

Phytophthora ramorum

a guide for Oregon nurseries

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Figure 1.—
Ramorum shoot
dieback and leaf
blight on
*Viburnum x
bodnantense*
'Dawn'.

A newly described funguslike organism named *Phytophthora ramorum* was discovered in 1993 to cause leaf blight, stem canker, and tip dieback on nursery-grown rhododendrons and viburnums in Germany and the Netherlands. At about the same time, many tanoaks (*Lithocarpus densiflorus*) and oaks (*Quercus* sp.) in the San Francisco Bay Area were dying from a new disease. The cause of this “sudden oak death” was also *Phytophthora ramorum*.

In 2001, the disease was detected in forest sites near Brookings, in southwest Oregon, on tanoak, Pacific rhododendron, and evergreen huckleberry. A 9-square-mile area was quarantined, and infected plant material was cut, piled, and burned in an attempt to eradicate the disease. Although a few new infested forest sites have been detected since then, they are all within the original quarantined area.

In May 2003, *P. ramorum* was discovered in a wholesale nursery in Clackamas County, Oregon, on *Pieris*, *Rhododendron*, and *Viburnum*. In June 2003, *P. ramorum* blight was reported on rhododendron and other hosts at a retail outlet in Washington that was affiliated with the Clackamas nursery. An international shipment of rhododendrons is

the suspected source of contamination for the Oregon and Washington nurseries. In a separate incident, in June 2003, infected camellias shipped from California were found in two Jackson County, Oregon, nurseries; they were destroyed. The same California nursery also had shipped camellias to two Portland-area garden centers. Approximately 300 of these plants were sold during January to July 2003. A public recall was initiated in summer 2003 to check plants and to remove and replace any infected plants found.

Further state and federal regulatory actions have been implemented to help prevent importing infested nursery stock; for more information, visit the Oregon Department of Agriculture Web site at <http://oda.state.or.us/plant/ppd/path/SOD/index.html>. Pacific Northwest nursery growers need to be alert for inadvertent introductions of this pathogen, especially when importing from areas with known infestations.

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An up-to-date list of hosts and associated species is online at <http://www.aphis.usda.gov/ppq/ispm/sod/list.pdf>

Figure 2.—Initial symptoms of ramorum leaf blight on *Viburnum plicatum* var. *tomentosum* ‘*Mariesii*’, showing necrotic leaf spots and shoot dieback.

Hosts

In the United States, the host list is growing; as of this writing, it includes 28 species in 12 plant families. Several more plant species are associated with *P. ramorum* but are not currently regulated, pending experimental confirmation.

Laboratory tests indicate that many more plant species, both wild and cultivated, are potentially susceptible to *P. ramorum*. In Europe, nursery hosts include rhododendron

cultivars, *Viburnum* spp., *Pieris* spp., *Hamamelis virginiana*, and *Camellia* spp. The disease has been reported from nurseries and gardens in Germany, the Netherlands, Belgium, France, Poland, Spain, Italy, Sweden, and the United Kingdom. *P. ramorum* also has been detected in a park on mature red oak specimen trees (*Quercus rubra* and *Q. falcata*) and on beech (*Fagus sylvatica*), horse chestnut (*Aesculus hippocastanum*), and seedlings of holm oak (*Quercus ilex*) in woodlands in the U.K.

Table 1. Nursery hosts reported in Oregon, plant part infected, and known symptoms of *Phytophthora ramorum*.

Plant species	Common name	Symptoms
<i>Camellia japonica</i>	Japanese camellia	Leaf lesions
<i>Camellia sasanqua</i>	Sasanqua camellia	Leaf lesions
<i>Pieris floribunda</i> x <i>japonica</i>	<i>Pieris</i> x ‘Brouwer’s Beauty’	Leaf lesions, shoot dieback
<i>Pieris formosa</i> x <i>japonica</i>	<i>Pieris</i> x ‘Forest Flame’	Leaf lesions, shoot dieback
<i>Pieris japonica</i>	Japanese pieris	Leaf lesions, shoot dieback
<i>Rhododendron</i> hybrids	Rhododendron	Leaf lesions, shoot dieback; death of mature plants
<i>Viburnum</i> x <i>bodnantense</i>	Bodnant viburnum	Stem lesions
<i>Viburnum plicatum</i> var. <i>tomentosum</i>	Doublefile viburnum	Leaf lesions, shoot dieback; death of mature plants

