EU Sixth Framework Project
Contract Number *502672*

Risk Analysis of *Phytophthora ramorum*, a Newly Recognised Pathogen Threat to Europe and the Cause of Sudden Oak Death in the USA (Acronym – RAPRA)

PRIORITY 8.1.B.1
POLICY-ORIENTED RESEARCH
SPECIFIC TARGETTED RESEARCH PROJECT – RAPRA

Deliverable Report D28

Report on the risk of entry, establishment, spread and socio-economic loss and environmental impact and the appropriate level of management for *Phytophthora ramorum* for the EU

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Citation:

Sansford CE, Inman AJ, Baker R, Brasier C, Frankel S, de Gruyter J, Husson C, Kehlenbeck H, Kessel G, Moralejo E, Steeghs M, Webber J, Werres S, 2009. Report on the risk of entry, establishment, spread and socio-economic loss and environmental impact and the appropriate level of management for *Phytophthora ramorum* for the EU. Deliverable Report 28. EU Sixth Framework Project RAPRA. http://rapra.csl.gov.uk/

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Versions: Two earlier versions of this Pest Risk Analysis were prepared. The first (21st November 2008) was provided to the European Commission (EC) (DG Research and DG SANCO). The second (23rd January 2009) had several small amendments to address issues of consistency within the text; this was also sent to DG SANCO, and circulated on the EC information system (CIRCA) to EU Member States, for discussion at the EC Standing Committee for Plant Health on 2nd and 3rd February 2009. This third and final version, for public dissemination, has modifications to authorship of some of the Deliverable Reports from the RAPRA Project and to citations within the text.

Comment on heathland: The first version of this Pest Risk Analysis accounted for the prediction that heathland habitats are at risk from *Phytophthora ramorum* (based upon host-range testing and climatic matching). This has now been proven by recent findings of *P. ramorum* on bilberry (*Vaccinium myrtillus*) in heathland in the UK (England); sampled December 2008. This information has not been incorporated into this final version of the PRA, but should be borne in mind by the reader.

SUMMARY: PEST RISK ANALYSIS FOR *PHYTOPHTHORA RAMORUM*

This summary presents the main features of a Pest Risk Analysis (PRA) which has been conducted on *Phytophthora ramorum* as the key deliverable from the EU-funded RAPRA Project. The PRA was prepared according to the EPPO Standard '*Guidelines on Pest Risk Analysis: Decision-support scheme for quarantine pests*' version 07-13727 (PM 5/3 (3). This summary is based upon the template for the EPPO '*Report of a Rest Risk Analysis*', version 06-12731, now superceded by 08-13988. Elements of both versions are included.

Pest: *Phytophthora ramorum* Werres, De Cock and Man In't Veld.

PRA area: European Union (27 Member States).

Assessors: Claire Sansford and Alan Inman, CSL, Sand Hutton, York, UK, YO41 1LZ.

Reviewers: RAPRA Partners.

Citation: Sansford CE, Inman AJ, Baker R, Brasier C, Frankel S, de Gruyter J, Husson C, Kehlenbeck H, Kessel G, Moralejo E, Steeghs M, Webber J, Werres S, 2008. Report on the risk of entry, establishment, spread and socio-economic loss and environmental impact and the appropriate level of management for *Phytophthora ramorum* for the EU. Deliverable Report 28. EU Sixth Framework Project RAPRA. http://rapra.csl.gov.uk/

Date: 26th February 2009.

STAGE 1: INITIATION

Reason for doing PRA: To take account of the new experimental and economic data that have been generated for *Phytophthora ramorum* from the EU Sixth Framework Project '*Risk Analysis for Phytophthora ramorum*' (RAPRA), together with other new information. This new PRA builds on previous ones which were only partially valid. It will contribute to the review of the EU emergency phytosanitary measures.

Taxonomic position of pest: Kingdom – *Chromalveolata*; Phylum – *Heterokontophyta* (heterkonts or stramenopiles); Class – *Oomycetes*; Order – *Peronosporales*; Family – *Pythiaceae*; Genus – *Phytophthora*

STAGE 2: PEST RISK ASSESSMENT

Probability of introduction
Entry

Geographical — **North America:** The pathogen occurs in the wild in parts of western

distribution:	California and Oregon, USA. The first nursery findings were made in California in 2001, then subsequently in Oregon and Washington State. In 2004 two large California nurseries and one in Oregon shipped millions of potentially infected plants to over 1,200 nurseries in 39 US states: the pathogen was found in 22 of these states (177 nursery-related detections) by the end of that year. Eradication action was taken on these findings. Nursery findings have been made in the USA in subsequent years. The pathogen has also been reported (under eradication) in British Columbia, Canada in a few nurseries (first finding in 2003) and some related residential plantings. There are three known molecular lineages in North America, NA1, NA2 and EU1. NA1 is present in forests and in nurseries but to date lineages NA2 and EU1 have been found almost exclusively in nurseries. **EU and Europe:** To date only lineage EU1 has been recorded in Europe. The pathogen has been reported from 19 EU countries, where it is under official control: Belgium, Czech Republic (eradicated nursery finding), Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain (including Mallorca), Sweden and the UK (all countries including the Channel Islands). It has also been recorded in Norway and Switzerland. **Area of origin:** The origin or origins of *P. ramorum* is/are not known, but it is speculated that the pathogen may have originated somewhere in Asia; possibly Yunnan, Taiwan or the eastern Himalayas. *P. ramorum* is considered to be an introduced exotic pathogen in both North America and in Europe. The NA1 and NA2 lineages are likely to have a separate geographic origin to the EU1 lineage; this is based upon genetic analysis.
Major host plants or habitats:	The host range of *P. ramorum* in North America and Europe is very wide. It includes many important shrubs and trees of ornamental or environmental significance; a few herbaceous plant species are also reported as hosts. Currently, natural hosts occur in 37 plant families, with 75 plant genera and more than 130 plant species affected. Experiments have been undertaken to determine the potential host-range. A number of those predicted to be natural hosts have been found to be naturally-infected.
Which pathway(s) is the pest likely to be introduced on:	Eight main '*commodity types*' are identified in this PRA: 1. Plants for planting (excluding seeds and fruit) of known susceptible hosts; 2. Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media; 3. Soil/growing medium (with organic matter) as a commodity; 4. Soil as a contaminant (e.g. on footwear, machinery, etc.);

5. Foliage or cut branches (for ornamental purposes) of susceptible foliar hosts;
6. Seeds and fruits of susceptible host plants;
7. Susceptible (isolated) bark;
8. Susceptible wood.

Probabilities of entry for each commodity type are assessed for four geographical origins where *P. ramorum* has been recorded: USA; Canada; non-EU European countries (Norway and Switzerland); and, the unknown area or areas of origin for *P. ramorum*. Although the origin is still unknown, based upon speculation that it may have entered Europe and the USA from parts of Asia, assessments of imports from China and Taiwan have been included in the assessment of the risk of entry.

Establishment

<u>Plants or habitats at risk in the PRA area:</u>

A large range of environmental and ornamental shrubs and trees are potentially at risk. There are many suitable habitats including: woodland (managed, semi-natural or natural), heathland, maquis (macchia) shrubland, and managed gardens (including those of heritage value), parks and public greens. Many of the potentially at-risk habitats are covered by the EC Habitats Directive (Council Directive 92/43/EEC). For trees, genera/species in the family Fagaceae with susceptible bark (especially *Quercus* and *Fagus*) are considered most at risk of developing potentially lethal stem cankers. This has already occurred on a limited scale in the PRA area.

Tree species with susceptible bark are only likely to be at high risk if they occur in close association with foliar hosts capable of supporting significant sporulation (e.g. *Rhododendron*, especially *R. ponticum*), or if they themselves are also foliar hosts (e.g. holm oak - *Quercus ilex*).

In southern Europe, plants in evergreen oak woodlands and laurel forests (laurisilva) are considered most at risk since establishment could occur on a range of foliar hosts which are known to have the potential to support sporulation of the pathogen. Maquis/matorral habitats could also be at risk where they contain susceptible host species (e.g. evergreen oaks or other susceptible species). *P. ramorum* has not been recorded in these habitats to date.

In northern Europe, heathland with *Calluna* and *Vaccinium* species, both of which are particularly susceptible in laboratory tests and have been shown to have a significant sporulation potential are also at risk. In Europe, species of these genera have been reported as hosts on nurseries, but not in European heathlands.

<u>Climatic similarity of present distribution with PRA area (or parts</u>

The area, or areas, of origin of *P. ramorum* are unknown. The pathogen is considered to have been introduced to North America where it has established in woodlands in the Pacific Northwest coast

thereof):	of the USA (California and southwest Oregon). These US areas have a Mediterranean climate that is *largely similar* in climate to European countries adjoining the Mediterranean. Other parts of Europe have less similar climates ranging from *not similar* to *slightly similar*. Climate matching, using CLIMEX, between Oregon/California and Europe indicates that the areas of north-west Spain, northern Portugal, south-west England, and parts of Italy and western Albania have the most similar climates; larger parts of the UK, Ireland, France, Belgium, the Netherlands, western Germany, Italy, the Adriatic coast of the Balkan peninsula, as well as north-west Turkey and east Bulgaria on the black sea coast, also have relatively good climate matches.
Aspects of the pest's biology that would favour establishment:	Establishment is favoured by the pathogen's very wide host range, capacity for asexual reproduction, ability to produce long-lived, thick-walled chlamydospores (resting spores) and, to survive for relatively long periods in soil and water. Asexual reproduction through the production of sporangia (spores involved in dispersal and infection) can occur under a wide range of environmental conditions (62–100% RH; >10°C and <30°C). The period from infection to production of infectious spores is relatively short. *P. ramorum* is heterothallic requiring opposite mating types to be present for sexual reproduction to occur. The current distribution of mating types (mainly A1 in Europe and A2 in North America) has not facilitated this, but this has not hindered the pathogens establishment and spread in (at least) some of the favourable areas of the USA (California and part of Oregon) and Europe. However, the mating system may be not be fully functional, so it is not certain that frequent sexual reproduction would occur should the opportunity arise. However recombination of genetic material might also occur through somatic hybridisation. Any progeny arising might have different adaptive characteristics to the parents. In the absence of controls, small populations of the pathogen are likely to become established. Other pathogens are unlikely to prevent establishment of *P. ramorum*. No natural enemies are known. The pathogen is favoured by certain nursery practices. Additionally, it can survive in growing media and can infect roots, largely asymptomatically. Cryptic infections and asymptomatic sporulation on aerial plant parts are also reported. This may favour spread in the nursery trade. *P. ramorum* cannot be detected based upon symptoms alone. In the absence of controls, it is likely to spread rapidly within trade networks that have scale-free network properties. Scale-free networks (those with super-connected nodes) have a lower epidemic threshold than other kinds of complex networks; in the absence of controls this favours rapid spread and establishment throughout the network, increasing the risk of wider spread in the environment.
Characteristics (other than climatic) of the PRA area that would favour establishment:	The host plants are widely distributed and traded in the PRA area as cultivated ornamental plants. There are numerous host plants in the natural or semi-managed environment. Soil type and pH do not affect the establishment potential of the pathogen directly. There are

no chemical treatments that can consistently eradicate the pathogen on infected plants. However, there may be situations where fungicides could be used as part of an eradication and containment programme.

Which part of the PRA area is the endangered area:	With respect to susceptible hosts of cultivated shrubs and trees on nurseries the whole of the PRA area is potentially endangered wherever these occur because the pathogen is favoured by certain nursery practices.

With respect to the semi-natural (including managed parks, gardens, public greens etc) or the natural environment, the parts of the PRA area that are most endangered based upon climatic factors alone (Figure A) are *Atlantic Central* and *Lusitanian* climatic zones; *Mediterranean* and *Atlantic North* climates are also potentially favourable, especially in coastal locations. (See Figure 13 of the PRA for distribution of the climatic zones). Although mild and wet climates are most likely to favour establishment and spread, the pathogen's ability to form long-lived chlamydospores enables it to survive Mediterranean climates with hot and dry summers, as demonstrated in California, and potentially also colder climates with cold winters. Areas with the most suitable climates coincide broadly with the areas that potentially have the most at-risk habitats. This is illustrated by the presence of potentially suitable broadleaved hosts/habitats in Figure B with some of the highest proportions occurring in the climatically favourable areas shown in Figure A. Heathland and maquis areas are not illustrated here but these also coincide with areas that appear to be climatically favourable. Those areas that are climatically favourable are only at risk where there are susceptible host plants that are capable of supporting sporulation. More detail is given below.

Potential Geographical Distribution of *Phytophthora ramorum* in Europe

The PRA for *P. ramorum* includes a range of climate-based risk maps in the probability of establishment section. Since these were created using different techniques and different parameters, it is not possible to combine them into one simple summary map of risk that represents the endangered area for *P. ramorum* hosts in Europe based on climate. It is also not possible to say that one technique or map is superior to another since validation of the methodology is not possible using the limited case data in Europe which is influenced by (a) the extent of the surveys for individual Member States and (b) by the pathogen being under statutory control, thus limiting its spread. Models using current pathogen distribution with climate matching are likely to predict a more limited distribution than those that do not. The climate-based risk map for Europe (Figure A) is based on the ranking system developed by Meentemeyer *et al.* (2004) to predict potential *P. ramorum* distribution in California. It uses climatic parameters that favour *P. ramorum*, with scores, ranks and weights assigned to precipitation, maximum temperature, relative humidity and minimum temperature. This European risk map does not incorporate the host-species index of Meentemeyer *et al*. (2004) (which is based on epidemiological significance and sporulation potential of different plant species) used for California since there is a lack of high-resolution host data (individual host distribution and also host associations) for the whole of Europe. However, since trees are considered to be one of the most at-risk plant types, the areas of broadleaved woodland in Europe are also shown below (Figure B); these broadly coincide with the areas that are predicted as most climatically favourable. The most suitable climatic locations for establishment based upon Meentemeyer *et al*. (2004) are northern Portugal, north-western Spain, the southern tip of Spain, the Adriatic coast of the Balkan peninsula (e.g. western parts of Greece, Albania, Montenegro, Bosnia and Herzegovina, Croatia, Slovenia), south-western France, north-west France (Brittany), northern coastal Spain, southern Turkey and western UK and south-west Ireland. Those areas that are climatically favourable are only at risk where there are susceptible host plants that are capable of supporting sporulation.

Figure A. *P. ramorum* risk ranking model based on Meentemeyer *et al.* (2004) for Europe using the 10' latitude/longitude resolution global climatology for December–May 1961–1990.

