcata* (southern red oak), *Q. phellos* (willow oak), *Q. virginiana* (live oak)
Potatoes
‘Gold Rush’
Raspberry
‘Marion’ and ‘Evergreen’
Strawberry
‘Earliglow’, ‘Tristar’, and cultivars derived *from Fragaria chiloensis, F. virginiana*, and *F. virginiana* subsp*. glauca*
Rhubarb
Tomato
Numerous varieties available. Marked with “V” in seed catalogs.

Plants not commonly infected: most apples and crabapples, asparagus, bean, birches, conifers, dogwoods, grasses, hawthorns, lettuce, oaks, pears, pea, sweet gums (*Liquidamber styraciflua*), sycamores and planes, walnuts, willows

if one is available (see tables at the left).

■ **Environment**: Pathogens release enzymes capable of rupturing plant cells and releasing the nutritious contents, while plants produce potent compounds capable of killing or inhibiting the offending pathogens. This battle occurs in the midst of the billions of other soil organisms not capable of attacking plant roots but to whom pathogens are a food source or competitor for resources. With chemicals of their own, these soil microbes can inhibit pathogens from surviving in the soil and infecting plants. The first step in growing healthy soil is encouraging a diverse community of beneficial soil microorganisms, in part by adding organic matter to soil.

Organic matter refers to carbon-containing materials such as proteins, fats, carbohydrates, and cellulose. Sufficient organic matter is critical to healthy soil but does not guarantee healthy, disease-free plants. Nitrogen is also important in stimulating soil microbes. Like plants, microbes are scavengers for nitrogen. If nitrogen is not applied with the organic matter, then bacteria and fungi will incorporate available nitrogen from the soil as they break down the freshly added carbon. The limited pool of nitrogen that was available to plants is locked into the bodies of fungi and bacteria. The result is a lack of nitrogen available to plants.

Materials like compost, with well-balanced nitrogen and carbon, stimulate microbes without starving plants of the nitrogen they need. Besides supplying slow-release nitrogen, compost is typically well suited for combating diseases. Compost piles support an elevated level of microbial growth compared to soils (which have much less organic matter). Antagonism against *Pythium* and *Phytophthora* species is common among the diverse and abundant microorganisms found in a compost pile.

Most root pathogens are favored by standing water and poor drainage. *Phytophthora* and *Pythium* zoospores can swim from a diseased plant to a healthy one in saturated soil. *Fusarium* spores are washed from infected roots and stems to adjacent healthy plants. Improve drainage by building raised beds or planting on mounds. Serious drainage problems can be addressed with a French drain or similar subsoil drainage mechanism (e.g., see Ohio State Univ. Extension Bulletin AEX-320-97).

Soil compaction is a common problem in landscapes and agricultural soils. Compaction inhibits the important nutrient-absorbing roots found in the top 18 inches of soil. When pore spaces are squeezed out, roots are no longer able to “breathe” or get water or nutrients to the rest of the plant and become more susceptible to opportunistic diseases. Soil compaction can be caused by vehicles, foot traffic, or even hard rain on bare soil. Mulching with compost or other forms of organic matter can minimize soil compaction. Create clear pathways in the garden to minimize foot traffic in planted areas. Use mulch to delineate buffers around trees and keep vehicles away from their root zones.

Crop rotation is another important disease-prevention strategy. The survival of a pathogen depends on the ability of individual organisms to spread in space and endure through time. Resting stages of *Armillaria*, *Rhizoctonia*, *Verticillium* and *Fusarium* are all resilient against attack by the billions of potential consumers in the soil and “awaken” when a compatible host is planted. Rotating between plant families will help prevent pathogens from building up in the soil. Especially, avoid planting species from the same family, e.g. the mustard family (cabbage, broccoli, etc.) or the nightshade family (tomato, eggplant, etc), in the same space year after year.

Biological Control and Mycorrhizae

The disease-suppressive abilities of compost have been demonstrated most clearly against *Pythium* and *Phytophthora*. *Rhizoctonia, Fusarium,* and *Armillaria* are harder to control with compost because of their ability to compete as saprophytes in the rich organic medium. Applying specific biological control agents that show unusual capacity to control pathogens (see table on last page) can be a useful tool to gain better control of these organisms, as well as improve control of water molds. Extracts of compost, also called compost tea, can be used to inoculate the soil with beneficial microbes. See the following chapter or many gardening books for instructions on making compost tea.