Symptoms

Phytophthora ramorum causes different symptoms on different hosts. “Sudden oak death” on tree species is characterized by “bleeding” cankers that girdle the trunks of tanoaks (Figure 9, page 7) and some other oak species. On *Rhododendron*, *Pieris*, *Viburnum*, *Camellia*, and evergreen huckleberry, the disease is characterized by leaf blights and shoot diebacks and is more appropriately called ramorum leaf blight or ramorum shoot dieback. Symptoms on rhododendron (Figures 10–12, back page) may be indistinguishable from those caused by other *Phytophthora* species. The leaf petiole and midrib may be discolored, or the leaf tip or entire leaf blade may be necrotic (Figure 10). Leaf spots can occur where water accumulates on the leaf margins (Figure 11). Shoots die back when disease is severe (Figure 12). On *Viburnum*, infected leaves may die and fall off, leaving dark, leafless stems (Figures 1–3). In more severe infections, *Viburnum* can be killed. On *Pieris*, infected leaves turn a dark brown (Figure 7, page 5). Young shoots and leaves of *Pieris* are very susceptible to infection. Other hosts such as camellia may be infected but have only subtle symptoms, such as small leaf lesions on the lower leaves (Figures 5–6, page 4). Infected leaves on these hosts often fall off.

Biology

Phytophthora ramorum is a funguslike organism well adapted to the cool, wet conditions of the Pacific Northwest and at the same time tolerant of heat and drought. Unlike most *Phytophthora* species that infect roots, *P. ramorum* is mainly a foliar pathogen. It produces several spore types, which helps the organism survive and spread (Figure 4). Spores landing on wet leaves or stems germinate and infect the plant. Young leaves are especially susceptible. Within a few days, sporangia are produced, and they release tiny,



Figure 3 (above).—*Viburnum plicatum* var. *tomentosum* ‘Mariesii’ infected with *P. ramorum*, showing a necrotic leaf as well as defoliation near the base of the plant.

swimming spores (zoospores). The sporangia themselves can also detach, germinate, and infect. Sporangia and zoospores can be moved with windborne rain, in irrigation water, or with water splashed onto foliage. *P. ramorum* produces chlamydozoospores, which in other *Phytophthora* species are important for surviving unfavorable conditions. There are two mating types, designated A1 and A2.

The forest isolates from California and Oregon are the A2 type; the European isolates are mainly A1.

Both types have been isolated from Oregon nurseries. If both mating types are in an infected plant, the pathogen could undergo sexual

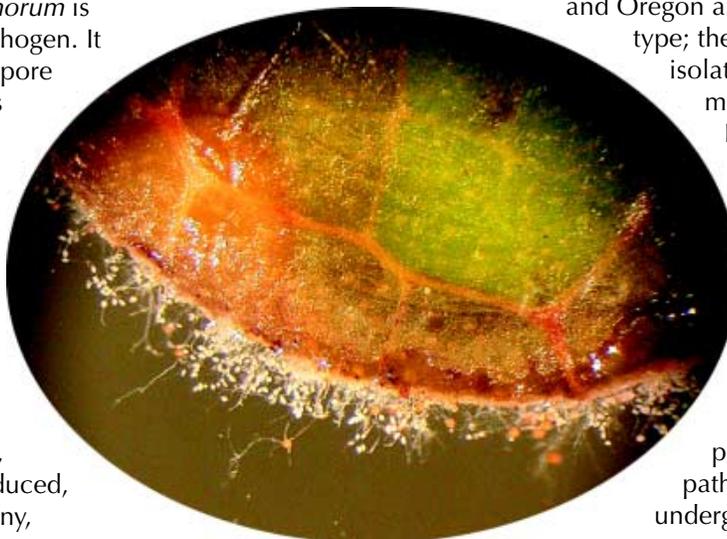


Figure 4 (at left).—Sporangia (clear) and chlamydozoospores (amber) of *P. ramorum* on an infected Oregon myrtlewood leaf.