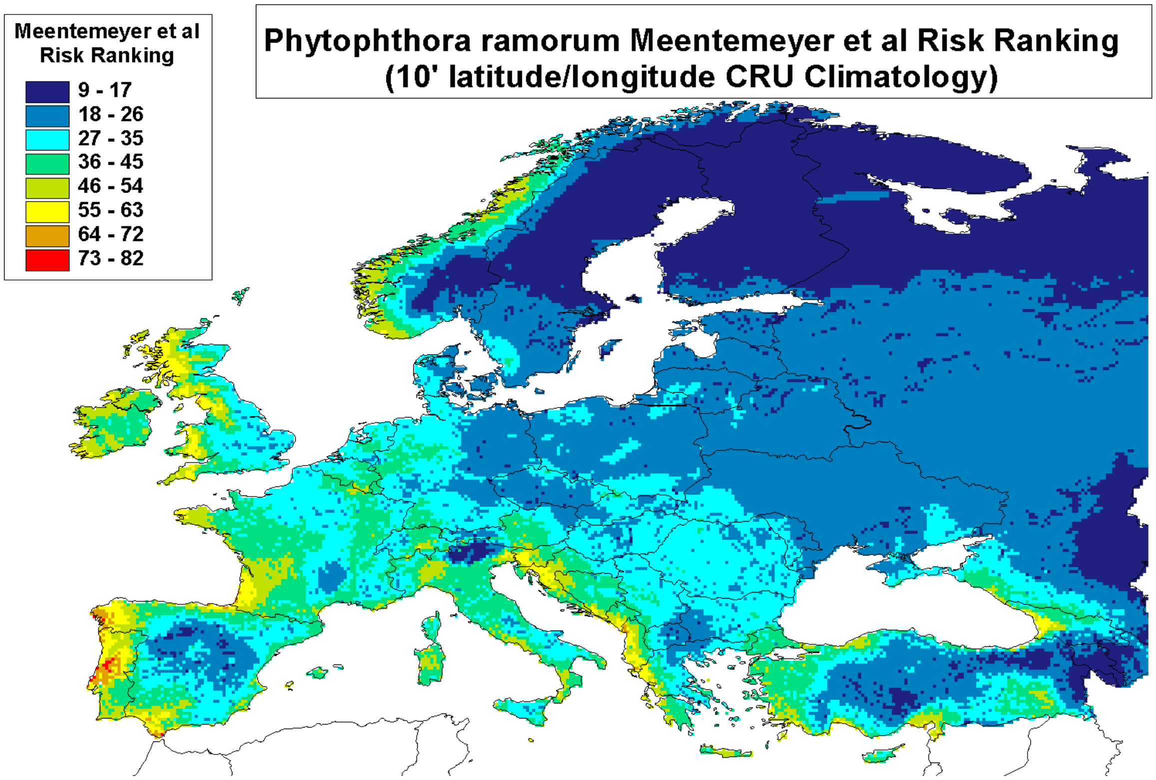
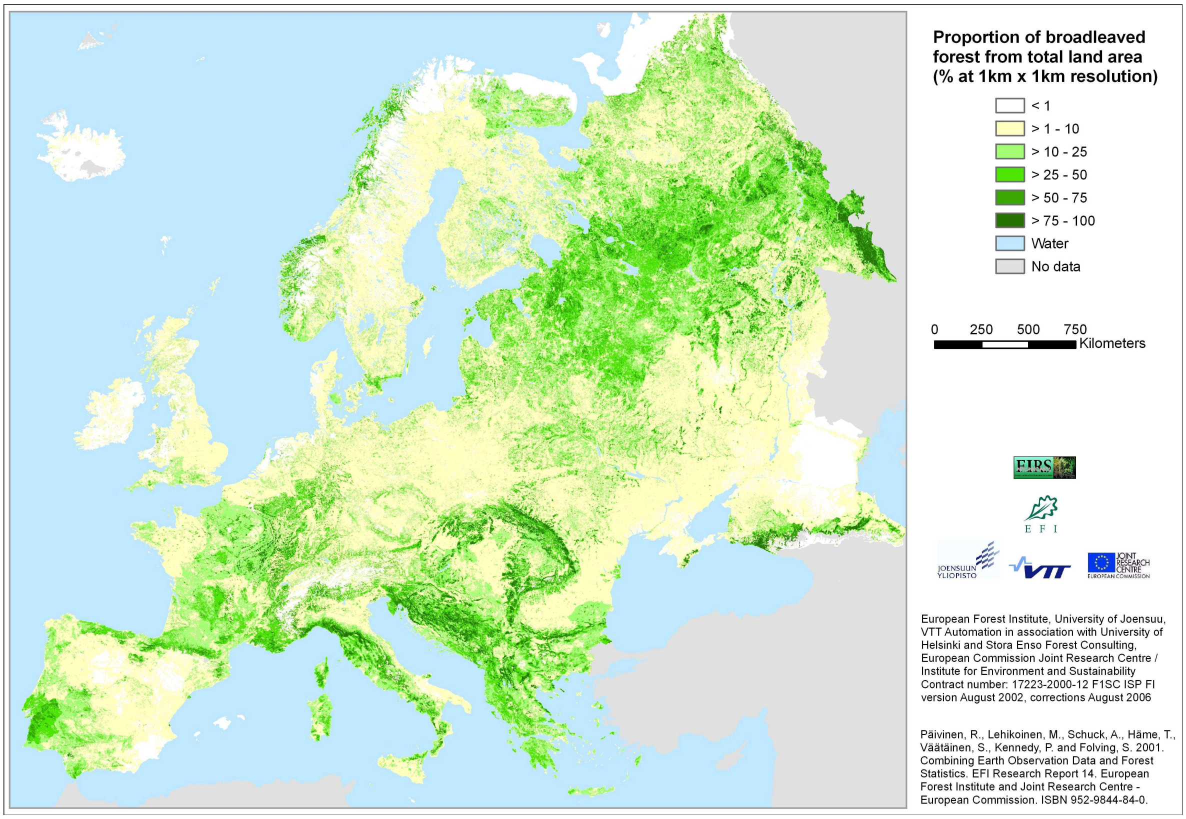


Figure B. Calibrated broadleaved forest map as a percentage of land area for Europe, produced by combining geographically referenced Earth observation data and forest statistics. Source: Päivinen *et al.* (2001 and Schuck *et al.* (2002).



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POTENTIAL ECONOMIC CONSEQUENCES

How much economic impact does the pest have in its present distribution:

Because *P. ramorum* is subject to official control in the countries where it is known to occur (19 EU Member States plus Norway and Switzerland; the USA and Canada) the direct economic impact that it has caused is not quantifiable and there is some uncertainty associated with the estimates. The scores assigned are subjective and individual Member States have/will vary in their assessment of the impact. However, the majority view is represented below based upon the limited evidence that is available.

The values that have been attributed to its impacts include the costs of phytosanitary measures and associated costs. However, in Europe the pathogen has a direct effect on the quality of nursery stock as well as the quality of plants in managed parks, gardens and public greens. Shrubs and trees in woodlands have become locally affected with some tree death in the UK and the Netherlands. In the USA the major impact has been environmental arising from massive tree death in coastal California and part of Oregon; the US and Canadian nursery trades have also subsequently become affected.

Nursery production: In the EU, surveys in Member States show that typically <5% of nurseries surveyed nationally have been affected by *P. ramorum.* The number of surveys that have been undertaken has varied by country and by year and some Member States have not supplied survey data. It is therefore difficult to know the true level of disease in the nursery trade and so estimations of impacts for the whole of the EU are not easy to determine. In the USA, *P. ramorum* has been found on nurseries in California, Oregon and more than 20 other states. In Canada, most recently, the 2007 national survey detected *P. ramorum* at 10 nurseries, all in British Columbia. In terms of yield, quality and control costs, excluding the cost of phytosanitary controls, the current impact on nursery grown ornamental species is thought to be **moderate** within the areas in which *P. ramorum* occurs in the EU, USA, and Canada. Including the costs of phytosanitary controls the impact is **major.** Losses in export markets arising from the presence of *P. ramorum* in the EU are not quantifiable but there are suggestions of losses for some Member States including the Netherlands, Germany and Belgium. Losses in exports (including intra-state trade) have also occurred in the USA and Canada.

Non-nursery findings: The number of Member State surveys have varied by year and by country (as per the nursery surveys). However, European countries that have reported findings of *P. ramorum* outside of nurseries (including managed parks, gardens, public greens, woodlands and forests) are Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Slovenia, Spain, Switzerland and the UK. The countries where *P. ramorum* has been found in woodlands or other semi-natural/natural environments are France, Germany, Ireland, the Netherlands and the UK. The UK seems to be most intensively affected. Specific details about the current impact of non-nursery findings have been difficult to obtain for all the European countries that have reported findings.

With respect to the natural and semi-natural environment, estimates have been made of the current (and future) impact of *P. ramorum* in three systems/scenarios in Europe (Kehlenbeck, 2008). In the '*northern European tree system*' (broadly-defined as trees with stem cankers in association with infected rhododendron in the Netherlands and the UK) the impact has been described as **moderate** and this is related to the environmental impact being limited to a few parts of the PRA area only with a relatively low number of infected sites. In the '*southern European tree system*', a hypothetical system based upon the presence of the infected foliar host *Q. ilex* (holm oak), the impact is **minimal** (zero) because the pathogen has yet to be introduced there.

There are other effects arising from findings in managed gardens. In the EU, managed parks and gardens are, or have been affected, in: Belgium, Denmark, Germany, Ireland, Luxembourg, the Netherlands, Slovenia, Spain, and the UK, as well as in the non-EU countries of Norway and Switzerland. The majority of findings have been in the UK and the Netherlands. The south-west of England is particularly badly affected where there is some impact on tourism due to the effect of the pathogen on the appearance of the plants and landscapes of the managed and historic gardens that contribute to the local economy.

In the USA, the major environmental impact of *P. ramorum* to date has been on the coastal woodland environment of California. Symptoms of *P. ramorum* were first reported on trees in California in the mid-1990s. Since then, it is estimated that over a million oak trees have been killed. Other species of woodland plants have suffered non-lethal foliar and shoot infections. Woodland in Curry County, Oregon, has also become affected. Knock-on effects resulting from loss of tree and understorey species include disruption to the ecology of the area, loss of recreational areas in woodland, dead trees increasing the risk of accelerated water run off, and, resultant soil erosion and sedimentation and endangering of certain plant species. There is a particular risk from forest fires due to dead trees.

Describe damage to potential hosts in the PRA area:

P. ramorum has already been found in the PRA area. It has affected the quality of plants in the nursery trade as well as those in parks, gardens (including heritage plants and gardens important to tourism), historic collections, public greens and woodlands. Limited tree mortality has occurred to date but this is at least partly because the pathogen has been under phytosanitary control since 2002 and therefore its full effect has been limited by attempts at containment and eradication. Heathland and maquis are yet to become affected, as well as ancient plant communities in southern Europe such as laurosilva habitats.

How much economic impact would the pest have in the PRA area:

P. ramorum is already present in the PRA area but subject to official control. It still has the potential to increase its host-range and to become more widespread in the nursery trade and in the natural and semi-natural environment than at present. The long-term potential for ecological damage is difficult to predict, especially if the pathogen adapts to new hosts or environments. There is the potential for the pathogen to affect timber production but this has not occurred to date in North America or Europe. The potential economic impacts have not been quantified for the PRA area as there are insufficient data to do so. The impacts will increase if controls are lifted.

If phytosanitary controls are maintained at the current level or increased/reduced, costs related to nursery production as well as managed gardens will continue to include:

- Surveillance and testing costs (National Plant Protection Organisation - NPPO)
- Administration and compliance costs including publicity (NPPO)
- Value of plants destroyed (grower, managed gardens)
- Costs of destroying plants (grower, managed gardens)
- Purchase of replacement plants to fulfill sales contracts (grower)
- Income loss from cropping restrictions (grower, managed gardens)
- Income loss from loss of sales due to effect on quarantined areas on reputation (grower)
- Income loss from impacts on tourism (managed gardens, businesses related to reductions in visitor numbers)
- Costs of alternative planting schemes (managed gardens)
- Equipment cleaning costs (grower, managed gardens)
- Facility cleaning costs (grower, managed gardens)
- Research and development costs including those needed to develop good management practices (EC, national government and levy bodies)

These costs are **major.**

Should phytosanitary controls be lifted globally the increase in production costs will principally fall on nurseries producing hardy ornamental nursery stock, and managed gardens.

These costs will include:

- Diagnoses and consultancy advice (grower, managed gardens)
- Loss of symptomatic plants (grower, managed gardens)
- Purchase of replacement plants to fulfill sales contracts (grower)
- Change in species grown or planted (grower, managed gardens)
- Additional control costs including fungicide costs and cultural control (grower, managed gardens)
- Implementation of production of healthy certified stock by the use of certification schemes
- Research and development costs (national government and levy bodies)

These costs are also **major.**

The impact that *P. ramorum* is likely to have on the yield/quality of cultivated ornamental species on nurseries in the EU without any control measures is likely to be **major.**

Although not crop plants, the impact that *P. ramorum* is likely to have on the quality of cultivated plants in managed gardens (especially heritage plants in gardens involved in tourism) in the EU without control measures is likely to be **massive**, but on a local-scale. Overall of the EU, the impact is likely to be **moderate.**

If controls are lifted, in the '*northern European tree system*' (described as trees with stem cankers in association with infected rhododendron) the environmental impact will increase as the pathogen becomes more widespread in the environment, increasing the number of infected foliar hosts that sporulate sufficiently to provide inoculum to infect tree stem hosts with subsequent tree mortality. This impact has the potential to be **major** on a local basis but **moderate** over the whole of the PRA area. In the '*southern European tree system*', should the pathogen be introduced, the impact would shift from minimal (zero) to **major** because the environment is considered to be highly favourable to the establishment of *P. ramorum*.

At risk habitats that are yet to become affected by *P. ramorum* include heathlands in northern Europe, as well as evergreen oak woodlands and laurel forests (laurisilva) and maquis/matorral habitats in southern Europe, but only where they contain susceptible host species that are capable of sporulating and favourable conditions for the pathogen. Should these areas become affected there will be knock-on effects on the ecology of the area.

The pathogen has yet to be found in timber plantations but should it do so, long-term, the impact may be **minor to moderate** in the absence of controls.

CONCLUSIONS OF PEST RISK ASSESSMENT

Summarize the major factors that influence the acceptability of the risk from this pest:

- *Phytophthora ramorum* is moving in trade in both North America and Europe
- The pathogen is favoured by some nursery practices. In the absence of phytosanitary controls it is likely to spread rapidly within the EU through the trade network
- It is very likely that the pest will survive or could remain undetected during existing phytosanitary measures
- Observations suggest that symptom expression <u>may</u> be suppressed by fungicide treatment.
- The pest is established in an area (Pacific Northwest of the USA) with similar climatic conditions (though not necessarily optimal for the pathogen) to some parts of the PRA area <u>and</u> causes serious economic damage in its area of establishment there (where it is considered to be an exotic introduction)
- It has a very wide host range and a reproductive strategy (asexual sporangia for dispersal and infection; long-lived chlamydospores for survival) likely to help establishment
- A large range of ornamental plants are at risk, both traded plants and those grown in heritage gardens, parks and public greens
- A large range of environmental shrubs and trees are potentially at risk across a range of habitats (e.g. woodland, heathland and maquis shrubland)
- The most at-risk habitats broadly occur in climatic areas that most favour the pathogen

Estimate the probability of entry:

In the absence of phytosanitary controls the overall probability of entry is considered to be **high**, mainly due to the wide host range and the ability of *P. ramorum* to persist in a variety of substrates (e.g. soil, growing media, bark, wood, foliage). The relative importance of the pathways is given below (based upon a 5 word ranking system where **very low** and **very high** are extremes):

In the absence of phytosanitary controls:

Plants for planting of susceptible hosts (excluding seeds and fruits) from the USA and the unknown area/areas or origin: **high risk.**

Plants for planting of susceptible hosts (excluding seeds and fruits) from Canada and the non-EU countries of Norway and Switzerland: **medium risk**.