Mycorrhizae are beneficial associations between plants and specific fungi. Depending on the species, mycorrhizal fungi either enter the roots of host plants or cover the root in a sheath, absorbing sugars from the host in both cases. In return, fine filaments of mycorrhizae increase the plant's nutrient-uptake ability, water absorption, and resistance to soil-borne pathogens. This mutually beneficial relationship develops naturally in undisturbed soils where the two partners are present. In areas exposed to flooding, burning, liming, and some chemical fertilizers or systemic fungicides, mycorrhizae may not form naturally. To increase mycorrhizae, inoculate soil with mycorrhizal fungi, follow proper crop rotation, minimize tillage, and use cover crops.

When Diseases Strike

The most effective disease control tools are preventative: building healthy soil and a good growing environment. Often, poor plant growth is caused by something other than a pathogen, such as nutrient deficiency, unfavorable weather, mechanical damage, excessive salts, or chemical injury. If a disease develops, first find out if a pathogen is involved. Often, the only way to be sure which soil-borne organism is responsible is to send a sample to a disease diagnosis laboratory (see box below).

If a disease caused by a plant pathogen is confirmed in your garden, the steps to curing the problem depend on the exact situation and the pathogens involved. In a food garden, removing the diseased plants may be practical. This will slow the reproduction and spread of the pathogen. Then follow a rotation that will place a non-host of the pathogen where the diseased plants had been. For the future, consider resistant varieties, amending with compost and applying specific biological control organisms. If a root disease develops in a tree or perennial garden, removal may not be a practical solution. A 30 or 40-year-old tree or rhododendron may be the centerpiece of a landscape and to replace it would cost thousands of dollars. If the tree is diagnosed with *Phytophthora*, for example, consider what practical changes can be made to the environment to improve drainage. Is the root zone being compromised by compaction or competition from turf or other plants? Try mulching with compost in the root zone both to add important antagonistic microorganisms and to decrease soil compaction. Inoculating with mycorrhizal fungi or biological control organisms will not likely cure the disease but may slow the spread of the organism and keep the tree alive.

No fungicides effective against *Phytophthora* are available to the general public. A certified applicator can use several pesticides registered for *Phytophthora*, but none will cure a moderately or severely infected plant. A fungicide application will also kill many important beneficial fungi and water molds. If you choose to have a fungicide applied, do so only after getting a disease diagnosis from a lab, and apply the fungicide in conjunction with environmental improvements such as increased drainage and application of compost or other amendments. Similarly, there are no fungicides that will cure infection by *Armillaria*, *Verticillium*, or *Fusarium*. Prevention is the most effective tool for soil-borne pathogens. ■

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/

Eastern Washington Plant and Insect Diagnostic Lab, WSU-Prosser, IAREC, 24106 N. Bunn Rd., Prosser WA 99350-9687; Tel: 509-786-9271; ellen_bentley@wsu.edu or www.prosser.wsu.edu/Faculty/Bentley/Bentley.html

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

Selected Soil-Applied Biological Control Agents

Product	Labelled For
SoilGard™	*Pythium* *Rhizoctonia*
Mycostop™	*Fusarium* *Pythium* *Phytophthora*
MicroGro™	*Fusarium* *Pythium* *Rhizoctonia*
Rootshield™	Root pathogens
Compete™	Growth promotion
Vesicular-arbuscular mycorrhizae (VAM)	Growth promotion for many plant species
Ectomycorrhizae	Growth promotion for forest nurseries and urban trees

Summary

- ❖ Amend soil with compost
- ❖ Avoid excessive quick-release nitrogen
- ❖ Improve drainage and don't over-water
- ❖ Plant resistant varieties
- ❖ Remove infected plants
- ❖ Don't move contaminated soil to clean areas of the garden, including on tools or shoes
- ❖ Learn to recognize above-ground symptoms
- ❖ Never treat without a proper diagnosis

The Washington Toxics Coalition is a non-profit organization dedicated to protecting public health and the environment by preventing pollution. Please write or phone for information: WTC, 4649 Sunnyside Ave N, Suite 540, Seattle, WA 98103. Phone: 206-632-1545. Visit our Internet Web site at www.watoxics.org.