Figure 5 (near right).—Symptoms on *Camellia* include leaf lesions and defoliation.

Figure 6 (far right).—Leaf spots on *Camellia japonica* caused by *P. ramorum*.



Table 2. Woodland plant hosts, plant part infected, and known impact of *Phytophthora ramorum*.¹

Plant species	Common name	State ²	Plant part infected and impact
<i>Acer macrophyllum</i>	Bigleaf maple	CA	Leaf lesions
<i>Aesculus californica</i>	California buckeye	CA	Leaf lesions
<i>Arbutus menziesii</i>	Madrone	CA	Leaf lesions; branch cankers
<i>Arctostaphylos manzanita</i>	Manzanita	CA	Leaf lesions; dieback; stem and branch cankers
<i>Heteromeles arbutifolia</i>	Toyon	CA	Leaf lesions; dieback; branch cankers
<i>Lithocarpus densiflorus</i>	Tanoak	CA, OR	Bole cankers; leaf lesions; death of large trees
<i>Lonicera hispidula</i>	California honeysuckle	CA	Foliar lesions
<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	Douglas-fir	CA	Foliar lesions; death of new shoots and small branches
<i>Quercus agrifolia</i>	Coast live oak	CA	Bole cankers; death of large trees
<i>Quercus chrysolepis</i>	Canyon live oak	CA	Bole cankers; death of saplings; possible death of large trees
<i>Quercus kelloggii</i>	California black oak	CA	Bole cankers; death of large trees
<i>Quercus parvula</i> var. <i>shrevei</i>	Shreve oak	CA	Bole cankers; death of large trees
<i>Rhamnus californica</i>	California coffeeberry	CA	Leaf lesions
<i>Rhododendron macrophyllum</i>	Pacific rhododendron	CA, OR	Leaf lesions; shoot dieback; death of mature plants
<i>Sequoia sempervirens</i>	Coast redwood	OR	Foliar lesions; branch cankers; death of sprouts; decline of saplings
<i>Trientalis latifolia</i>	Western starflower	CA	Leaf lesions
<i>Umbellularia californica</i>	Oregon myrtlewood, California bay laurel	CA, OR	Leaf lesions (tip necrosis or speckling)
<i>Vaccinium ovatum</i>	Evergreen huckleberry	CA, OR	Leaf lesions; shoot dieback

¹Adapted with permission from Davidson et al., 2003.

²CA=California, OR=Oregon

reproduction and form oospores. So far, oospores of *P. ramorum* have been observed only under laboratory conditions, so their role in disease epidemiology is not known. In other *Phytophthora* species, oospores are also thick-walled, like chlamydozoospores, and are important for surviving unfavorable conditions.

Disease prevention

Management efforts in Pacific Northwest nurseries are focused on eradicating the pathogen where it is found and preventing new infections. Early detection is vital to preventing disease spread. Practices useful in managing other foliar *Phytophthora* diseases also should help protect plants from infection by *P. ramorum*. The following strategies can reduce the risk of this disease in Pacific Northwest nurseries.

Exclusion and avoidance

- ▲ If importing nursery stock of trees or shrubs from any source (out of state or international), you must notify the Nursery & Christmas Tree Program Supervisor at the Oregon Department of Agriculture by fax (503-986-4786) or e-mail (quarantine@oda.state.or.us). Plants must be certified as being free from *P. ramorum*. For more information on Oregon's import regulations, go to <http://oda.state.or.us/plant/ppd/path/SOD/index.html>. Illegal importations may result in significant fines. The USDA's quarantine regulations regarding *P. ramorum* are online at <http://www.aphis.usda.gov/ppq/ispm/sod>
- ▲ Keep imported known hosts and plants associated with *P. ramorum* in a separate block at least 7 feet from other plants in the nursery for 3 to 6 months, to see the development of any symptoms that initially might have been masked by fungicides or delayed by weather.
- ▲ Do not transport oak firewood or other potentially infected plant materials from infested areas in California to Oregon.
- ▲ If you visit infested areas, wash your vehicle and shoes before traveling to disease-free areas.