Soil as a commodity from the USA, Canada, the unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **medium risk.**

Susceptible isolated bark from the USA and the unknown area/areas or origin: **medium risk.**

Plants for planting of non-hosts (excluding seeds and fruits) accompanied by contaminated growing media from the USA, Canada, the unknown area/areas of origin and the non-EU countries of Norway and Switzerland: **low risk.**

Soil as a contaminant of travellers shoes and imported machinery, vehicles etc from the USA and the unknown area/areas of origin: **low risk.**

Susceptible wood from the USA and the unknown area/areas of origin: **low risk.**

Foliage or cut branches of susceptible hosts from USA, Canada, the unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **very low risk.**

Seeds and fruits of susceptible hosts from the USA, Canada, unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **very low risk.**

Susceptible isolated bark from Canada and the non-EU countries of Norway and Switzerland: **very low risk**

Susceptible isolated wood from Canada and the non-EU countries of Norway and Switzerland: **very low risk.**

Estimate the probability of establishment:

The probability of establishment in the PRA area is **high**.

A wide range of host plants is cultivated on nurseries in the EU. Outside of nurseries, managed parks and gardens growing susceptible host species have already become affected in parts of the EU. In some of these areas (e.g. parts of the UK), containment with a view to suppressing the level of inoculum to protect susceptible trees and to reduce spread, has become necessary. This is because total eradication of the pathogen may not be possible in part of the PRA area.

Some parts of the area have very favourable climatic conditions; certain nursery practices favour the pathogen; long-lived chlamydospores aid survival and establishment.

Estimate the potential economic impact:	The potential economic impact for the nursery trade is **high**. Without controls the pathogen has the potential to spread further in the trade network and could potentially expand its host-range, which is already very wide. For cultivated plants, damage is principally to the quality of hardy ornamental hosts. Loss of exports may increase if third countries maintain requirements for imports of ornamental plants from the EU. If controls are lifted, environmental impacts may become locally **major** but this may take some time (possibly decades) as this relies on further spread of the pathogen. Social impacts will increase as a result of damage to plants in managed gardens that are visited by the public firstly impacting on visitor numbers and ultimately affecting the tourism industry where such gardens are part of that economy. Costs borne by National Plant Protection Organisations will increase if increased phytosanitary controls are recommended in an effort to reduce further spread to the environment. However, there will be environmental benefits if controls focus on removal of foliar sporulating hosts that are invasive species such as *R. ponticum.*
Degree of uncertainty	Pathways Although there are data available in the Eurostat Comext database for six of the eight pathways the level of uncertainty surrounding the data is **high** for Pathway (i) plants for planting (hosts), Pathway (ii) plants for planting (non-hosts) and Pathway (v) foliage/cut branches of susceptible hosts because the only named hosts in the database are rhododendron (including azalea) and roses and this is only for plants for planting. It is assumed that Pathway (ii) plants for planting (non-hosts) contains some susceptible hosts. The level of uncertainty for Pathway (iv) volume of soil as a contaminant is **high** because there are no data. The level of uncertainty for Pathway (vii) volume of susceptible bark is **high** because the data are part of a general wood waste category in Eurostat with no named genera. The level of uncertainty is **high** for Pathway (iii) volume of soil/growing media as a commodity from non-EU European countries (Norway and Switzerland) as no data are available in the Eurostat database, as well as for Pathway

(vii) susceptible bark and Pathway (viii) susceptible wood from these countries too, as no data were obtained.

Pathway (vi), the volume of seeds and fruits has **medium** to **high** uncertainty as only a few genera are named and these data refer to nuts and fruit only.

The only categories where the data on volumes of imports has **low** uncertainty are for Pathway (iii) soil as a commodity from Canada, USA, China and Taiwan as this is banned and Pathway (viii) susceptible wood from these countries as five of the known host genera are named in the Eurostat Comext database including *Quercus* spp.

Establishment

It is uncertain as to whether the mating system is fully functional and therefore what risks arise from the introduction of the A2 mating type into the EU.

The potential for adaptation to new hosts or environments is uncertain.

There is a lack of high-resolution data on host distribution for Europe. This has limited the determination of the endangered areas outside of nurseries.

The rate of spread in the absence of phytosanitary controls is uncertain.

The ability for asymptomatic root infections to become systemic is uncertain.

The significance of asymptomatic sporulation is uncertain.

The role of inoculum contaminating the growing media of plants that are traded is uncertain.

The suppression of symptoms by the use of fungicides (with fungistatic properties) is based upon observations.

The likelihood of eradication in non-nursery environments is uncertain.

Economic impact

The impact in the area or areas of origin is unknown, as this has yet to be identified. This has a high level of uncertainty.

The impact in the absence of phytosanitary measures is not known for the EU where measures have been in place since

2002.

The potential for hybridisation with other species of *Phytophthora* is uncertain.

The potential for timber plantations to become affected by *P. ramorum* is uncertain.

OVERALL CONCLUSIONS The pest fulfils the criteria of a quarantine pest. There is a risk of further entry (of known or new lineages and/or mating types), establishment and economic impact. The risk from the pest is considered not to be acceptable.

STAGE 3: PEST RISK MANAGEMENT

IDENTIFICATION OF THE PATHWAYS

Pathways studied in the pest risk management section

Pathway (i):
Plants for planting (excluding seeds and fruit) of known susceptible hosts that are permitted entry from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin. Plants for planting of known hosts from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a pathway.

Pathway (ii):
Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Plants for planting of non-host plant species with contaminated growing media from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a potential pathway.

Pathway (iii):
Soil/growing medium (with organic matter) as a commodity from the USA and Canada, or from the as yet unknown area/s of origin for *P. ramorum.* Soil/growing media as a commodity from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

Pathway (iv) :
Soil as a contaminant (e.g. on footwear, machinery, etc.) from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Soil as a contaminant from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

Pathway (v):
Foliage or cut branches (for ornamental purposes) of susceptible foliar hosts from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Foliage or cut branches of susceptible foliar hosts from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

Pathway (vi):
Seeds and fruits of susceptible host plants from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Seeds and fruits of susceptible host plants from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

Pathway (vii):
Susceptible (isolated) bark from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Susceptible (isolated) bark from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

Pathway (viii):
Susceptible wood from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Susceptible wood from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

Other pathways identified but not studied	None

IDENTIFICATION OF POSSIBLE MEASURES

Pathway (i): Plants for planting (excluding seeds and fruit) of known susceptible hosts that are permitted entry from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Detection of the pathogen in consignments by inspection and testing at export and/or import
Detection of the pathogen by inspection and testing during post-entry quarantine

Measures related to the crop or to places of production:
Pest freedom for the crop, place of production or area.
Domestic certification schemes if supported by testing of symptomatic material.

Other possible measures:
Surveillance and eradication in the importing country of the EU

Pathway (ii): Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Physical removal of any surplus growing media just before export.

Measures related to the crop or to places of production:
In areas where the pathogen occurs, treatment (sterilisation) of the growing media prior to planting and prevention of reinfestation during the growing period.

Pest freedom for the crop, place of production or area (i.e. non-host plants to be produced away from host-plants to avoid contamination.)

Other possible measures:
Surveillance and eradication in the importing country of the EU.

Pathway (iii): Soil/growing medium (with organic matter) as a commodity from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Depending upon the volume of material heat treatment could be considered but may not be practical. Testing may be feasible but may not detect low levels of the pathogen.

Measures related to the crop or to places of production:
Pest free crop, place of production or area. (This refers to the area from which the soil or growing media is collected).

Other possible measures:
Surveillance and eradication in the importing country of the EU.

Pathway (iv): Soil as a contaminant (e.g. on footwear, machinery, etc.) from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Cleaning and (if feasible without damage to the machinery) disinfection of used machinery or vehicles imported from an area where *P. ramorum* occurs.

Measures related to the crop or to places of production:
Not applicable

Other possible measures:
Inspection of human traveller's footwear and possible treatment at the point of entry where travellers have entered from an area where *P. ramorum* occurs.

Pathway (v): Foliage or cut branches (for ornamental purposes) of susceptible foliar hosts from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Detection of the pathogen in consignments by testing at export and post-entry (this is only applicable to known hosts and given the volume of material may not be feasible)
Removal of the pest from the consignment by suitable heat treatment (affects quality)

Measures related to the crop or to places of production:
Pest–free area for the crop, place of production or area.

Other possible measures:
Controls on recycling – this is unlikely to be practical except where known infected material is to be disposed of.

Surveillance and eradication in the importing country of the EU.

Pathway (vi): Seeds and fruits of susceptible host plants from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Detection of the pathogen in consignments by inspection and testing at export and import
For contaminated seed lots, removal of the pest from seed consignments by physical removal of contaminating plant debris

Measures related to the crop or to places of production:
Pest-free crop, place or area of production

Other possible measures:
Surveillance and eradication in the importing country of the EU

Pathway (vii): Susceptible (isolated) bark from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Limited end-use of known infected bark (i.e. not to be used in the nursery trade or the landscaping industry)

Note that current prescribed treatments for isolated bark of conifers in the EC Plant Health Directive requires either fumigation or heat treatment at 56°C for 30 minutes before it can enter the EU. The efficacy of this treatment against cankered bark is unknown as one study has suggested that a treatment at 56°C for 30 minutes might not be adequate to kill *P. ramorum* in wood of tanoak (*L. densiflorus*). The efficacy of other prescribed treatments is also unknown.

Measures related to the crop or to places of production:
Pest-free crop, place of production or area.

Other possible measures:
Surveillance and eradication in the importing country of the EU.

Pathway (viii): Susceptible wood from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin, and Norway and Switzerland

Measures related to consignments:
Limited end-use of known infected wood (i.e. not to be used in the nursery trade or the landscaping industry) (but the risk of establishment from such a use is extremely low.)

Note that one of the current prescribed treatments for wood of conifers and wood waste of various types in the EC Plant Health Directive requires heat treatment at 56°C for 30 minutes before it can enter the EU. The efficacy of this treatment against cankered wood is unknown as one study has suggested that a treatment at 56°C for 30 minutes might not be adequate to kill *P. ramorum* in wood of tanoak (*L. densiflorus*). The efficacy of other prescribed treatments is also unknown

Measures related to the crop or to places of production:

Pest freedom of the crop, place of production or area

Other possible measures:
Surveillance and eradication in the importing country of the EU.

EVALUATION OF THE MEASURES IDENTIFIED IN RELATION TO THE RISKS PRESENTED BY THE PATHWAYS

The risks presented by the pathways have been ranked from high to very low depending upon the type of commodity as well as the origin.

Degree of uncertainty

The area of origin or origins has not been identified and although it has been speculated to be Asia (possibly Yunnan, Taiwan or the eastern Himalayas) this is still not proven. Because of this it is not possible to regulate all of the pathways.

The efficacy of fungicide treatments for host plants is not 100%.

The potential for spread in asymptomatic roots of host plants is a possibility, but is not proven to have led to new findings.

The significance of asymptomatic sporulation is uncertain.

The potential for spread in growing media has not been shown to occur in practice, but it has the potential to do so.

It is not known whether there are imports of machinery or vehicles from area where *P. ramorum* occurs

It is not known whether areas where foliage or cut branches are harvested for export to the EU are affected by *P. ramorum*

There is no evidence of seed-borne infection to date so the potential for this to be a pathway is uncertain.

The evidence for fruit-borne infection is only experimental so the potential for this to be a pathway is uncertain.

The efficacy of phytosanitary treatments that are routinely prescribed for bark and wood are not known but there is doubt as to the efficacy of 56ºC for 30 minutes.

The potential for spread from infected bark and wood to host plants is not known; spread from bark is more likely than from wood.

CONCLUSION:

Recommendation for possible measures:

The measures below do not account for pre-existing EC phytosanitary measures for *P. ramorum* or any measures that may have an impact on the risks posed by *P. ramorum* under the EC Plant Health Directive (2000/29/EC).

Because of the uncertainty surrounding the origin or origins of *Phytophthora ramorum* it is not possible to regulate the 8 main '*commodity types*' from this origin, albeit this continues to present a risk of entry of *P. ramorum* to the EU.

For foliage and cut branches, measures may only be necessary for areas where *P. ramorum* occurs if material is harvested there. This is likely to be only California and Oregon in the USA. Norway and Switzerland may only need to be regulated if the pathogen occurs in areas where foliage and cut branches are harvested and if these are exported to the EU. These measures could be recommended but the risk of establishment from this pathway is likely to be low.

It is thought that measures are not necessary for seeds and fruit of susceptible host plants as there are no records of infection in the field and plants with edible fruit that are likely to be traded are not hosts. There are no data to show that seed transmission is possible.

For susceptible bark, measures are only necessary for parts of the USA where *P. ramorum* occurs in woodlands and forests (California and Oregon) as there are no woodlands/forests affected in Canada, Norway or Switzerland.

For susceptible wood, measures seem not to be necessary because of the end-use of the material. If measures are maintained then they are only necessary for parts of the USA where *P. ramorum* occurs in woodlands and forests (California and Oregon) as there are no woodlands/forests affected in Canada, Norway or Switzerland

The recommended measures are listed below:

Pathway (i): <u>Plants for planting (excluding seeds and fruit) of known susceptible hosts</u> that are permitted entry from the USA and Canada, Norway and Switzerland	Phytosanitary Certificate (PC) and, if appropriate, Re-export Certificate (RC) *Measures related to consignments:* Detection of the pathogen in consignments by inspection <u>and</u> testing at export and/or import *or* Detection of the pathogen by inspection <u>and</u> testing during post-entry quarantine *Measures related to the crop or to places of production:* Pest freedom for the crop, place of production or area. Domestic certification schemes <u>if</u> supported by testing of symptomatic material. *Other possible measures* Surveillance and eradication in the importing country of the EU

Pathway (ii): <u>Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media</u> from the USA and Canada, Norway and Switzerland	PC and, if appropriate, RC *Measures related to consignments:* Physical removal of any surplus growing media just before export. *Measures related to the crop or to places of production:* In areas where the pathogen occurs, treatment (sterilisation) of the growing media prior to planting and prevention of reinfestation during the growing period Pest freedom for the crop, place of production or area (i.e. non-host plants to be produced away from host-plants to avoid contamination) *Other possible measures* Surveillance and eradication in the importing country of the EU

Pathway (iii): <u>Soil/growing medium (with organic matter) as a commodity</u> from the USA and Canada, and Norway and Switzerland	PC and, if appropriate, RC *Measures related to consignments:* Depending upon the volume of material heat treatment could be considered but may not be practical. *Measures related to the crop or to places of production:* Pest free crop, place of production or area. (For the area where soil or growing media are collected) *Other possible measures* Surveillance and eradication in the importing country of the EU.

