GLOBAL INVASIVE SPECIES DATABASE

FULL ACCOUNT FOR: ***Phytophthora ramorum***

Phytophthora ramorum **System:** Terrestrial

Kingdom	Phylum	Class	Order	Family
Fungi	Oomycota	Peronosporea	Peronosporales	Peronosporaceae

Common name sudden oak death (English), SOD (English), maladie de l'encre des ch'nes rouges (French), ramorum dieback (English), ramorum leaf blight (English), ramorum blight (English), mort subite du ch'ne (French)

Synonym

Similar species *Phytophthora cinnamomi, Phytophthora lateralis, Phytophthora nemorosa*

Summary Until 2000, Phytophthora ramorum, the causal agent of Sudden Oak Death, was undiscovered and unnamed. This water mould or oomycete is the cause of much concern in North America and Europe due to three factors: (i) the high level of local destruction it causes in California, (ii) the lack of knowledge of its epidemiology (due to its recent discovery), and (iii) its high prevalence in nurseries (which increases the potential of spread to a new location and/or country). The oomycete has an extensive host range, covering many plant genera and several families and including treees and shrubs and woody and herbaceous perennials. Phytophthora ramorum causes canker development, shoot drooping and leaf blight. Spores spread to new locations mainly by the nursery trade and are spread locally by vectors: soil, water and articles associated with humans.

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Species Description

Morphology: In culture hyphae are highly branched, contorted and dendritic. Chlamydospores, produced on hyphal tips, are at first hyaline, then darken to cinnamon brown, 30-90 µm. Sporangia (a particularly diagnostic characteristic) are oval-shaped, semi-papillate, 30-90 µm, and deciduous. Oospores have not been observed.
Disease symptoms: While most temperate-climate members of the Oomycota genus *Phytophthora* are root-infesting, soil and water-bourne organisms, *P. ramorum* spreads mostly aerially and generally infests trees and plants above the soil line (including leaves, shoots, woody stems and bark). Infections on the bark develop into cankers, which produce a red/brown/black sappy exudate (a symptom referred to as \"bleeding\"). Cankers can occur on the trunk at the root crown up to 20m above the ground, but do not enlarge below the soil line into the roots. Individual cankers are delimited by thin black lines in the inner bark and can be over 2m in length. Aerial seeps not connected to the root collar are a good indication that a tree is infected by *P. ramorum* (other *Phytophthora* can cause identical seeps linked to root infections). Infections on the leaves cause spotting and browning. Infections on the twigs cause branch drooping and dieback (ANR, 2003; Garbelotto, 2004; Rizzo *et al.*, 2002b).
Please see PaDIL (Pests and Diseases Image Library) Species Content Page *Fungi: Sudden oak death* \r\n for high quality diagnostic and overview images.

Notes
Publications, management guidelines and educational resources can be assessed from:
ANR, 2003. *Marin County UCCE. Sudden Oak Death: Publications*.
Pdfs on a wide range of topics including the biology, genetics and management of SOD can be assessed from:
UC Berkeley, 2004. *Sudden Oak Death Science Symposium*

Lifecycle Stages
The oomycete develops sporangia, which hold and produce zoospores and which can be airborne. The sporangium releases zoospores once it has landed on a suitable host surface. The leaves and twigs of susceptible hosts are readily colonised by zoospores. A water film and/or warm temperatures (around 18–20°C) facilitate infection. Leaves and twigs then develop black lesions (which spread to branches in some species, causing dieback). In conditions of high humidity (close to 100%) and moderate temperature, new sporangia and resting round structures (chlamydospores) will be produced on the lesions in approximately 48 hours. Infectious propagules accumulate in the soil beneath the plant in water bodies. In the final disease phase, the main stems of tanoaks and oaks may be infected. The pathogen preferentially colonises the sugar-rich phloem of the host, only marginally colonising the outer bark and xylem. As a result of phloem colonisation a canker develops under the bark, and sappy exudates will flow outside the bark. In tanoaks multiple cankers often occur on tanoaks at different heights (thought to be caused by sporangia produced on leaves of the infected host tanoak or on the leaves of adjacent infected hosts). On the less susceptible coast live oaks cankers normally only occur near the soil line (presumably caused by the accumulation of sporangia from the leaves of adjacent infected hosts). As oak leaves are rarely colonised by *P. ramorum* re-infection from the host tree is not likely. This is why infection in oaks is epidemiologiclly linked to, and depends on, the presence of adjacent infected foliar hosts (such as bay laurel). If girdling occurs the irreversible death process is started (although it may take a year or more for browning of the tree's crown to occur). Girdling leads to the establishment of secondary organisms and opportunistic pathogens (such as wood decay fungi and canker rots) (Garbello, 2004).

Habitat Description
Reports from the USA suggest the pathogen has an optimum growth temperature of 20°C, there is no mycelial growth at greater that 30°C or at less than 2°C (Sansford, Jones and Brasier, 2003). Areas with wet climates and constant mild temperatures, resembling the central California coast are optimal to disease developement. Most sporangia production occurs during the rainy season (Garbelotto, 2004).\r\n
In North America forests of three main types are affected: mixed evergreen-bay-arbutus (dry open forest with grass and dense shrub understory), Tanoak-Douglas-fir (wet forest, often has a *Vaccinium* understory), Coast Redwood (open forest, often has a tanoak understory). In Europe the pathogen is mainly a pest species of *Rhododendron* and *Viburnum*. European countries where *Rhododendron* is affected have cool to cold winters with rain throughout the year. The pathogen therefore may be capable of establishment in other northern areas or some southern coastal Atlantic/Mediterranean areas in Europe. (The pattern of *Rhododendron* distribution may, however, reflect the movement of the infected stock) (Sansford, Jones and Brasier, 2003).