Cultural management

- ▲ Familiarize yourself and your staff with the range of symptoms of *Phytophthora ramorum*. Check your plants often. Diseases caused by other *Phytophthora* species can cause similar symptoms. If you suspect *P. ramorum*, call the Oregon Department of Agriculture's Invasive Species Hotline, 1-866-INVADER, or your Nursery Inspector at 503-986-4644. Diagnosis, using several techniques, may take 1 to 2 weeks.
- ▲ While waiting for the diagnosis, do not move or ship symptomatic plants **or** any nearby plants; even if they look healthy, they may be contaminated.
- ▲ Be alert for symptoms on **any** shrub and tree species, not just those on the list of hosts and plant species associated with *P. ramorum*.
- ▲ Disinfect tools and shoes that may have been in contact with contaminated plants or potting media. Incinerate contaminated pots and trays or treat them with aerated steam to kill the pathogen.
- ▲ Propagate cuttings only from plants known to have been free of disease for several months. Sanitize cuttings to eliminate the pathogen; soak cuttings in a disinfectant before storage and/or sticking in rooting medium. Use clean, pathogen-free potting media and clean, new pots.



Figure 7.—Leaf and stem necrosis and shoot dieback on *Pieris japonica*.

- ▲ Manage irrigation to reduce the length of time that foliage is wet. If possible, increase watering intervals. Improve drainage to avoid puddling and splashing. Place pots on fast-draining surfaces.
- ▲ Use only clean water for irrigation. Treat irrigation water to kill spores of *P. ramorum* and other *Phytophthora* species. Remove and destroy any fallen leaf material, dead branches, or plants.

Table 3. Plant species associated with *P. ramorum* but not currently regulated, pending experimental confirmation.

Plant species	Common name	Location ¹
<i>Abies grandis</i>	Grand fir	CA
<i>Aesculus hippocastanum</i>	Horse chestnut	E
<i>Arbutus unedo</i>	Strawberry tree	E
<i>Camellia reticulata</i>	Camellia	E
<i>Camellia</i> × <i>williamsii</i>	Camellia hybrid	E
<i>Corylus cornuta</i>	California hazelnut	CA
<i>Fagus sylvatica</i>	Beech	E
<i>Kalmia latifolia</i>	Mountain laurel	E
<i>Leucothoe fontanesiana</i>	Drooping leucothoe	E
<i>Pieris formosa</i> var. <i>forestii</i>	Chinese pieris	E
<i>Pieris formosa</i> var. <i>forestii</i> × <i>P. japonica</i>	Pieris hybrid	E
<i>Pittosporum undulatum</i>	Victorian box	CA
<i>Quercus falcata</i>	Southern red oak	E
<i>Quercus ilex</i>	Holm oak	E
<i>Quercus rubra</i>	Northern red oak	E
<i>Rhamnus purshiana</i>	Cascara	OR
<i>Rubus spectabilis</i>	Salmonberry	OR
<i>Syringa vulgaris</i>	Lilac	E
<i>Taxus baccata</i>	European yew	E
<i>Toxicodendron diversiloba</i>	Poison-oak	OR
<i>Vaccinium vitis-idaea</i>	Lingonberry	E
<i>Viburnum davidii</i>	David viburnum	E
<i>Viburnum farreri</i> (= <i>V. fragrans</i>)	Fragrant viburnum	E
<i>Viburnum lantana</i>	Wayfaringtree viburnum	E
<i>Viburnum opulus</i>	European cranberry bush viburnum	E
<i>Viburnum</i> × <i>burkwoodii</i>	Burkwood viburnum	E
<i>Viburnum carlcephalum</i> × <i>V. utile</i>	Viburnum hybrid	E
<i>Viburnum</i> × <i>pragense</i>	Prague viburnum	E

¹ CA=California, E=Europe, OR=Oregon

Protection and suppression with fungicides

Use fungicides as preventive treatments on known host plant species. Most fungicides used to manage *Phytophthora* do not kill this organism. They can only prevent the organism from becoming established. They also can prevent continued growth if the organism is already inside the plant—thereby masking symptoms that might have developed. Once chemical activity has subsided with time (about 3 to 6 months), the organism can resume growth within infected plants. This is why plants from other nurseries must be held for several months to see whether symptoms become evident.