Pathway (iv): <u>Soil as a contaminant</u> (e.g. on footwear, machinery, etc.) from the USA and Canada, Norway and Switzerland	*Measures related to consignments:* Cleaning and disinfection of used machinery or vehicles imported from an area where *P. ramorum* occurs. *Measures related to the crop or to places of production:* Not applicable *Other possible measures* Inspection of human travellers footwear and possible treatment at the point of entry where travellers have entered from an area where *P. ramorum* occurs

Pathway (v): <u>Foliage or cut branches</u> (for ornamental purposes) of susceptible foliar hosts from the USA (Norway and Switzerland – but only if foliar hosts are affected where harvesting and export to the EU occurs)	PC and, if appropriate, RC *Measures related to the crop or to places of production:* Pest–free area for the crop, place of production or area. *Other possible measures* Controls on recycling for known infected material Surveillance and eradication in the importing country of the EU

Pathway (vii): <u>Susceptible (isolated) bark</u> from the USA	PC and, if appropriate, RC *Measures related to consignments:* Limited end-use of known infected bark (i.e. not to be used in the nursery trade or the landscaping industry) *Measures related to the crop or to places of production:* Pest-free crop, place of production or area

REFERENCES FOR SUMMARY

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INTRODUCTION

Project Background

Phytophthora ramorum is a newly described species (Werres *et al.*, 2001) that is exotic to Europe and thought to have been relatively recently introduced from an unknown area, or areas, of origin. Prior to being formally named and described, the pathogen was first observed infecting rhododendron and viburnum in Germany (Werres and Marwitz, 1997) and rhododendron in the Netherlands, since at least 1993. At around the same time, increased mortality of oaks (*Lithocarpus* and *Quercus* species) was observed in California, USA and described as 'sudden oak death'; the causal agent was identified as a new and unnamed *Phytophthora* species in 2000 (Frankel, 2008). The first formal pest risk assessment in Europe, for the US *Phytophthora*, was produced in September 2000 (Brasier, 2000). No specific phytosanitary measures were identified as the assessment was undertaken using the EPPO risk assessment scheme, which pre-dated the EPPO Pest Risk Analysis (PRA) scheme, thus not including the third stage of PRA, i.e. risk management. The conclusion of the assessor was that the US *Phytophthora* had potential to establish in the UK, possibly entering on nursery stock, and that it posed a significant risk to (at least) UK native and exotic oaks. By January 2001, the *Phytophthora* causing sudden oak death in California and the *Phytophthora* which had been isolated from rhododendron in the Netherlands and Germany (and viburnum) were considered to be the same species. EPPO added the pathogen to their Alert List (an early warning, without a full PRA) in January 2001. A second PRA was produced by the UK (published June 2001; Jones and Sansford, 2001). An EPPO-style Datasheet was also produced by the UK but was never published, although it was updated with each subsequent revision of the PRA described below. The revised PRA highlighted the risks to the UK, EU and EPPO region, identified uncertainties and research needs, and recommended surveys in the EU/EPPO region to determine the pathogen's distribution. It also suggested that phytosanitary measures should be considered, such as controls on imports of known susceptible hosts and their products into and within the EU/EPPO region from areas/countries where the pathogen has been found, to try and prevent further entry. It was recommended that consideration should be given to continuation of EPPO Alert listing and to making the pathogen an EU/EPPO quarantine pest. As a result of the PRA, in the summer of 2001, Defra's Plant Health and Seeds Inspectors (PHSI) for England and Wales and the Dutch Plant Protection Service commenced limited surveys for the as yet unnamed *Phytophthora*.

After the pathogen was formally named as *P. ramorum* in October 2001 (Werres *et al.*, 2001) a third formal UK PRA was published in January 2002 (Jones, 2002). In February 2002, as a result of the ongoing survey work, Defra (UK) detected *P. ramorum* on a symptomatic *Viburnum tinus* plant from a garden centre in southern England (Lane *et al.*, 2003). This was the first UK record of *P. ramorum.*

Following on from the PRA work, UK (England) legislation aimed at *P. ramorum* was enacted in May 2002 (Anon., 2002a). This was somewhat earlier than the EC legislation, which came into force in September 2002 (Anon., 2002) based largely on actions taken by the UK and the Netherlands. The UK (England) legislation was revoked and replaced in November 2002 (Anon., 2002b) reflecting the first EC requirements (Anon., 2002). The EC legislation broadened controls on imports of susceptible material and had requirements for controls on movement of susceptible plants within the EU, as well as controls on outbreaks, and a requirement for EU Member States to conduct surveys to be reported back to the EC by December 2003. One other European PRA (a Report of a PRA) was prepared by the Netherlands in October 2002 (de Hoop *et al.*, 2002) to ensure that phytosanitary measures arising from the new EC legislation to be taken in that country were technically justified.

Accounting for ongoing research results, literature, and findings of *P. ramorum* in the EU and North America, the PRA was updated again and was published in March 2003 (Jones *et al*., 2003); it was revised further and published again in October 2003 (Sansford *et al.*, 2003). This last revision pre-dated the first tree findings in the UK and the Netherlands in late October 2003. A full update of the Datasheet was prepared during the following year (Sansford and Brasier, 2004), and a draft PRA, but prior to completion, the first UK findings of the new pathogen *Phytophthora kernoviae* (also in October 2003), and the expansion in its host range over the following year led to changing priorities and the PRA work for *P. ramorum* was put on hold.

More informal assessments of risk have also been made for Europe (Werres, 2003) and for specific regions, e.g. for the Mediterranean (Moralejo and Descals, 2003) and for Italy (Vettraino *et al*., 2007).

The RAPRA project commenced in January 2004. EC legislation for *P. ramorum* was amended in April 2004 (Anon., 2004) accounting for changes in host range and assessed risk. The legislation was revised again in March 2007 (Anon., 2007). Current measures still require official surveys to be reported back to the EC at the end of the year, and broadly-speaking, import and internal movement controls of rhododendron, viburnum and camellia (the three most commonly affected traded genera in the EU) with statutory action to be taken on findings.

In 2007, a full update of the UK Datasheet accounting for the results of the full UK research programme, key aspects of the EU and USA research programme, including parts of the RAPRA Project, as well as EU and North American survey findings was prepared (Sansford and Woodhall, 2007) to re-examine the risks to the UK and to suggest risk management options in preparation for a UK policy review for *P. ramorum* in 2008.

In Europe, at the time of the RAPRA Project proposal in November 2003, the pathogen had been found predominantly on ornamental plants on nurseries in several European countries. However, it had also been found outside of nurseries in a few managed gardens and semi-natural woodland areas on hardy shrubs (principally rhododendron) and affecting a very small number of trees in the UK and the Netherlands. From both European and North American records, the pathogen is now known to affect more than 130 plant species, comprising 75 plant genera in 37 different families. Its origin is still unknown and it is still only recorded in North America and the EU where it is found both outdoors and in the nursery trade. In the EU, it is still only the UK and the Netherlands that have reported trees with bleeding cankers caused by *P. ramorum*, and these are all associated with infected rhododendron. In contrast to the USA, tree mortality is minimal.

In the USA (California/Oregon), *P. ramorum* is causing extensive oak mortality (*Lithocarpus* and *Quercus* species) but also affects a wider range of other woodland species including understorey and herbaceous plants. The impacts on affected woodland ecosystems are severe. The pathogen was first intercepted in Canada on nurseries in 2003 and there have been subsequent interceptions on US plants. It has been found in residential gardens on plants associated with introductions with US plants, but not in forests (Anon., 2006). It has been found on a few nurseries (as part of national surveys or as interceptions in 2003–2007) but is subject to eradication (S. Sela, CFIA, Canada. *personal communication*, 2008). Both the US and Canada have produced PRAs.

P. ramorum is thought to have been introduced separately to both the USA and Europe. Though belonging to the same species, phylogenetically North American and European isolates comprise distinct genetic lineages (Ivors *et al.*, 2006; Martin, 2008; Grünwald *et al.*, 2008). Isolates in US woodlands (lineage NA1) and isolates in Europe (lineage EU1) can be distinguished on the basis of neutral molecular polymorphisms (e.g. by microsatellite profiles and mitochondrial sequence analysis) and also by their colony characteristics in culture and growth rate in culture (Werres and Kaminski, 2005; Brasier *et al.*, 2006). A third lineage (NA2) has been found in US nurseries. In North America, isolates of the EU1 lineage have also been found on nurseries and recovered from a river about 2 km from an infested nursery.

P. ramorum is heterothallic and both mating types (A1 and A2) are required for sexual reproduction. Isolates of the NA1 and NA2 lineages have all proven to of the A2 mating type; the EU1 isolates have all been of the A1 mating type with the exception of three isolates from Belgium (Werres and De Merlier, 2003; Werres and Kaminski, 2005; K. Heungens, ILVO, Belgium, *personal communication*, 2007). If the European and American lineages come into contact there is a risk of sexual reproduction and genetic recombination recombination between them. Any progeny that might potentially be generated via sexual recombination may show new adaptive behaviours and present new risks. Additionally, although there is uncertainty over whether the mating system is fully functional, there is potential for somatic recombination to occur even in the absence of sexual recombination.

The following risks therefore exist to Europe from: (1) the establishment and spread of the EU1 lineage in Member States, especially into the wider environment; (2) the introduction and spread of non-EU lineages from North America or from other unknown areas of origin; and (3) the introduction and spread of isolates of A2 mating type, regardless of lineage.

This RAPRA Project aimed to principally determine the risks posed by the recently described pathogen *Phytophthora ramorum* to European trees, woodland ecosystems and other environmentally important habitats (e.g. heathlands) and ornamental plants in the nursery trade and in public gardens.

Project Aims: '*Risk Analysis for Phytophthora ramorum*'

The overall objective of the RAPRA project is to produce a European Pest Risk Analysis (PRA) for *Phytophthora ramorum* including risk management strategies and contingency plans applicable to the pathogen within the European Union. This PRA is the **key deliverable** of the RAPRA Project. The overall objectives of RAPRA have been achieved through a range of specific and measurable objectives, each one related to a specific Workpackage (WP), as follows:

1. **To collate and publish available information on the extent of entry and distribution of *Phytophthora ramorum* in the EU and Europe as a geographic area.** This information included: the natural and potential ranges of host species; the detected presence of A1 and A2 mating types; and the population structure of *Phytophthora ramorum* defined as the range of variation in genotype, pathogenicity and host specificity [**WP1**].

2. **To establish the level of susceptibility (to both European and American isolates) of tree and non-tree species of significant environmental and economic value to the EU.** This included at least the following: tree species within the Fagaceae (*Quercus robur*, *Q. petraea*, *Q, suber*, *Q.ilex*, *Q. cerris*, *Q. rubra* and *Fagus sylvatica*), other hardwood (*Castanea sativa*, *Aesculus hippocastaneum*, species of *Ulmus*, *Corylus*, *Tilia*, *Acer* and *Betula*) and conifer species (*Pinus sylvestris*, *P. nigra*, *Picea abies*, *P. sitchensis*, *Abies* spp., *Taxus baccata* and *Pseudotsuga menziesii*). Non-tree species also tested for susceptibility included ornamental species and varieties marketed by the horticultural trade of *Viburnum*, *Camellia* and *Pieris* as

well as key species of European heaths, moorlands and maquis (*Rhododendron*, including *R. simsii, Vaccinium*, *Arctostaphylos, Calluna* and *Erica* species) [**WP2**].

3. **To quantify the sporulation, germination, infection, incubation period, latency, survival and dispersal components of the epidemiology of European and American isolates of *P. ramorum*.** This included defining the minimum, maximum and optimal temperature and moisture requirements for spore production and germination in both European and American populations of *P. ramorum* (at least five isolates of each); the potential for leaves of important tree and non-tree hosts (at least ten species of each) to produce inoculum of the pathogen; the survival time of long-lived chlamydospore inoculum under different regimes of temperature and moisture availability. The process of infection in wounded and unwounded hosts using containerised trees and excised material was tested on trees (*Quercus*, *Fagus*, *Abies* and *Taxus*) and ornamentals (*Viburnum*, *Rhododendron*) and the incubation period from infection to symptom expression was defined in at least three model hosts (high, medium and low susceptibility). The dispersal potential of the pathogen from discrete disease foci was evaluated in nurseries and natural habitats, by analysing foliage, soil and water samples using standard isolation methods and molecular diagnostics [**WP3**].

4. **To establish the potential for mating between *P. ramorum* (predominantly A1 mating type) found in Europe and *P. ramorum* (predominantly A2 mating type) present in the USA** by first analysing the mating type of more than 300 isolates (at least 200 European and 100 American), then assessing the functionality of the breeding system by defining the viability and abortion levels in sexually produced oospores [**WP4**].

5. **To evaluate the likely environmental and socio-economic impact of *P. ramorum*** should it establish in Europe and prove to be damaging to trees or important ecosystems such as heathland and maquis, by producing a quantitative prediction of the direct economic impact on ‘crop’ losses, the cost of control measures, losses to rural livelihoods and changes in the aesthetic and environmental quality of affected landscapes [**WP5**].

6. **To evaluate at least three existing and at least two new chemical active ingredients for the control of *P. ramorum* in ornamentals.** Several aspects of eradication, containment and fungicide control was addressed including assessing the level of tolerance to fungicides that is already present in populations of *P. ramorum*, and the efficacy *in vivo* and *in planta* of already available and new fungicide products [**WP6**].

7. Using information from WPs 1-6 **to define outbreak scenario’s, evaluate existing strategies for eradication and containment and to produce technical guidelines for management plans for dealing with *P. ramorum* in Europe while minimising** the need to disrupt to free trade [**WP7**].

8. **To develop, refine and publish a European Pest Risk Analysis for *P. ramorum* and provide information to underpin and advise EU plant health policy and legislation**. The experimental work defined in the objectives above provided the required information for consideration by legislative authorities responsible for EU plant health policy and legislation. Data was also be used to provide a quantitative prediction of the risk of *P. ramorum* establishing on oaks and other tree and plant species in Europe by combining climatic data derived from WP1 and new pathogen data from WP1-5 [**WP8**].

9. **To disseminate the results and achievements of the project** to EU and US Phytosanitary policy makers and to the wider community including the EU citizenry through a project

website, on-line symposia, mid-term and final presentations to DG SANCO and an end-of-project workshop [**WP9**].

10. **To co-ordinate research and development work of the project, organise meetings and the reporting of results during the life of the project** [**WP10**].

The overall aim of the RAPRA Project was therefore to develop a European PRA (Workpackage 8) for *P. ramorum*, including: assessment of potential entry, potential establishment; assessment of environmental and socio-economic impacts; and assessment of risk management strategies and guidelines for the development of contingency plans. The RAPRA Project aimed to: document the current host range and geographical distribution of the pathogen, including confirmation of the distribution of mating types within each North American and European population; determine the potential for sexual recombination by investigating the functionality of the mating system; investigate the host range (tree and non-tree), as well as aspects of the pathogen's epidemiology related to establishment risk. The results of the RAPRA Project will allow a review of EU phytosanitary policy in relation to risk whilst minimising disruption to trade.

Workpackage 8: '*Pest Risk Analysis for* Phytophthora ramorum *for the EU*'

The aim of this Workpackage is to produce a new Pest Risk Analysis (PRA) for *P. ramorum* for the EU to provide an assessment of the risk from North American and European isolates and to determine risk management options. Specific objectives of WP8 are to:

- Determine the risk of entry, establishment, spread and socio-economic and environmental loss from *P. ramorum* for the EU.
- Determine the appropriate level of risk management for Europe for *P. ramorum* in relation to the assessed level of risk determined by the Project.

A summary of the work plan is given in Annex I.

The determination of the risk of entry, establishment, spread, socio-economic loss and environmental impact and the appropriate level of management for *P. ramorum* in the EU in relation to the assessed level of risk determined by the Project, based on the most up-to-date FAO International Standard for Phytosanitary Measures (ISPM) for Pest Risk Analysis (FAO, 2004), is presented in this Deliverable Report.

The PRA draws upon the Deliverable Reports from the rest of the RAPRA project and any other information that has been provided by the Project partners in the course of the production of the PRA.

PEST RISK ANALYSIS FOR *PHYTOPHTHORA RAMORUM*

A recent draft of the European and Mediterranean Plant Protection Organisation (EPPO) Standard entitled '*Guidelines on Pest Risk Analysis: Decision making scheme for quarantine pests'* **(07-13727)** (EPPO, 2007) has been used as a basis for this Pest Risk Analysis (PRA) for *Phytophthora ramorum*. Most of the explanatory text that accompanies the draft EPPO standard has been removed for clarity; only the questions and a small part of the preamble to each of the main sections have been retained.

