NOBANIS –Invasive Alien Species Fact Sheet

Phytophthora ramorum

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Species description

Scientific names: *Phytophthora ramorum* Werres, De Cock & Man in`t Veld, Oomycetes, Chromista.
Synonyms: None.
Common names: Twig and leaf blight (EU), Ramorum leaf blight (North America), Sudden Oak Death= SOD (North America), maladie de l'encre des chênes rouges (FR), mort subite du chêne (FR), tammen äkkikuolema (FI), europæisk visneskimmel (DK, European isolate) / californisk visneskimmel (DK, North American isolate), Plötslig ekdöd (SE).

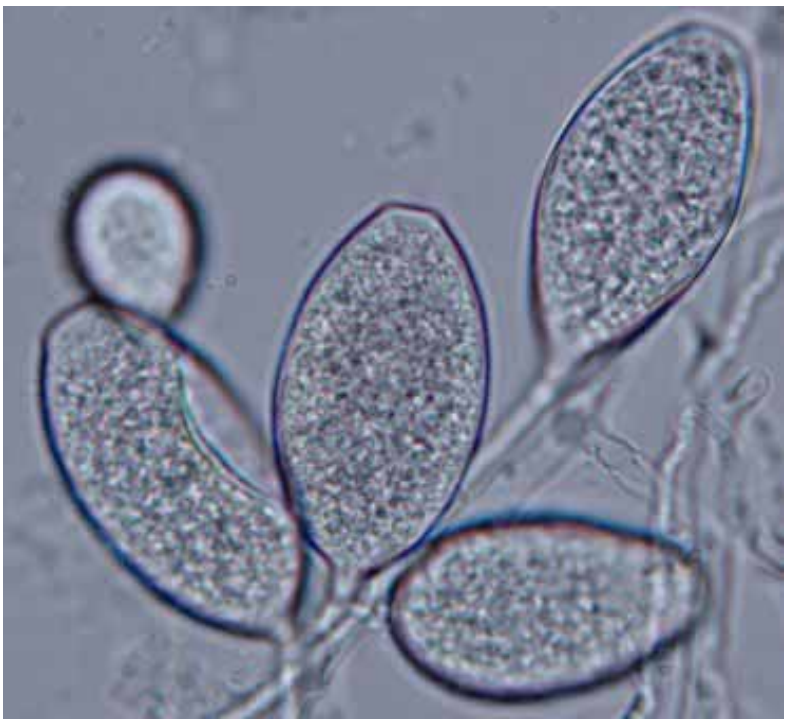

Fig 1. Sporangia of *Phytophthora ramorum* in soil extract water, photo by Arja Lilja.

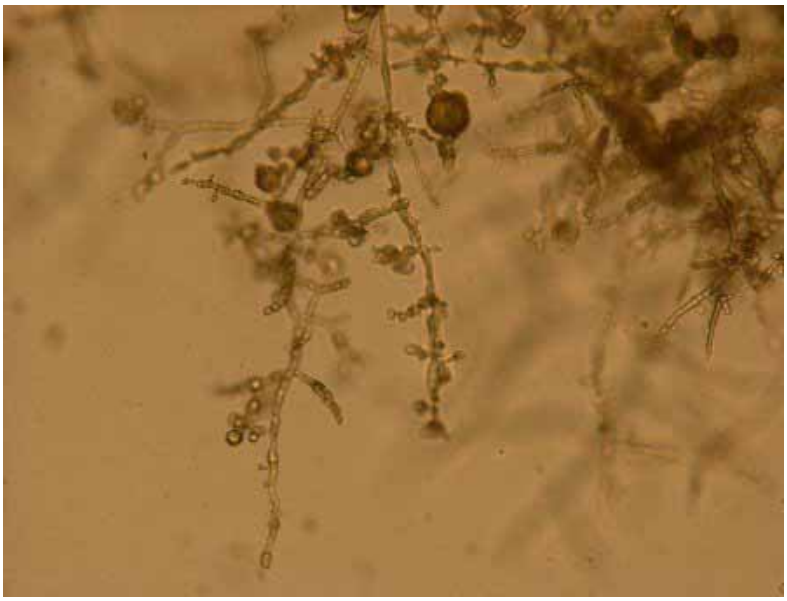

Fig 2. Branched dendroid like hyphae of *Phytophthora ramorum* on bottom of agar plate, photo by Arja Lilja.