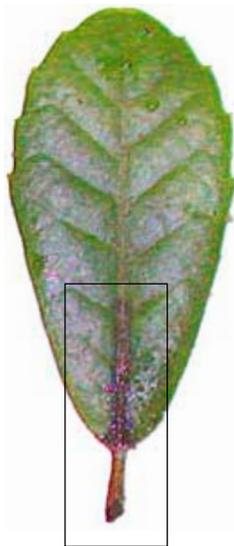
If you choose to use fungicides, alternate among ones from different fungicide families with different modes of action. For specific fungicide recommendations, consult the *PNW Plant Disease Management Handbook* or *An Online Guide to Plant Disease Control* at <http://plant-disease.ippc.orst.edu/index.cfm>

Detection and eradication

If *P. ramorum* is found in your nursery, ODA and USDA will work with you, at no charge, to prevent further disease spread, to eradicate the infestation, and to monitor your nursery to verify when it is free from *P. ramorum*. USDA is drafting uniform procedures for dealing with nursery infestations. Check the regulatory action plan on the ODA and USDA-APHIS Web sites for up-to-date information. The plan may include many of the following provisions.

- ▲ Samples will be taken from symptomatic plants to confirm the pathogen's identity. Testing usually will be part of the annual survey.
- ▲ Samples will be taken from other plants in the nursery to determine the extent of the infestation.
- ▲ Host plants will not be sold or moved during the investigation (generally, less than 2 weeks).
- ▲ Blocks of plants containing infested plants will be destroyed by deep burial or by incineration under ODA's direct supervision.

- ▲ Healthy host plants within 10 meters of infested blocks will be held for 90 days* to observe symptoms. These plants may not be treated with fungicides during this time so that symptoms will not be masked.
- ▲ Nonhost plants can be shipped during this time.
- ▲ Surrounding properties will be surveyed for *P. ramorum*.
- ▲ Trace-back investigations will be made to determine the source of infected plants, and trace-forward investigations will be made if any plants from the infested block(s) were shipped.
- ▲ ODA will monitor water, potting mix, soil, and plants for the presence of *P. ramorum*. When tests have been negative for 90 days*, the nursery may once again ship host plants.
- ▲ The nursery will be tested each spring for the next 2 years as a precaution.



For more information

Oregon State University Extension Service.
An Online Guide to Plant Disease Control.
▲ <http://plant-disease.ippc.orst.edu/index.cfm>

Pscheidt, J.W. and C.M. Ocamb, eds. Pacific Northwest Plant Disease Management Handbook (revised annually). Corvallis, OR: Extension Services of Oregon State University, University of Idaho, and Washington State University.

California Oak Mortality Task Force
▲ <http://suddenoakdeath.org/>

Davidson, J.M., S. Werres, M. Garbelotto, E. Hansen, and D.M. Rizzo. 2003. Sudden Oak Death and associated diseases caused by *Phytophthora ramorum*. Plant Health Progress, Plant Management Network International.
▲ <http://www.plantmanagementnetwork.org/pub/php/diagnosticguide/2003/sod/>

Oregon Department of Agriculture, Sudden Oak Death Alert.

▲ <http://oda.state.or.us/plant/ppd/path/SOD/index.html>

USDA Animal and Plant Health Inspection Service (APHIS), Pest Detection and Management Programs, Invasive Species and Pest Management: Sudden Oak Death.

▲ <http://www.aphis.usda.gov/ppq/ispmsod/>

Figure 8 (above left).—Foliar symptoms on susceptible oaks include a darkened petiole and midrib, as on this tanoak leaf, or necrosis at the leaf base.

Figure 9 (above right).—Bleeding canker on the trunk of a mature tanoak.

*The 90-day period must be during active plant and pathogen growth; otherwise, the waiting period may be extended.



Figure 10 (above left).—Rhododendron 'Unique' plants with ramorum leaf blight. Plant in center foreground was killed by ramorum leaf blight; plant in background shows early symptoms of ramorum leaf blight on lower leaves.

Figure 11 (above right).—Lesions on leaf margins of Rhododendron 'Unique'.

Figure 12 (at right, below).—Ramorum shoot dieback on wild rhododendron.



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