The EPPO PRA Standard is based on FAO ISPM No. 11 (FAO, 2004). It provides detailed instructions, for the following stages of PRA for quarantine pests: initiation; pest categorisation; probability of introduction and spread; assessment of potential economic consequences; and pest risk management. It provides a simple scheme based on a sequence of questions for deciding whether an organism has the characteristics of a quarantine pest, and if appropriate to identify potential management options. The scheme is also relevant for PRAs initiated by the identification of a pathway or the review of a policy. Expert judgement may be used in interpreting the replies. In responding to the questions it has not always been possible, where required, to select a one-word answer. Where this has occurred an explanation has been provided of the difficulties encountered in responding in this way.

Phytosanitary terms used in this PRA are defined in FAO ISPM No. 5 (2007).

Stage 1: Initiation

The aim of the initiation stage is to identify the pest(s) and pathways which are of phytosanitary concern and should be considered for risk analysis in relation to the identified PRA area.

1. Give the reason for performing the PRA.

This new PRA is being conducted primarily to take into account the experimental and economic data for the quarantine organism *Phytophthora ramorum* that has been specifically generated for the EU from the EU Sixth Framework Project '*Risk analysis for Phytophthora ramorum*'. Hereafter this is referred to as the RAPRA Project. Summaries of Deliverable Reports from the RAPRA project will be available at: http://rapra.csl.gov.uk/objectives/results/index.cfm

This work and other published data has allowed an EU Pest Risk Analysis (PRA) to be produced. This PRA will contribute to the review of EU emergency phytosanitary measures that is scheduled for 2008/9 and will inform EU policy.

Go to 2

2. Specify the pest or pests of concern and follow the scheme for each individual pest in turn. For intentionally introduced plants specify the intended habitats. If no pest of concern is identified the PRA may stop at this point.

The pest of concern is:

Name:	*Phytophthora ramorum* Werres, De Cock and Man In't Veld (Werres *et al*., 2001)
Synonym:	None
Taxonomic position:	Kingdom[1] – *Chromalveolata*
	Phylum – *Heterokontophyta* (heterkonts or stramenopiles)
	Class – *Oomycetes*
	Order – *Peronosporales*
	Family – *Pythiaceae*

Common name(s) of the disease:

Sudden oak death (in the USA); Ramorum bleeding canker (Hansen *et al.*, 2002; Brasier *et al.*, 2004a; Ramorum (shoot) dieback (Hansen *et al.*, 2002); Ramorum leaf blight (Hansen *et al.*, 2002)

Go to 3

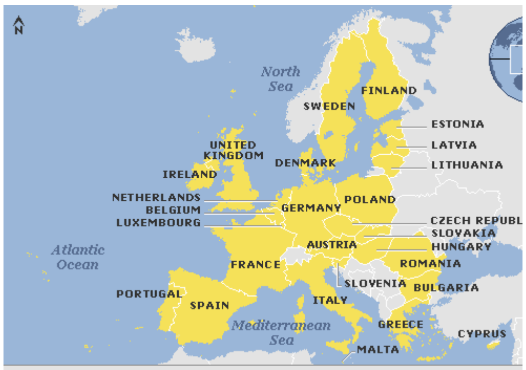
[1] Alternative classifications have been proposed at the Kingdom and Phylum levels, e.g. Kingdom Chromista with Phylum Oomycota

3. Clearly define the PRA area.

The PRA area is the European Union (27 Member States), though the mapping of endangered areas is extended to some other parts of European and the wider EPPO (European and Mediterranean Plant Protection Organisation) region (Figure 1).

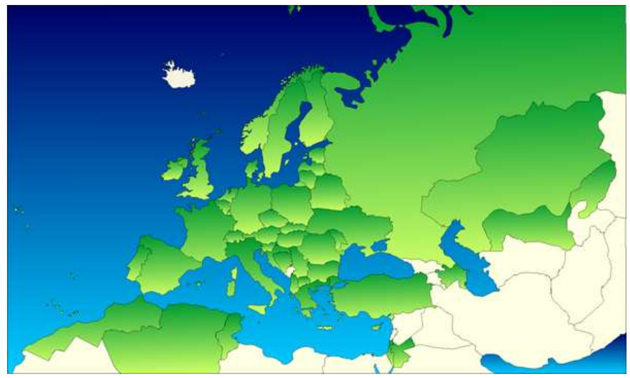
Figure 1. The PRA area: The European Union Member States – a subset of the EPPO (European and Mediterranean Plant Protection Organisation) region.

The EU (27 Member States)



Source: http://encarta.msn.com/media_941538636_761579567_-1_1/map_of_the_european_union.html

The EPPO region (50 countries including the EU)



Source: http://www.eppo.org/ABOUT_EPPO/about_eppo.htm

Go to 4

Earlier analysis

4. Does a relevant earlier PRA exist?

Yes. The first PRA in Europe was an EPPO-style pest risk assessment produced by Forest Research, UK in September 2000 (Brasier, 2000) for the as yet unnamed *Phytophthora* species causing sudden oak death in California, USA. This assessed the risks to the UK.

The assessment did not propose specific phytosanitary measures as it was undertaken using the EPPO risk assessment scheme (pre-dating the EPPO PRA scheme, thus not including the third stage of PRA, i.e. risk management). This risk assessment concluded that the pathogen had potential to establish in the UK, possibly entering on nursery stock, with a significant risk posed to (at least) UK native and exotic oaks. Although there was much uncertainty identified, the author felt that urgent research was required to address this, while suggesting that a decision be taken on the status of the pathogen before more information became available.

In January 2001, European and Californian scientists determined that the new *Phytophthora* species causing sudden oak death in California and the *Phytophthora* isolated from rhododendron in the Netherlands and Germany (and viburnum) were the same species (Garbelotto and Rizzo, 2005). EPPO added the pathogen to their Alert List (an early warning, without a full PRA) in January 2001. A second PRA was produced by the UK in April 2001 (published June 2001; Jones and Sansford, 2001) with an accompanying Datasheet (unpublished). The PRA highlighted the risks to the UK, EU and EPPO region, again identifying uncertainties and research needs, but also recommending surveys in the EU/EPPO region to determine distribution, as well as consideration of phytosanitary measures including controls on imports of known susceptible hosts and their products into and within the EU/EPPO region from areas/countries where the pathogen has been found, to try to prevent entry. It was recommended that consideration should be given to continuation of EPPO Alert listing and to making the pathogen an EU/EPPO quarantine pest. As a result of the PRA, in the summer of 2001, Defra's Plant Health and Seeds Inspectors (PHSI) for England and Wales commenced limited surveys for the as yet unnamed *Phytophthora*.

After the pathogen was formally named as *P. ramorum* in October 2001 (Werres *et al*., 2001) a third formal UK PRA was published in January 2002 (Jones, 2002) with an accompanying Datasheet (unpublished). In February 2002, as a result of the ongoing survey work, Defra's Plant Health and Seeds Inspectors (PHSI) submitted one symptomatic plant of *Viburnum tinus* to CSL from a garden centre in southern England, and it was confirmed to be infected with *P. ramorum* (Lane *et al*., 2003). This was the first UK record of *P. ramorum.*

Following on from the PRA work, UK (England) legislation aimed at *P. ramorum* was enacted in May 2002 (Anon., 2002a). This was somewhat earlier than the EU legislation, which came into force in September 2002 (Anon., 2002) based largely on actions taken by the UK and the Netherlands (the Netherlands started surveying and imposing measures in 2001: M. Steeghs, Plant Protection Service, the Netherlands, *personal communication*). The UK (England) legislation required that susceptible plant material (listed as 11 genera at this stage) entering England from the USA must be accompanied by a phytosanitary certificate (PC) with an additional declaration (AD) that it originated in an area free from *P. ramorum.* Post-entry controls were also required. The UK (England) legislation was revoked and replaced in November 2002 (Anon., 2002b) reflecting the first EU requirements (Anon., 2002). (NB: Generally speaking, once enacted, EC legislation is usually adopted by individual EU Member States in domestic legislation; thus the Devolved Administrations of the UK (England, Wales, Scotland and Northern Ireland) each have their own legislation). The EU legislation broadened controls on imports of susceptible material not just from the USA, but also from other non-EU countries and had requirements for controls on movement of susceptible plants within the EU, as well as controls on outbreaks, and a requirement for EU Member States to conduct surveys to be reported back to the European Commission (EC) by December 2003. One other European PRA (a Report of a PRA) was prepared by the Netherlands in October 2002 (de Hoop *et al*., 2002) to ensure that phytosanitary measures arising from the new EU legislation to be taken in that country were technically justified.

Accounting for ongoing research results, literature, and findings of *P. ramorum* in the EU and North America, the PRA (and datasheet) were updated again and the revised PRA was published in March 2003 (Jones *et al*., 2003) and revised further and published again in October 2003 (Sansford *et al*., 2003). This last revision pre-dated the first tree findings in the UK and the Netherlands in late October 2003. A full update of the datasheet was prepared during the following year (Sansford and Brasier, 2004) and a draft PRA was initiated but not completed at the time.

EU legislation for *P. ramorum* was amended in April 2004 (Anon., 2004), accounting for changes in host range and the assessed risk, and again in March 2007 (Anon., 2007). Current measures still require that (a) official surveys be reported back to the EC at the end of the year and (b) import controls are imposed on all listed susceptible hosts imported from the USA (as well as on a separate list of species for susceptible wood), that there is a prohibition on imports of susceptible bark from the USA (same listed species as those for susceptible wood), and, that there is internal movement controls in the EU (Plant Passporting) of *Rhododendron*, *Viburnum* and *Camellia* (the three most commonly affected traded genera in the EU) with statutory action to be taken on findings.

In 2007, a full update of the UK datasheet accounting for the results of the UK research programme, key aspects of the EU and USA research programme, as well as EU and North American survey findings was prepared (Sansford and Woodhall, 2007) to re-examine the risks to the UK and to suggest risk management options in preparation for a UK policy review for *P. ramorum* in 2008.

In Europe, at the time of the RAPRA Project proposal in November 2003, the pathogen had been found predominantly on ornamental plants on nurseries in several European countries. However, it had also been found outside nurseries in a few managed gardens and semi-natural woodland areas on hardy shrubs (principally rhododendron) and affecting a very small number of trees in the UK and the Netherlands. The pathogen is now known to affect more than 130 plant species in 75 plant genera belonging to 37 different plant families found on two continents. Its geographical origin is still unknown and to date it has only been recorded in North America and Europe where it is found both outdoors and in the nursery trade. In the EU, only the UK and the Netherlands have reported trees with bleeding cankers caused by *P. ramorum* and these are all associated with infected rhododendron. In the UK to date, 28 trees have been reported with bleeding bark cankers caused by *P. ramorum*, of which 13 have been felled or have died. In the Netherlands, there have been 17 trees with bleeding bark cankers, of which at least two have died.

PRAs have been also been produced by the USA and Canada where the pathogen occurs as well by others, e.g. Australia. These assess the risks to the respective countries rather than the risk the EU.

If yes	**Go to 5**
If no	Go to 6

5. Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?

The earlier UK and European PRAs are only partially valid. They do not account for all the new biological, epidemiological and socioeconomic data from the RAPRA Project or from other more recent sources. The UK datasheet (Sansford and Woodhall, 2007) is partially-valid as it was prepared for the purpose of a policy review for the UK in 2008. It is not a full literature review but it does account for the results of the UK research programme as well as key aspects of the European and US research programmes. It did not account for the recent reports from the IUFRO meeting, '*Phytophthoras* in Forests and Natural Ecosystems', in Monterey, August 2007. It has been reviewed by UK researchers and by the USDA Forest Service.

If entirely valid	End
If partly valid proceed with the PRA, but compare as much as possible with the earlier PRA	**Go to 6**
If not valid	Go to 6

6. **Specify the host plant species (for pests directly affecting plants) or suitable habitats (for non parasitic plants) present in the PRA area.**

The natural range of host plant species consists of a large number of ornamental and wild plants, primarily shrubs and trees. *P. ramorum* is recorded on over 130 plant species worldwide, and many of these hosts occur in Europe. There are also a number of experimentally susceptible hosts which are yet to be recorded as natural hosts. A full list of plants recorded as natural hosts is provided in Appendix II. A full list of experimentally susceptible hosts is provided in Appendix III. See *Question 14* for more details.

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7. **Specify the pest distribution**

North America: The pathogen has been reported in the wild in parts of California and Oregon. Infected material (under eradication) has been found in nurseries in more than 20 other states. The pathogen has also been reported (but subject to eradication) in British Columbia, Canada in a few nurseries, and some related residential plantings, that apparently arose from incursions from the USA (Anon., 2006). The 2007 national survey for Canada detected *P. ramorum* at 10 nurseries, all in British Columbia; all are subject to eradication (S. Sela, CFIA, Canada, *personal communication*, 2008). Most infected plants in the USA are associated with a clonally reproducing North American (NA1) lineage; NA1 isolates have all been of the A2 mating type (Brasier and Kirk, 2004; Werres *et al.*, 2005). There have also been findings in the USA of isolates of the lineage introduced into Europe (EU1): these have primarily been in nurseries, although there have been recent reports (2006) of the EU1 lineage in woodlands in Humbolt, California (COMTF, 2008) in a river near McKinleyville: the infested river is approximately 2 km from an infested retail nursery; all these EU1 lineage isolates were of A1 mating type (Hansen *et al*., 2003a; Osterbauer *et al*., 2004). A third lineage (NA2), also of A2 mating type, has been found in, or traced back to, nurseries in Washington State (Ivors *et al*., 2006). The NA2 lineage has also been detected in nurseries in Sacramento and San Luis Obispo Counties, California, USA (C. Blomquist, CDFA, California, *personal communication*). Martin (2008) identified four mitochondrial haplotypes: three corresponded to the existing lineages (NA1, NA2, EU1) classified by Ivors *et al.* (2006) whilst a fourth, from an Oregon forest, appeared to be derived from the NA1 lineage through a single base mutation after its introduction in to the USA; the four haplotypes (haplotype I, IIa, IIb and III) have been classified within the existing lineage nomenclature as EU1, NA1a, NA1b, NA2 respectively (Grünwald *et al.*, 2008; Martin, 2008; Table 1). The NA2 lineage is considered ancestral to the NA1 and EU1 lineages (Martin, 2008).

Central America:
No record.

South America:
No record.

Caribbean:
No record.

Europe:
In the EU, *P. ramorum* has been recorded as present in Belgium, Czech Republic (eradicated nursery finding), Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain (including Mallorca), Sweden

and the UK (all countries, and including the Channel Islands). Elsewhere in Europe, *P. ramorum* has also been recorded in Norway and Switzerland. In Norway, isolates are believed to be of the EU1 lineage. Ten isolates from Norway were tested and found to be the A1 mating type, consistent with them being of the EU1 lineage, and to have a uniform growth in culture that conformed to the EU1 lineage: M. Herrero, Bioforsk, Norway, *personal communication*. The genotype of Swiss isolates has not yet been investigated (D. Rigling, WSL, Switzerland, *personal communication*). Although the species was not formally described at the time, *P. ramorum* was first found on *Rhododendron* species in Germany and the Netherlands and *Viburnum* in Germany as far back as 1993 (Werres *et al*., 2001). In Europe, the pathogen is mainly present on non-tree hosts grown in containers at nurseries and retail garden centres. However, in Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Slovenia and Spain, the UK, as well as the non-EU countries of Norway and Switzerland, some infected plants have been found outside nursery situations in managed parks and gardens and/or in wild (woodland) situations (http://rapra.csl.gov.uk/objectives/wp1/distribution.cfm). Infected trees with bole cankers have only been found in the UK and the Netherlands. To date, the majority of EU1 lineage isolates have been of the A1 mating type (http://rapra.csl.gov.uk/objectives/wp1/popStructure.cfm; Werres *et al.*, 2005). However, the A2 mating type was identified from *Viburnum bodnantense* in Belgium (Werres and De Merlier, 2003) in 2002 and was confirmed as belonging to the EU1 lineage of *P. ramorum*. Since that initial finding, two further A2 isolates of the EU1 lineage have been found in Belgium, one on viburnum dating back to 2002 and one on rhododendron dating back to 2003; both were part of a culture collection that was being screened for mating types of *P. ramorum* and both originated from nursery stock (K. Heungens, ILVO, Belgium, *personal communication*, 2007). Isolates belonging to North American lineages have not been reported in Europe.