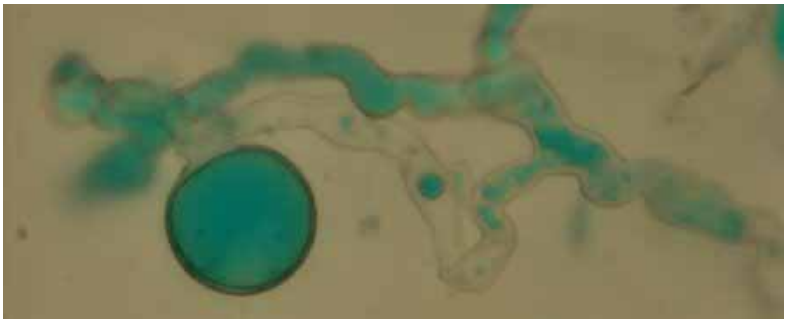

Fig 3. Clamydospore of *Phytophthora ramorum*, photo by Arja Lilja.

Species identification

Phytophthora ramorum is a heterothallic species characterized by abundant production of chlamydospores and elongate, ellipsoid, deciduous sporangia. The mean sporangium length was 43.6 µm ± 5.3 with a range from 20-79 µm and the mean sporangium width was 23.9 µm ± 2.6 with a range from 12-40 µm in measurements done by Werres and Kaminski (2005). Oogonia with amphigynous antheridia were produced by parings with *P. cryptogea* and other heterothallic *Phytophthora* species representing opposite mating type A2 or A1 (Werres *et al.* 2001, Werres and Kaminski 2005).
In general different mating types occurred in Europe (A1) and in North America (A2). However, in 2003 the occurrence of a few isolates of *P. ramorum* belonging to A1 type was reported from horticultural nurseries in North America and A2 type from Europe (Hansen *et al.* 2003, Werres and De Merlier 2003).
The EU phytosanitary legistation (Comission Decision 2002/757/EC) concerning plant import distinguish between European and non-European isolates of *P. ramorum*.

Native range

Phytophthora ramorum has been separately introduced into North America and into Europe from a third area which remains unknown (Brasier 2003, Ivors *et al.* 2004, Rizzo *et al.* 2005).

Alien distribution

History of introduction and geographical spread

In 2001 a *Phytophthora* associated with a twig blight disease on *Rhododendron* and *Viburnum* in Germany and Netherlands was described as a new species, *P. ramorum* (Werres *et al.* 2001). Later it was found to be responsible for the Sudden Oak Death disease (SOD) of *Quercus* and *Lithocarpus* spp. in California, USA (Rizzo *et al.* 2002). The spread of *P. ramorum* in North America has been very rapid. The disease was first discovered on *Lithocarpus* spp. near Mill Valley in 1995. Since then it has spread throughout coastal counties around the San Franscisco Bay area where many *L. densiflorus*, *Q. agrifolia*, and *Q. kelloggii* have been killed (Rizzo *et al.* 2002, Davidson *et al.* 2002, 2005). It has now spread to Washington and Oregon and has once been reported in a nursery in British Columbia, Canada (Hansen *et al.* 2003, Davidson *et al.* 2005).

P. ramorum has been found mainly in nurseries and garden centres, in many European countries, *e.g.* in Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Norway, Poland, Slovenia, Spain, Sweden and Switzerland (Werres *et al.* 2001, Delatour *et al.* 2002, Moralejo and Werres 2002, Orlikowski and Szkuta 2002, De Merlier *et al.* 2003, Heiniger *et al.* 2004, Orlikowski *et al.* 2004, Pintos *et al.* 2004, Zerjav *et al.* 2004, Orlikowski 2005, Swedish Board of Agriculture 2005). In the UK and the Netherlands *P. ramorum* has also been found on mature trees (Brasier *et al.* 2004, Anonymous 2004a, Anonymous 2004b).

Pathways of introduction

It is not known how *P. ramorum* originally entered Europe or North America, but the mating type and population distribution suggests that separate introductions into Europe and into North America may have occurred from a third unknown location (Ivors *et al.* 2004). It is, however, probable that imported, infected ornamentals have been the main source of the pathogen.

Alien status in region

In Europe, *P. ramorum* was first found on *Rhododendron* and *Viburnum*, but later it was isolated on a variety of plant genera and species, *e.g. Arbutus, Calluna vulgaris, Camellia, Hamamelis, Kalmia, Laurus, Leucothoe, Parrotia, Photinia fraseri, Pieris, Syringa* and *Vaccinium vitis-idaea* (Orlikowski and Szkuta 2002, Werres and De Merlier 2003, Beales *et al.* 2004a, Beales *et al.* 2004b). In 2003, the pathogen was found on *Quercus falcata* in the UK, and shortly afterward on *Fagus sylvatica, Fraxinus excelsior, Quercus ilex, Q. cerris, Castanea sativa, Taxus baccata, Nothofagus* and *Aesculus hippocastanum* (Brasier *et al.* 2004, Lane *et al.* 2004, Anonymous 2004a, Orlikowski *et al.* 2004, Orlikowski 2005). In the Netherlands the microbe has been isolated from *Q. rubra* near diseased *Rhododendron*s (Anonymous 2004b).