P. ramorum infects: \r\ntanoak (*Lithocarpus densiflorus*), coast live oak (*Quercus agrifolia*), black oak (*Quercus kelloggii*), Pacific huckleberry / evergreen huckleberry (*Vaccinium ovatum*), rhododendron and azalea species (*Rhododendron*), maple species (*Acer*), manzanita species (*Arctostaphylos*), Pacific madrone (*Arbutus menziesii*), California buckeye (*Aesculus californica*), California bay laurel (*Umbellularia californica*), California honeysuckle (*Lonicera hispidula*), toyon / Christmasberry (*Heteromeles arbutifolia*), California coffeeberry (*Rhamnus californica*), coast redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), Western star flower (*Trientalis latifolia*), hybrid viburnum (*Viburnum bodnantense*) (only in cultivation), *Pieris* spp. (only in cultivation), *Camellia* spp. (only in cultivation).
For an updated list of plants reported (or suspected) to be susceptible to *P. ramorum* please see: \r\nPPQ, 2004. *List of Hosts and Plants Associated with Phytophthora ramorum*

Reproduction
Phytophthora ramorum produces large amounts of asexual infectious swimming propagules (zoospores) in oval-shaped sporangia, as well as producing hard, round, resting propagules (chlamydospores). To complete its sexual cycle *P. ramorum* requires individuals bearing two mating types (A1 and A2). In nature in North America only A2 individuals have been reported, while - with a single exception - only A1 have been reported from nursery or nursery-linked infections in Europe (as of April 2004) (Garbelotto, 2004).

General Impacts
There are two categories of hosts for *Phytophthora ramorum*, each of which are susceptible to the pathogen in different organs: bark canker hosts and foliar hosts. Bark canker hosts become infected on their trunks. In highly susceptible species (tanoaks and to a lesser extent oaks) cankers eventually girdle the tree, resulting in starvation and death. Mortality may occur in as short a timespan as two years. Foliar hosts become infected on their leaves and twigs. Leaf infection is accompanied by branch infections and branch dieback in some foliar hosts (for example, rhododendrons, Pacific madrone, Pacific huckleberry and Toyon / Christmasberry); in other foliar hosts only leaves are affected (for example, bay laurel, maples and buckeye). Foliar hosts only occaasionally die from infection. (Tanoaks belong to both host categories as they may develop bark and/or foliar infections. Foliar infections are common in young tanoaks and result in leaf blight and the killing of the plant from the \"top down\") (ANR, 2003; Garbelotto, 2004).
Many plants within the host range of the oomycete are grown for economic gain or have environmental or social valued. Tanoak, coast live oak and black oak in USA hardwood forests infected with the oomycete die in a short period of time following the onset of symptoms. Oak plays an important role in European natural ecosystems, especially forest and savanna-woodland ecosystems. It can be found in parks and open countrysides. It has been estimated that there are about 200 million oak trees in the UK and their loss from could have a major impact on soil erosion, hydrology, sedimentation in rivers in certain areas. Other possible effects include loss of associated organisms (biodiversity) and a negative impact on tourism, cultural history and local woodland economies (Braisier, 2000a, unpub., in Sansford, Jones and Brasier, 2003).

Management Info
Preventative measures: Preventing the introduction of *Phytophthora ramorum* into new areas should be the first priority when managing Sudden Oak Death (SOD). This entails identifying the likely sources of infection. In order of importance these sources are live plants (especially those supporting sporulation), green waste, soil and water, debarked untreated wood, entire logs and firewood. Quarantine and sanitation measures for nursery plants, wood products and soil associated with infestation sites should be employed to prevent both long and short distance spread. \r\n
Drenth *et al*. 2006 describe the development and validation of a DNA-based diagnostic assay that can detect and identify 27 different *Phytophthora* species. Belbahri *et al* (2007) report that the \"new specific hybridization probes for a real-time PCR amplification method\" they developed for early detection of *P. ramorum* is found to be rapid, robust and labour-saving, and has proved suitable for routine use in a molecular diagnostic laboratory. Please follow this link *managing Phytophthora ramorum* for detailed management options.

Pathway
In the case of Europe interregional transport of the disease appears to have already occurred due through the trading and sales of ornamental plants (Garbelotto, 2004). Infected plants have been found in nurseries in Europe and the USA. *P. ramorum* could be spread to new countries by the nursery trade.
The combined microsatellite, sequencing and morphological analyses by Ivors *et al.* (2006) suggest the 151 isolates analysed clustered in three clades, represent distinct evolutionary lineages. All three clades were identified in some US nurseries, emphasizing the role of commercial plant trade in the movement of this pathogen. Movement of contaminated soil (or other habitat material) may spread the pathogen. The leaves of susceptible hosts may become infected when splashed with infected soil (Garbelotto, 2004). How *P. ramorum* originally entered Europe and the USA is unknown, but the seperate clades (a clade is defined as a group of species that share a common ancestor, which is not shared by another species outside of the clade) are of different mating types (A1 and A2 respectively) and appear to be from distinct genetic lineages, suggesting the pathogen is from a third location (with both mating types and representations of both lineages) (Garbelotto, 2004).

Principal source: Sansford, Jones and Brasier, 2003. *Pest Risk Analysis: Phytopthora ramorum*. Garbelotto, 2004. *Sudden Oak Death: A Tale of Two Continents.*

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