Asia:
No record.

Africa:
No record.

Oceania:
No record.

Origin of *Phytophthora ramorum*: The geographical origin of *P. ramorum* is still a matter of speculation. The recent discovery of the pathogen suggests that it was introduced relatively recently into both North America and Europe from an unidentified third country or countries. The substantiation for this recent introduction of *P. ramorum* is based on various lines of evidence:

Distribution of mating types

The distribution of mating types provides evidence for the exotic origin of the pathogen. *Phytophthora ramorum* is heterothallic and therefore requires both mating types (A1 and A2) to be present for sexual recombination to occur. It is assumed that both mating types are present in the area or areas where the organism evolved. Indeed, when heterothallic *Phytophthora* species are first introduced outside their natural range, it is not unusual for only one mating type to be initially observed within an introduced population due to founder effects. When *P. ramorum* was first discovered, only one mating type was found in either North America or Europe. The European population was of the A1 mating type whilst the North American population was the A2 mating type. This indicated that the pathogen had been introduced separately to each continent from an area or areas where both mating types were present. However, since these initial findings, the A2 mating type has been found in Europe, albeit only three times; these A2 isolates all belonged to what is now known as European lineage EU1. Also, isolates of the EU1 lineage, again only of A1 mating type, have been found in nurseries in British Columbia, Canada and in California, Oregon and Washington State, USA (Ivors *et al*., 2006), and more recently in a woodland stream in Humbolt county, California, suggesting an introduction either from Europe or from an unidentified third country origin.

Genetic diversity

Genetic studies have revealed a high degree of heterozygosity in *P. ramorum* isolates, suggesting frequent sexual recombination and out-crossing in the past, presumably in the pathogen's native range (Goss and Grünwald, 2008; Goss *et al.*, 2009). However, genetic profiling by analysing Amplified Fragment Length Polymorphisms (AFLPs) indicates that the North American population is now largely clonal (Ivors *et al*., 2004), whilst the European population consists of diverse, but very closely-related AFLP types (Ivors *et al*., 2004). Single nucleotide polymorphisms exist in the *coxI*, β-tubulin and cellulose binding elicitor lectin genes between the NA1 and EU1 lineages (Kroon *et al*., 2004; Bilodeau *et al*., 2004).

A more recent analysis of genetic variation using micro-satellite markers has also indicated significant genetic variation between European and North American populations (Ivors *et al*., 2006). This and other studies indicate that the North American NA1 genotypes are very closely related, suggesting the founder population was a limited introduction, thus confirming the exotic nature of the pathogen (Ivors *et al.*, 2006; Mascheretti *et al*., 2008; Martin, 2008). Indeed, Mascheretti *et al.* (2008) proposes two areas of initial introduction around the San Francisco Bay area of California based on genetic studies. The micro-satellite study (Ivors *et al*., 2006) confirmed that genetic diversity amongst isolates of the EU1 lineage was slightly higher, suggesting the introduction of a few closely related genotypes followed by the creation of new genotypes via mitotic recombination and/or mutation.

The evidence discussed above supports the exotic nature of the pathogen and indicates that, initially, it has been introduced to Europe and to the USA separately. However, there are few clues as to the geographical origin/s of *P. ramorum*. Based on mitochondrial sequence analysis, Martin (2008) considered the EU1 lineage to be basal to the main North American (NA1) lineage, and for the NA2 lineage to be ancestral to both. It has been suggested (Goss and Grünwald, 2008; Goss *et al.*, 2009) that the NA1 and EU1 lineages had diverged for at least 11% of their history, an evolutionarily significant amount of time roughly estimated to be on the order of 165,000 to 500,000 years. There is also evidence for historical recombination between the NA1 and EU1 lineages, indicating that the ancestors of these *P. ramorum* lineages were members of a sexually reproducing population (Goss and Grünwald, 2008; Goss *et al.*, 2009).

The closest relatives of *P. ramorum*, based on analysis of ribosomal DNA Internal Transcribed Spacer (ITS) sequences and mtDNA sequences are *Phytophthora lateralis* and *Phytophthora hibernalis* (Werres *et al*., 2001; Martin and Tooley, 2003; Martin *et al.*, 2004). *Phytophthora lateralis* is an invasive pathogen mainly affecting trees in Oregon and northwestern California, but is believed to have originated from Asia (E. Hansen, *personal communication* as cited by Brasier *et al*., 2004). The most important hosts of *P. lateralis* are *Chamaecyparis* spp. particularly *C. lawsoniana* (Tucker and Milbrath, 1942). *Taxus brevifolia* is an occasional host (first reported in DeNitto and Kliejunas, 1991). According to Hansen (E. Hansen, Oregon State University, USA, *personal communication*, 2006) published reports on hosts other than cedars (*C. lawsoniana* or *Chamaecyparis* spp.) and *T. brevifolia* are considered to be misidentifications.

Brasier *et al*. (2004) suggested that *P. ramorum*, like *P. lateralis*, may have originated in forested areas of Asia where, having co-evolved with native hosts, it is relatively benign in its natural habitat. Brasier *et al*. (2004) goes on to suggest that Yunnan, Taiwan and the eastern Himalayas may be possible areas of origin for *P. ramorum*. Yunnan was mentioned in particular, due to its vegetation, climate and for being a popular destination for plant collectors. Goheen *et al*. (2005) were unable to detect *P. ramorum* at four forestry sites they visited in Yunnan province. However, an abundance of *P. ramorum* host genera were present and foliar and dieback symptoms similar to those caused by aerial *Phytophthora* species were observed. An expedition to a remote area of Western Nepal (Vannini *et al.*, 2007), where temperate and sub-tropical forests were sampled, failed to detect *P. ramorum* in that region.

Stage 2: Pest risk assessment

Section A: Pest categorisation

At the outset, it may not be clear which pest(s) identified in Stage 1 require(s) a PRA. The categorization process examines for each pest whether the criteria in the definition for a quarantine pest are satisfied. In the evaluation of a pathway associated with a commodity, a number of individual PRAs may be necessary for the various pests potentially associated with the pathway. The opportunity to eliminate an organism or organisms from consideration before in-depth examination is undertaken is a valuable characteristic of the categorization process.

An advantage of pest categorization is that it can be done with relatively little information; however information should be sufficient to adequately carry out the categorization.

Identify the pest (or potential pest)

8. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?

Yes. The organism can be readily distinguished morphologically and genetically from other *Phytophthora* species (Werres *et al.*, 2001; Rizzo *et al.*, 2002; Martin and Tooley, 2003), including: two other new species (*P. nemorosa* and *P. pseudosyringae*) causing stem cankers on oaks in California and Oregon (Hansen *et al.*, 2003; Ivors and Garbelotto, 2002; Martin and Tooley, 2003); other *Phytophthora* species commonly found on European tree species and in hardy ornamental nursery stock. Phylogenetically, *P. ramorum* is most closely related to *P. hibernalis* and *P. lateralis* based on both nuclear rDNA internal transcribed spacer (ITS) regions (Garbelotto *et al*., 2001; Ivors *et al*., 2004) and mitochondrially-encoded cytochrome oxidase II (*cox* II) mtDNA sequences (Martin and Tooley, 2003).

As referred to at the initiation stage the pest is:

Name:	*Phytophthora ramorum* Werres, De Cock and Man In't Veld (Werres *et al*., 2001)
Synonym:	None
Taxonomic position:	Kingdom – *Chromalveolata* (see *Footnote 1*) Phylum – *Heterokontophyta* (heterkonts or stramenopiles) Class – *Oomycetes* Order – *Peronosporales* Family – *Pythiaceae*
Common name(s) of the disease:	Sudden oak death (in the USA); Ramorum bleeding canker (Hansen *et al.*, 2002; Brasier *et al.*, 2004); Ramorum (shoot) dieback (Hansen *et al.*, 2002); Ramorum leaf blight (Hansen *et al.*, 2002)

This PRA relates to isolates of the European (EU1) lineage identified by Ivors *et al.*, 2006) and non-European isolates (including identified North American lineages and other as yet unidentified lineages of unknown origin) of *P. ramorum.* The pathogen is a recently described species of *Phytophthora* (Werres *et al.*, 2001). It is different from the 100 or so other species of

Phytophthora currently known throughout the world. It was first described using from isolates obtained from rhododendrons and viburnums in Germany and rhododendron in the Netherlands (Werres *et al*., 2001). *P. ramorum* was also shown to be morphologically identical to the *Phytophthora* sp. found causing sudden oak death in California and Oregon (Rizzo *et al*., 2002; Garbelotto and Rizzo, 2005; Frankel, 2008). Analyses with neutral molecular markers, *viz* sequencing of the nuclear internal transcribed spacer (ITS) of the ribosomal DNA, a single genetic locus (Rizzo *et al*., 2002) and an isozyme analysis of multiple loci (Man in't Veld *et al*., 2002), both confirmed that North American and European isolates are of the same species. Equally, it is becoming clear that European and North American isolates represent distinct genetic lineages of *P. ramorum.* With amplified fragment length polymorphism (AFLP) analysis (Ivors *et al*., 2004) (neutral molecular markers) the two groups of isolates (European and North American woodland isolates) fall into different evolutionary lineages. More recently, DNA analyses using microsatellite markers (Ivors *et al.*, 2006) have shown that European isolates belong to a single evolutionary lineage designated EU1, comprised of multiple, closely-related genotypes. North American woodland isolates belong to a second evolutionary lineage (designated NA1) which is apparently a clonally-reproducing population. Several isolates from US nurseries have also been identified as belonging to a third genetic lineage (NA2). All three lineages have occurred in US nurseries. Mitochondrial sequence analysis (Martin, 2008) has identified a fourth haplotype that has apparently arisen via a single base mutation of the NA1 lineage; these have been designated NA1b and NA1a respectively (Table 1).

Lineage	Provenance	Microsatellite profile[1]	Mitochondrial sequence [2]	Growth rate [3]	Colony type [4]	Mating type
EU1	European and US nurseries and woodlands	Clade 1	Haplotype I	Fast	Aerial	A1[6]
NA1	US woodlands and nurseries	Clade 2	Haplotype IIa, Haplotype IIb[5]	Slow	Appressed	A2
NA2	US nurseries	Clade 3	Haplotype III	Fast	Aerial	A2

Table 1. Characteristics of *Phytophthora ramorum* lineages. [1] Ivors *et al*., 2006; [2] Martin (2008); [3] Growth rate determined on V8 agar; [4] Mycelial growth habit on V8 agar at room temperature; [5] Haplotype IIb from an Oregon forest; [6] Includes three A2 isolates from Belgium nurseries.

With regard to behavioural characters, isolates of the EU1 lineage and NA1 lineage show marked differences in growth rate and differences in colony type (Brasier, 2003; Anon., 2005; Werres and Kaminski, 2005; Brasier *et al.*, 2006). Small differences are also reported between the sporangial morphology of American and European isolates (Zielke and Werres, 2002), though these are within the accepted range for the species. In addition, there appear to be differences in the pathogenic potential between EU1 and NA1 lineages of *P. ramorum.* Isolates sampled from the EU1 lineage have been found to be, on average, significantly more aggressive than isolates of the NA1 lineage isolates when inoculated into bark of *Quercus rubra* (Brasier *et al.*, 2002; Brasier, 2003; Brasier *et al.*, 2006). EU1 isolates have also been shown to be more pathogenic than NA1 isolates on rhododendron; the reaction of the same rhododendron clone to US isolates was more variable (Pogoda and Werres, 2002). EU1 and NA1 lineages therefore appear to comprise separate, differently adapted populations (Brasier, 2003; Brasier *et al.*, 2006).

P. ramorum has been shown to be potentially out-crossing with two mating types, A1 and A2. Initially, only the A1 mating type was found in the European population (Werres *et al*., 2001;

Werres and Zielke, 2003; Brasier 2003; Werres and Kaminski, 2005; Husson *et al.*, 2007). However, a single A2 mating type belonging to the EU1 lineage was isolated from *Viburnum bodnantense* in Belgium in 2002 (Werres and De Merlier, 2003); two additional A2 isolates of the EU1 lineage were later identified from cultures obtained from nurseries in the northern part of Belgium (Flanders) from two separate sites and from different hosts (viburnum dating back to 2002, and rhododendron dating back to 2003) (K. Heungens, ILVO, Belgium, *personal communication*, 2007). In contrast, only isolates of A2 mating type have been found in the NA1 lineage present in US woodlands (Werres and Zielke, 2003; Brasier, 2003; Werres and Kaminski, 2005; Ivors *et al.,* 2006) and in isolates of the NA2 lineage which has so far only been found in US nurseries. However, in 2003, A1 isolates of the EU1 lineage were first identified in North America, on ornamental hosts in one nursery in northern Oregon, one in Washington and one in British Colombia, Canada (Hansen *et al*., 2003a; Garbelotto *et al.*, 2005); EU1 isolates of A1 mating type have also recently been found in a woodland river in Humbolt county California.

Gametangia (sexual structures) have been obtained in interspecific pairings carried out *in vitro* between European A1 isolates of *P. ramorum* and an A2 mating type tester strain of other species, such as *P. cryptogea*, *P. cambivora*, *P. cinnamomi* or *P. drechsleri* (Werres *et al*., 2001; Werres and Zielke, 2003; Brasier 2003; Werres and Kaminski, 2005). Similar interspecific pairings between American A2 isolates of *P. ramorum* and A1 mating type tester strains of other species have also resulted in gametangia (Werres and Zielke, 2003; Brasier, 2003; Werres and Kaminski, 2005). However, gametangial production in these interspecific pairings has been sporadic with many of the *P. ramorum* isolates studied. Experimental attempts to pair European A1 and American A2 mating types of *P. ramorum* in culture were successful in *in vivo* pairings on rhododendron twigs after 5-8 days incubation of infected plant tissue on the agar plates but initially unsuccessful in *in vitro* pairings (Werres and Zielke, 2003) but the *in vitro* pairings were subsequently achieved (Brasier and Kirk, 2004). At that time the viability of the resulting oospores (sexual spores) was undetermined, but studies on the functionality of the breeding system and viability of progeny are the subject of WP4 of the RAPRA Project (see *Section B*) and have concluded that the mating system may not be fully functional (Brasier *et al.*, 2007). Boutet and Chandelier (2007) also came to the same conclusion.

If yes indicate the correct scientific name and taxonomic position	**Go to 10**
If no	Go to 9

9. Even if the causal agent of particular symptoms has not yet been fully identified, has it been shown to produce consistent symptoms and to be transmissible?

Question not applicable (go to 10).

If yes	Go to 10
If no	Go to 19

<u>Determining whether the organism is a pest</u>

10. Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?