In North America tree hosts are besides *L. densiflorus*, *Q. agrifolia*, *Q. kellogii* and *Q. parvula* var. *shrevei* species such as *Q. chrysolepis*, *Umbellularia californica, Sequoia sempervirens, Pseudostuga menziesii, Abies grandis, Acer macrophyllum* and *Aesculus californica*. The pathogen has also been found on *Arbutus menziesii, Arctostaphylos manzanita, Camellia* spp., *Corylus cornuta, Heteromeles arbutifolia, Lonicera hispidula, Maianthemum racemosum, Pittosporum undulatum, Rhamnus californica, Rhododendron* spp., *Rosa gymnocarpa, Rubus spectabilis, Rhus diversiloba, Rhamnus purshiana, Toxicodendron diversilobatum, Trientalis latifolia* and *Vaccinium ovatum* (Davidson *et al.* 2002, Goheen *et al.* 2002, Rizzo *et al.* 2002, Knight 2002, Hong 2003, Hüberli *et al.* 2004, 2005, Murphy and Rizzo 2003, Hansen *et al.* 2005, Maloney *et al.* 2005, USDA 2006., Vettraino *et al.* 2006).

Today over 40 plant genera have been susceptible to this pathogen in inoculation trials (Denmann *et al.* 2005, Hansen *et al.* 2005). Among tested plants only a few tree species had had very low disease incidence: *Populus tremuloides, P. trichocarpa x P. deltoides, Pinus contorta, P. ponderosa, P. nigra* var. *maritima*, *P. sylvestris*, *Salix hookeriana* and *S. lasiandra* (Denmann *et al.* 2005, Hansen *et al.* 2005). Highly susceptible broad-leaved species not yet found in nature as hosts are such as *Cornus nuttalii, Prunus emarginata* and *Ulmus procera* (Denman *et al.* 2005, Hansen *et al.* 2005). *Acer pseudoplatanus, Alnus glutinosa, A. rubra, Betula pendula, Caprinus betulus, Cornus sativa, Corylus avellana, Ilex aquifolium, Prunus avium, Q. petraea, Q. robur, Q. suber* and *Thilia cordata* were also possible hosts, but less susceptible (Denman *et al.* 2005, Hansen *et al.* 2005). Among conifers *Abies procera* was severely affected in inoculations and *Picea abies, P. sitchensis, S. sempervirens* and *Tsuga heterophylla* were also susceptible,while *Taxus baccata* and *Chamaecyparis lawsoniana* were more resistant (Denmann *et al.* 2005, Hansen *et al.* 2005). Many understory species have also been highly susceptible e. g. *V. membranaceum* and *V. parvifolium* (Hansen *et al.* 2005).

P. ramorum has been found in many European countries, *e.g.* in Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Norway, Poland, Slovenia, Spain, Sweden and Switzerland (see also table 1).

Country	**Not found**	**Not established**	**Rare**	**Local**	**Common**	**Very common**	**Not known**
Denmark		X					
Estonia	X						
European part of Russia							X
Finland		X					
Faroe Islands							X
Germany			X				
Greenland							X
Iceland	X						
Latvia	X						
Lithuania	X						
Norway		X					
Poland		X					
Sweden		X					

Table 1. The frequency and establishment of *Phytophthora ramorum* , please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available.

Ecology

Habitat description
The microbe is regarded as a cool-temperate organism with an optimum temperature for growth at 20°C and minimum and maximum at 2°C and 30°C respectively (Werres *et al.* 2001). In woody plant material one week of heat treatment at 55 °C was needed to kill the pathogen (Garbelotto 2004). Wet conditions are needed for sporangia production and successful infection. The pathogen has been found in forest, forest and ornamental nurseries, gardens and parks.

Reproduction and life cycle
Two types of asexual spores, zoospores (in sporangia) and chlamydospores, are produced under wet conditions and moderate temperature on infected leaves or twigs. Sporangium release zoospores after landing on susceptible host. The swimming zoospores are responsible for new infections. Chlamydospores are the resting structures involved in survival. Under suitable conditions they germinate and produce mycelia or sporangia.
P. ramorum is a heterothallic species and paring of opposite mating types is needed for sexual reproduction. However, sexual structures, oogonia, antheridia and oospores, have not yet been found in nature. In artificial pairings they have born both in plants and on agar medium (Werres and Zielke 2003, Brasier and Kirk 2004).