Yes, it is a primary plant pathogen as demonstrated by Koch's postulates for published host records. *Phytophthora* species are mostly necrotrophic plant pathogens: the genus name is derived from the Greek and means plant (*phyto*) destroyer (*phthora*).

If yes, the organism is considered to be a pest **Go to 12**
If no Go to 11

11. Does the organism have intrinsic attributes that indicate that it could cause significant harm to plants?

Question not applicable (go to 12).

If yes or uncertain, the organism may become a pest of plants in the PRA area **Go to 12**
If no Go to 19

<u>Presence or absence in the PRA area and regulatory status (pest status)</u>

12. Does the pest occur[2] in the PRA area?

Yes (see *footnote* [2]). All isolates from Europe that have been investigated have proven to belong to the European lineage (EU1) of *P. ramorum.* All except three of the many hundreds of European isolates tested belong to the A1 mating type. North American lineages have not been found in Europe; nor have other as yet unknown lineages from any centre/s of origin.

If yes **Go to 13**
If no Go to 14

13. Is the pest widely distributed[3] in the PRA area?

No (see *footnote* [3]). The pathogen is reported from nineteen EU Member States, where it is (or has been) under official control, and two other European (non-EU) countries. Member States have been required to conduct surveys since 2002 and report their findings annually. EU distribution data from these surveys, and from other sources, is available from the RAPRA database up to 2006 (http://rapra.csl.gov.uk/objectives/wp1/distribution.cfm). In Europe, the pathogen has primarily been found on nurseries. Although the locations of infested nurseries are generally widely distributed, the proportion of these infested nurseries has been generally low (Slawson *et al.*, 2008; de Gruyter and Steeghs, 2006; Schenck, 2006). The pathogen has also been found outside of nurseries in Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Slovenia, Spain, and all countries in the UK (mainly England and Wales, but also Northern Ireland and Scotland). Most findings outside of nurseries have been on hardy shrub hosts, principally *Rhododendron*, *Viburnum*, *Camellia*, *Pieris* and *Magnolia* species. In Poland, the pathogen has also been reported as having been detected in 2 rivers: the Rawka (in 2006 and 2007) and the Ner (in 2007) (Orlikowski *et al.*, 2007). In the UK over 70% of all findings has been on *Rhododendron* species (S. Matthews-Berry, CSL, UK, *personal communication*, 2006). The number of infected trees with bleeding bark cankers in the environment (Sansford and Woodhall, 2007) is currently small and restricted to the UK (28 trees,

[2] *occurrence: the presence in an area of a pest officially recognised to be indigenous or introduced and/or not officially reported to have been eradicated [FAO, 2007]. This includes organisms which have been introduced intentionally and which are not subject to containment (notably cultivated plants). Organisms present for scientific purposes under adequate confinement (e.g. in botanic gardens) are not included.*

[3] *Note: a quarantine pest may be 'present but not widely distributed'. This means that the pest has not reached the limits of its potential area of distribution either in the field or in protected conditions; it is not limited to its present distribution by climatic conditions or host-plant distribution. There should be evidence that, without phytosanitary measures, the pest would be capable of additional spread. If the pest is present but not widely distributed in the PRA area, it may already be under official control, with the aim of eradication or containment. If it is not already under official control and if the conclusion of this PRA is that it should be regulated as a quarantine pest, then the pest should also be placed under official control.*

of which 13 have died or been felled because of advanced symptoms; Webber, 2008; J, Webber, Forest Research, UK, *personal communication,* November 2008) and the Netherlands (17 trees with bleeding bark cankers, of which at least two have died; M. Steeghs, Plant Protection Service, Netherlands, *personal communication*, October 2008); trees with foliar infections have also been recorded (e.g. *Quercus ilex, Castanea sativa, Fraxinus excelsior, Drimys winteri*). Since the number of findings outside of nurseries on established shrubs and trees has been relatively small, and the proportion of affected nurseries is low (typically <5% of nurseries nationally), the pathogen is classified in this PRA as 'not widely distributed' in the PRA area, since it has the potential to become more widely distributed within the nursery trade and within the natural environment in parts of Europe if phytosanitary measures were to be lifted. Details of the pathogen's currently known distribution in Europe and elsewhere are given in *Question 7* above.

If not widely distributed	**Go to 14**
If widely distributed	Go to 19

<u>Potential for establishment and spread in the PRA area</u>

14. Does at least one host-plant species (<u>for pests directly affecting plants</u>) or one suitable habitat (for non-parasitic plants) occur in the PRA area (outdoors, in protected cultivation or both)?

Yes. *P. ramorum* has a very wide known and potential host range. Currently, natural hosts are known in 37 plant families, with 75 plant genera and more than 130 plant species affected, with diverse biogeographic origins. These include both trees and shrubs which are both ornamental nursery/garden plants and environmentally important taxa plus a small number of herbaceous plant species. (See Appendix II). Not all of these occur in the PRA area but many of them do. Appendix III lists those species which have been subject to host susceptibility testing. Many non-tree hosts are susceptible to infection by *P. ramorum* and some of these (e.g. rhododendron), and potentially some tree hosts that have foliar susceptibility (e.g. *Quercus ilex*, *Castanea sativa*), serve as the source of inoculum for those trees which suffer from stem infection only. However, some trees with susceptible bark also have susceptible foliage and could therefore self-perpetuate the disease without the need for other foliar hosts. Of the trees, those in the family Fagaceae (e.g. beech, oaks and sweet chestnut) are considered most at risk based on known natural host records and experimental log tests (Brasier *et al.*, 2002; Webber, 2006; Moralejo *et al.*, 2007a; Moralejo *et al.*, 2008, 2008a). However, various non-fagaceous trees are also susceptible in log tests and are also known natural hosts in Europe, e.g. horse chestnut (*Aesculus hippocastanum*) and sycamore (*Acer pseudoplatanus*). In additional to ornamental shrubs and trees, heathland plants and habitats are also considered potentially at risk; for example, known or potentially susceptible species are present in northern Europe, e.g. *Calluna vulgaris* (known natural host recorded from a nursery in Poland (Orlikowski and Szkuta, 2004); experimentally susceptible (Inman *et al.*, 2005; Werres *et al.*, 2007; Kaminski and Wagner, 2008) and various *Vaccinium* species, e.g. *V. myrtillus* (bilberry) is an experimental host with a high sporulation potential (Morelejo *et al.*, 2007), *V. vitis-idaea* (cowberry) is a known natural host in the UK (D. Slawson, Defra PHSI, UK, *personal communication*, October 2008), *V. ovatum* (huckleberry) is a known natural hosts in the USA (see also Appendix II; Appendix III for experimentally susceptible plant species, and Inman *et al.*, 2005).

If yes	**Go to 15**
If no	Go to 19

15. If a vector is the only means by which the pest can spread, is a vector present in the PRA area? (If a vector is not needed or is not the only means by which the pest can spread go to 16).

No vector is needed for spread of *P. ramorum.* (This question refers to vectors only, i.e. it does not refer to inoculum sources). So the question is not applicable.

If yes/not applicable	**Go to 16**
If no	Go to 19

16. Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?

Yes. A detailed investigation of this aspect forms part of the full assessment of the risk of establishment in Section B of this PRA. In addition, *P. ramorum* is known to survive and perpetuate itself under nursery conditions in the PRA area, as well as outside of nurseries in some European countries.

If yes	**Go to 17**
If no	Go to 19

Potential for economic consequences in the PRA area

17. With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?

Yes. *P. ramorum* has caused severe damage to woodland ecosystems in coastal regions of the Pacific northwest coast of the USA (California and, to a lesser extent, Oregon). By the end of 2006, it was estimated that more than a million trees had been killed in California, with at least another million infected (Palmieri and Frankel, 2006). These include tanoaks (*Lithocarpus densiflorus*) and North American *Quercus* species (*Q. agrifolia, Q. chrysolepis, Q. kelloggii* and *Q. parvula* var. *shrevei*). In Europe, trees with susceptible bark found in association with foliar hosts that act as sources of inoculum (currently mainly rhododendron) are at risk in semi-managed or unmanaged environments. Several tree species have already been found with bleeding cankers in Europe, principally European beech (*Fagus sylvatica*) and North American red oaks (*Q. rubra*), though other species have also been recorded with bleeding cankers in the UK (e.g. *Acer pseudoplatanus, Aesculus hippocastanum, Cinnamomum camphora, Castanea sativa, Nothofagus obliqua, Quercus acuta, Q. cerris, Q. falcata, Q. petraea* and *Schima argentea*.) (Appendix II). In the Netherlands (Steeghs and de Gruyter, 2005), at least two trees have died (M. Steeghs, Plant Protection Service, the Netherlands, *personal communication*, 2008). In contrast, trees of different species near nurseries, or in the single case of infected shrubs (*Rhododendron* and *Pieris*) in a forest area in Germany, have not become infected (Schroeder *et al.*, 2007). Trees near infected *Rhododendron* in forests in two northwestern French regions (first discovered in the summer of 2007) have also not yet become infected (C. Husson, INRA, France, *personal communication*, 2008). Several other countries in the EU have reported finding *P. ramorum* infecting plants in non-nursery situations but no tree stem infections have been reported. Woodland habitats containing at-risk tree species are potentially threatened, including woodlands protected by the EC Habitats Directives (Anon., 1992), provided sporulating foliar hosts are present and the climate is favourable. Impacts might especially be expected in evergreen oak woodlands in areas of Europe where these occur. In addition to woodland habitats, heathland or maquis/matorral habitats could also be at risk where they contain susceptible host species (e.g. heathland with *Calluna* and *Vaccinium* species, both of which have been shown to have a significant sporulation potential (Inman *et al.*, 2005), maquis with evergreen oaks or other susceptible species). The pathogen could also have a significant socio-economic impact resulting from damage to hardy shrubs and trees in semi-managed environments such as historic gardens (especially those involved in tourism or in the curation of rare plant taxa or plant collections) or parks. Economic impacts could also be expected in the hardy ornamental nursery stock sector, both in terms of direct control costs if phytosanitary measures were removed and due to the potential loss of export markets to those countries which list the pathogen as a quarantine organism. However, the major impacts are expected to be environmental and social.

A fuller analysis of the potential economic consequences is presented in *Section B* of the Pest Risk Assessment stage of this PRA.

If yes or uncertain **Go to 18**
If no Go to 19

Conclusion of pest categorisation

18. This pest could present a risk to the PRA area (summarise the main elements leading to the conclusion that the pest presents a risk to the PRA area)

P. ramorum is already categorised as a quarantine pest for the EU and emergency phytosanitary measures have been in place since September 2002 (Anon., 2002). It is on the EPPO Alert List (http://www.eppo.org/QUARANTINE/Alert_List/alert_list.htm). The pathogen has caused significant environmental impacts in coastal areas of California and Oregon in the USA due to high levels of tree mortality amongst several American oak (*Lithocarpus* and *Quercus)* species. European tree species (especially in the family Fagaceae) are similarly at risk, as are heathland/maquis habitats containing susceptible plant species, if climatic and ecological (e.g. the species composition of plant communities) conditions favour establishment and spread. Risks to trees and woodland habitats will, however, be related to the close association of sporulating foliar hosts since many at-risk trees are terminal hosts that do not produce epidemiologically significant levels of inoculum. Since *P. ramorum* produces sporangia which are primarily dispersed short distances by rain splash, its rate of non-facilitated spread might be limited (Moralejo *et al.* 2006; Mascheretti *et al.*, 2008; Hansen, 2008). It is therefore very likely that many potential susceptible habitats have yet not been exposed to the pathogen.

The pathogen is present in the EU and some other European countries in nurseries and, to a much more limited extent, outside nurseries in the environment. It is currently under official control (eradication and containment) in the EU, but has the potential to further enter new areas and establish, spread and cause environmental and socio-economic damage. It has already killed several trees in north-west Europe (e.g. *F. sylvatica* and *Q. rubra*) and has been found causing bleeding bark cankers on a range of other species and genera. It has therefore already demonstrated that it has the ability to establish and cause damage to trees and shrubs outside of nurseries in some parts of Europe.

There is also the potential for genotypes of the non-European lineages to enter, establish and spread in the EU. Of particular concern would be the introduction and establishment of A2 mating type isolates since these might, if the breeding system is partially or fully functional, sexually recombine with European isolates of the A1 mating type and give rise to progeny of greater adaptive fitness or virulence. Although the breeding system currently appears not to be fully functional, the introduction of any non-European genotypes could still be significant if they have increased fitness or virulence; there may also be the potential for them to undergo somatic recombination with European genotypes.

More detail is given in *Section B* of the Risk Assessment stage of this PRA.

Go to section B

Section B: Assessment of the probability of introduction (entry and establishment) and spread and of potential economic consequences

This part of the risk assessment process firstly estimates the probability of the pest being introduced into the PRA area (its entry and establishment) and secondly makes an assessment of the likely economic impact if that should happen. From these assessments, it should be possible to estimate the level of risk associated with the pest, which can then be used in the pest risk management phase to determine whether it is necessary to take phytosanitary measures to prevent the introduction of the pest, and if the measures chosen are appropriate for the level of risk.

The evaluation is based on the replies to a series of questions, mostly expressed in the first instance as the choice of an appropriate phrase out of a set of five alternatives (e.g. very unlikely, unlikely, moderately likely, likely, very likely). It is important to identify especially high or especially low risks. The user of the scheme should add to all replies any details which appear relevant indicating the source of information used. In addition the level of uncertainty attached to each answer should be given.

Answer as many of the following questions as possible. If any question does not appear to be relevant for the pest concerned, it should be noted as "irrelevant". If any question appears difficult to answer no judgement should be given but the user should note whether this is because of lack of information or uncertainty.

1. Probability of introduction

Introduction, as defined by the FAO Glossary of Phytosanitary Terms, is the entry of a pest resulting in its establishment.

Probability of entry

Identification of pathways

Pathway is defined in the Glossary as 'any means that allows the entry or spread of a pest'.

1.1. Consider all relevant pathways and list them.

Phytophthora ramorum is most likely to enter the PRA area (EU 27 Member States) from the pathways listed below (i-viii). More detail on the significance of each pathway is given in *Question 1.3*. The pathways relate to the entry into the PRA area of isolates of both European and non-European lineages, though these respective isolates may represent different risks. Isolates of the EU1 lineage (Ivors *et al.*, 2006) from non-EU European countries (i.e. Norway and Switzerland) are likely to represent an equivalent level of risk to those isolates already present in EU Member States. Non-European lineage isolates from the USA, Canada and from the pathogen's unknown area/s of origin potentially represent a higher risk due to: their different/potentially different genetic composition or adaptive fitness compared to the EU1

lineage isolates; and the potential for isolates of the A2 mating type, regardless of lineage, to sexually recombine with EU1 lineage isolates of the A1 mating type.
The main potential pathways of entry are as follows:

i. Plants for planting (excluding seeds and fruit) of known susceptible hosts (see Appendix II) that are permitted entry[4] from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin. Plants for planting of known hosts from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a pathway.

ii. Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media[5] from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Plants for planting of non-host plant species with contaminated growing media from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a potential pathway.

iii. Soil/growing medium (with organic matter) as a commodity from the USA and Canada, or from the as yet unknown area/s of origin for *P. ramorum.* Soil/growing media as a commodity from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

iv. Soil as a contaminant (e.g. on footwear, machinery, etc.) from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

v. Foliage or cut branches (for ornamental purposes) of susceptible foliar hosts from third countries where the pathogen occurs (as detailed in i-iii above).

vi. Seeds and fruits of susceptible host plants (Appendix II) from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

vii. Susceptible (isolated) bark[6] from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

viii. Susceptible wood[7] from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

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[4] Council Directive 2000/29/EC (Anon., 2000) Annex IIIA lists certain host plants that are prohibited entry into the community from: non-European countries (e.g. plants of *Abies* and *Pseudotsuga* other than fruits and seeds*;* plants of *Castanea* and *Quercus* with leaves, other than fruit and seeds; plants of *Prunus* and *Rosa* except dormant plants free from leaves, flowers and fruits); from non-European countries except Mediterranean countries, Australia, New Zealand, Canada and the continental USA (plants of *Prunus* except seed); from USA and various parts of SE Asia (plants of *Photinia* for planting other than dormant plants free from leaves, flowers and fruit). Emergency measures for *P. ramorum* on imports of plants for planting are listed in Council Directive 2002/757/EC as amended (Anon., 2002, 2004, 2007) and discussed under 1.10

[5] Council Directive 2000/29/EC (Anon., 2000) Annex IVAI lists requirements relating to growing media (article 34) attached to or associated with plants from various non-European and European countries; other articles relate to trees and shrubs from third countries intended for planting (e.g. Annex IVAI, articles 39, 40, 43) as well as annual/biennial plants and herbaceous perennials from certain third countries (Annex IVAI articles 41, 44)

[6] 'Susceptible bark' is defined by the EC emergency measures for *P. ramorum* (Anon., 2002, 2004, 2007) in relation to certain known tree hosts in the USA, bark of which is prohibited; tree hosts in the as yet unknown area of origin for *P. ramorum* are undetermined. Council Directive 2000/29/EC (Anon., 2000) Annex IIIA prohibits isolated bark of *Castanea* from all third countries and isolated bark of *Quercus* from North America; Annex IVAI has requirements related to isolated bark of conifers originating in non-European countries.