Dispersal and spread
Infection occurs through zoospores (liberating from sporangia) and chlamydospores. As for other *Phytophthora*s, the disease can be transmitted by infected plants and soil. The sporangia of the pathogen are deciduous which means that they could also possibly be transported by water splashes and wind. Foliar infections on woody shrubs or other hosts in the understory have shown to serve as a source of inoculum for bark (Rizzo *et al.* 2005). Soil from vehicle tires has been proved to contain viable spores of *P. ramorum*. In addition, hikers have been shown to carry spores on their shoes after visits in infested areas during the rainy season (Tjosvold *et al.* 2002).

Infected plants have been found in nurseries and in garden centres both in Europe and North America. Thus *P. ramorum* might spread to new locations within a country by infected planting material. It might also spread further into surrounding environment from gardens and parks. Bark beetles and ambrosia beetles are commonly found on diseased trees but their potential role as vectors has not been studied yet (McPherson *et al.* 2005). The spread to new countries happens by plant trade.

Impact

Affected habitats and indigenous organism
P. ramorum affects the aerial parts of plants and disease symptoms can be diverse depending on the plant species. On woody shurbs or small trees such as *Rhamnus* and many other understory hosts such as *Rhododendron* , *P. ramorum* mainly causes leaf lesions or/and twig blight. On *Camellia, Griselinia*, *Kalmia, Laurus, Leucothoe, Photinia* and *Syringa* the pathogen causes brown to black leaf lesions (Orlikowski and Szuta 2004, DEFRA 2005, Forestry Commission. 2005, Vettraino *et al.* 2006). Leaf leasons occur mainly at the tip or edges of the leaves. On *Calluna* apical shoot parts turned brown and infected shoots might have shepherd crook shape (Orlikowski and Szuta 2004). In larger trees, bark infections

cause cankers with tarry or rusty colored exudations. The leaves of infected trees may turn brown over a short period, but death may take one or more years (Garbelotto *et al.* 2001). On *Lithocarpus densiflorus,* the pathogen affects both bark and leaves and death can be rapid. On *Viburnum*, the stem base infection cause wilting and death. On conifers, *P. ramorum* causes needle blight and dieback of young shoots (DEFRA 2005, Forestry Commission. 2005).

Genetic effects
No genetic effects.

Human health effects
No human health effects have been reported.

Economic and societal effects (positive/negative)
The economic and social effects have been considerable especially in the USA. Oaks as well as many other host species are important forest and amenity trees also in Europe. However, no such significant tree mortality has yet been observed in Europe as in the USA. The ornamental nursery industry is anyhow, also in Europe highly valued and many produced plant species are known as natural hosts for *P. ramorum*. Many ecologically and environmentally important woody species have also been hosts or have been in inoculations highly susceptible. The potential for *P. ramorum* to cause serious diseases or undermine ecosystems in Europe depends on factors, many of which are unknown at present (DEFRA 2005, Forestry Commission. 2005).

Management approaches

Prevention methods
The spread of *P. ramorum* and it's opposite mating types to new geographical areas by plant trade should be avoided. The European Commission's Regulation 2004/426/EG imposes strict import regulations for the host plants of *P. ramorum*. Possible host plants must have a plant passport and nurseries producing these plants must be a part of the obligatory official plant production control.

Eradication, control and monitoring efforts
Management of *P. ramorum* in nurseries through IMP (intergrated pest management) practices include cultural practices, fungicides, and host resistance (Orlikowski 2004). According to the EU Regulation 2004/426/EG, the national plant protection services are required to sample plants with suspected infections of *P. ramorum* and destroy infected plants together with all other host plants within a 2 m radius. Trade from infected nurseries is suspended and further inspections are required before trade can resume.
Extensive surveys to check for the presence of *P. ramorum* have been done both in Europe and North America (Forestry Commission. 2005, USDA 2006).

Information and awareness

Information to nurseries, environmental managers and the general public on the environmental effects and management of *P. ramorum* is spread by the National Plant Protection Service in each country through information on the Internet.

Knowledge and research
None reported.

Recommendations or comments from experts and local communities
None reported.

References and other resources

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Links
A project within the EU 6th Framework R & D Programme, priority 8.1.B.1. Sustainable management of Europe's natural resources. RAPRA. Risk analysis for *Phytophthora ramorum*.

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European and Mediterranean Plant Protection Organisation (EPPO). *Phytophthora ramorum*

National Biological Information Infrastructure (NBII) and Invasive Species Specialist Group (ISSG) Global invasive species database *Phytophthora ramorum* (fungus).

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