[7] 'Susceptible wood' is defined by the EC emergency measures for *P. ramorum* (Anon., 2002, 2004, 2007) in relation to certain known tree hosts in the USA; tree hosts in the as yet unknown area of origin for *P. ramorum* are undetermined. Council Directive 2000/29/EC Annex IVAI has specific requirements for the entry of wood or wood products of certain genera imported from outside the community.

Other pathways may exist but are not considered further in this PRA. When considering pathways in this and subsequent sections of this PRA, only known natural hosts are accounted for (Appendix II): experimental hosts (Appendix III) are not included in the analysis.

The RAPRA database also provides details of the currently known natural host range (http://rapra.csl.gov.uk/objectives/wp1/naturalhostsearch.cfm) and the currently known experimental host range (http://rapra.csl.gov.uk/objectives/wp1/potentialhost.cfm).

Go to 1.2

1.2. Estimate the number of relevant pathways, of different commodities, from different origins, to different end uses.

Very few, Few, Moderate number, **Many**, Very many.

The number of relevant pathways is **Many**.

Level of uncertainty: **Low**

It is impossible to accurately enumerate the number of individual pathways based on the number of different geographical sources (origins), commodities and end-uses.

Geographical sources:

There are at least 4 main geographical sources where the pathogen exists outside of the EU PRA area:

- The USA
- Canada
- At least one, as yet undetermined, third country which represents the organism's area of origin (Asia is speculated, especially Taiwan and the eastern Himalayas, and the Yunnan province of China: Brasier *et al*., 2004; Goheen *et al*., 2005)
- Non-EU European countries (currently Norway and Switzerland)

Commodities:

There are at least 8 main generic commodity types, as detailed in *Question 1.1*. The individual number of commodities could theoretically be estimated more precisely from the number of known natural host plant species intended for planting, currently estimated as at least 130 different natural host species across at least 75 plant genera and 37 plant families, plus the additional commodity pathways of bark, wood, foliage, contaminated soil/growing media (accompanying hosts or non-hosts; associated with footwear/machinery/etc.; or as a commodity) and seeds or fruits. However, it is likely that the natural host list will continue to grow. The pathogen's hosts in its unknown area/s of origin are currently unknown and may increase the number of natural hosts. It is also impossible to enumerate the number of non-host plant species that might introduce the pathogen into the EU through contaminated growing media. There are limited detailed data on imports of plants for planting. There are also only limited data on the susceptibility of fruits and the potential of fruits and seeds of various hosts to be significant pathways. Limited data are available on the volume of imported seeds, fruits or foliage of known susceptible natural and potential hosts from areas where the pathogen is known to occur. The frequency of entry through contaminated footwear or machinery cannot be enumerated.

End uses:

End-uses are variable and depend on the commodity:

- The highest-risk commodities are host plants (excluding seeds and fruits) since the end-use is planting and the pathway is therefore direct. Non-host plants (excluding fruits and seeds) with contaminated attached growing media are also a direct pathway, if these are planted-out in areas where susceptible hosts occur.
- Soil/growing media as a commodity would be used for growing plants and therefore constitutes a direct pathway from those countries where *P. ramorum* is present and from which soil/growing media are not banned from entering the EU (i.e. Norway and Switzerland).
- Soil contaminating footwear, especially footwear used for hiking (Tjosvold *et al*., 2002a; Cushman and Meentemeyer, 2005; Cushman *et al.*, 2008) in woodland areas in the USA (principally California but also Oregon) where the pathogen occurs, represents a potential direct pathway if footwear is not cleaned or disinfected (and contaminating soil/debris kept moist) and is then used for the same purposes within the EU.
- The end-uses for machinery would be many and varied, depending on the type of machinery, but this represents a direct pathway if soil-contaminated machinery is used in nurseries or outside of nurseries in the environment.
- Foliage and cut branches would be used principally for ornamental home-use. This represents an indirect pathway if infected material ends up in municipal or domestic compost heaps and if the resulting composted material contains viable propagules of *P. ramorum.* The pathway would be complete if the compost is used to enhance soil where susceptible hosts are grown or if it is used as potting material for susceptible hosts.
- Seeds would be used for planting and therefore represent a direct pathway if *P. ramorum* is transmitted via seed. If used for human consumption the risk is low as the end-use does not complete the pathway.
- Fruits represent an indirect pathway since their end-use is for consumption or for processing. If used as ornamental material there is a potential for this to end up in municipal or domestic compost heaps. Fruits of ornamental and environmentally-important plants have been shown to be susceptible to infection (Moralejo *et al.*, 2007; Moralejo *et al.*, 2006, 2006a; Denman *et al.*, 2008).
- Isolated bark would primarily be used for mulching in nurseries (weed suppressant), gardens (weed suppressant, decorative purposes) or recreational areas (e.g. playground cover), so it could be a direct pathway. This is most likely to be conifer bark. Non-coniferous bark may be used as a fuel in sawmills but this is not certain. (R. Burgess, Forestry Commission, UK, *personal communication*, 2008)
- The end-uses of wood would be variable but this is likely to be an indirect pathway only.

Go to 1.3

1.3. Select from the relevant pathways, using expert judgement, those which appear most important. If these pathways involve different origins and end uses, it is sufficient to consider only the realistic worst-case pathways. The following group of questions on pathways is then considered for each relevant pathway in turn, as appropriate, starting with the most important.

EU phytosanitary measures apply to some of the following potential pathways. These measures are described further in *Question 1.10* and referred to in the footnotes in *Question 1.1.* The most important potential pathways are:

Direct principal pathways:

i. Plants for planting (excluding seeds and fruit) of known susceptible hosts (see Appendix II for known hosts to date) from the USA and Canada, or from undetermined third countries that represent the pathogen's unknown area/s of origin. These pathways have the most potential to introduce non-European isolates into the EU, including those of the A2 mating type. Plants for planting of known hosts from non-EU European countries where the pathogen occurs (Norway and Switzerland) is considered a lower-risk pathway since isolates from these countries are currently believed to belong to the European EU1 lineage that is already present in the EU (see *Stage 1: Initiation, Question 7*). However, plants imported from these countries still pose a risk of further entry of *P. ramorum*.

ii. Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Again, plants for planting (excluding seeds) of non-host plant species with contaminated growing media from non-EU European countries (Norway and Switzerland) where the pathogen occurs is not considered such a high-risk pathway since the isolates present in these countries are currently believed to belong to the European EU1 lineage of *P. ramorum*. Plants imported from these countries still pose a risk of further entry of *P. ramorum* into the EU.

iii. Soil/growing medium (with organic matter) as a commodity is a potential direct pathway from areas where the pathogen occurs in the USA and Canada or from the as yet unknown area/s of origin for *P. ramorum.* Soil/growing media from non-EU European countries where the pathogen occurs (Norway and Switzerland) is considered a lower-risk pathway since the isolates present in these countries are currently believed to belong to the European EU1 lineage of *P. ramorum*. However there is still the potential for further entry of *P. ramorum* into the EU from these non-EU European countries.

iv. Soil as a contaminant from the USA and Canada (e.g. on footwear, machinery, etc.), or from the as yet unknown area/s of origin for *P. ramorum* is also a potential direct pathway of entry. Soil as a contaminant from non-EU European countries where the pathogen occurs (Norway and Switzerland) is considered a lower-risk pathway since the isolates present in these countries are currently believed to belong to the European EU1 lineage of *P. ramorum*. However there is still the potential for further entry of *P. ramorum* into the EU from these non-EU European countries.

Less significant direct or indirect pathways:

v. Foliage or cut branches (for ornamental purposes) of susceptible foliar hosts from third countries where the pathogen occurs (as detailed in i-iii above). This is an indirect pathway and therefore a lower-risk route of entry compared to plants for planting. Foliage and cut branches from non-EU European countries where the pathogen occurs (Norway and Switzerland) is considered a lower-risk pathway since this currently relates to isolates of the EU1 lineage already present in the EU although this continues to pose a risk of further entry.

vi. Seeds and fruits of susceptible plant hosts (Appendix II) from third countries where the pathogen occurs (as detailed in i-iii above). Although there is no evidence that *P. ramorum* is truly seed transmitted, it is possible that the organism could be seed-borne (e.g. through colonisation of the outer seed coat, or through infected debris accompanying seed, especially if chlamydospores are formed in these tissues); this could therefore represent a direct pathway if seeds are for planting. Fruits of some susceptible plant species have been shown to be infected by *P. ramorum* (Moralejo *et al.*, 2006, 2006a; Denman *et al.*, 2008; Inman *et al.*, 2005; Moralejo *et al.*, 2007), so fruits and any seeds contained therein could potentially be infected/contaminated. The significance of fruits as a potential pathway is uncertain; it would be considered a low-risk commodity given this uncertainty and the indirect nature of the pathway.

vii. Susceptible (isolated) bark[8] from third countries where the pathogen occurs (as detailed in i-iii above) is a potential direct pathway.

viii. Susceptible wood[9] from third countries where the pathogen occurs (as detailed in i-iii above). A pathway potentially exists, from the USA and from the, as yet undetermined, area/s of origin for *P. ramorum*, where *P. ramorum* exists in the environment. Currently Canada, Norway and Switzerland have not detected *P. ramorum* in their forests or woodlands so this is not a pathway at present. Recent work (Brown and Brasier, 2007; Parke *et al.*, 2008) has shown that *P. ramorum* can colonise the xylem that underlies infected bark; and that hyphae and chlamydospores can be found in such tissue (Parke *et al*., 2008). The significance of this pathway is uncertain, but would be considered low-risk given that it is an indirect pathway, based on the most likely end-uses of imported wood.

In responding to the following questions these commodities are considered separately for each geographical source.

Go to 1.4

Probability of the pest being associated with the individual pathway at origin.

1.4. How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?

Note that phytosanitary measures are not considered here but are commented on for consideration under 1.10.

For the purposes of this PRA, this question is answered based on the worst-case scenario: commodities are assumed to come from areas whether the pathogen specifically occurs. The likelihood of *P. ramorum* being associated with each pathway at origin (excluding consideration of phytosanitary measures) varies according to geographical origin and commodity (Table 2).

With respect to origin outside of Europe, the pathogen is most likely to be present on commodities from the USA (North American (NA1, NA2) and European (EU1) lineages) and from non-EU European countries (Norway Switzerland; EU1 lineage) since the pathogen is established there on both nurseries and in the environment. Plant material of susceptible hosts and contaminated growing media/soil with hosts or non-hosts can all enable entry of *P. ramorum* into the EU on the specified commodities.

[8] 'Susceptible bark' is defined by the EC emergency measures for *P. ramorum* (Anon., 2002, 2004, 2007) in relation to certain named known tree hosts in the USA; tree hosts in the as yet unknown area of origin for *P. ramorum* are undetermined.

[9] 'Susceptible wood' is defined by the EC emergency measures for *P. ramorum* (Anon., 2002, 2004, 2007) in relation to certain known tree hosts in the USA; tree hosts in the as yet unknown area of origin for *P. ramorum* are undetermined.

Prevalence on commodities from Canada is less likely since the pathogen has only been recorded there on a relatively few nurseries in British Columbia (and residential plantings arising from affected nurseries). All affected nurseries and residential plantings have been subject to eradication (Wong, 2008). *P. ramorum* was first detected in Canada in 2003 on rhododendron container plants from Oregon at a nursery in British Columbia. In 2004, positive plants were recovered from 9 retail garden centres and 3 wholesale nurseries, all of which were in the south coastal area of British Columbia as a result of trace forward inspections on plants shipped from California or as part of the national survey. Recall of plants and additional survey activities in 2004 detected infected plants at 17 residential properties that had planted nursery plants in south coastal British Columbia. In each of these cases, eradication action of positive plants and a surrounding buffer area of plants were eradicated. In 2006, *P. ramorum* was detected at three retail garden centres that had been positive in 2004 (but negative in 2005) and eradication efforts continued at one wholesale nursery where *P. ramorum* was detected in late 2005 (Anon., 2006: CFIA undated). In 2007, *P. ramorum* was found on 10 nurseries in British Columbia; all were subject to eradication (S. Sela, CFIA, Canada, *personal communication*, 2008). *P. ramorum* remains a quarantine pest for Canada; it has not been found in forests there. Survey results for Canada can be found at:
http://www.inspection.gc.ca/english/plaveg/pestrava/phyram/sodmsce.shtml

Prevalence on material coming from the pathogen's unknown area/s of origin (Asia is speculated: Brasier *et al*., 2004; Goheen *et al*., 2005) is uncertain; it is not known whether the pathogen is present there only in the environment, whether trees are affected, and whether it is also present on nursery stock. However, the original introduction of the EU1 lineage of the pathogen into Europe proves that a pathway has previously existed. This is most likely to have been plants for planting, though whether these were nursery-grown plants or were collections made from the wild is not known. With respect to the US situation, based upon molecular analysis of isolates, Mascheretti *et al.* (2008) suggested that *P. ramorum* was introduced via infected plants into two separate coastal areas of California, 62 miles apart.

With respect to life stages of the pathogen, four types of structures can be considered: mycelium; sporangia (propagules mainly involved in dispersal and infection); zoospores/zoospore cysts (propagules mainly involved in dispersal and infection); and chlamydospores (propagules involved in longer-term survival).

All of these structures have the potential to be associated with infected host plants, though the presence of sporangia and chlamydospores may vary with the host species (Parke *et al.*, 2002; Davidson *et al.*, 2005; Turner *et al.*, 2005; Denman *et al.*, 2006; Turner and Jennings, 2008), the plant part concerned and with the time of year (Maloney *et al.*, 2002; Davidson *et al*., 2005; Rizzo *et al.*, 2005). On foliage, for example, sporangial production varies significantly with host species (Parke *et al.*, 2002; Turner *et al.*, 2005). Chlamydospore production is also influenced by the host; they form abundantly in some hosts but not all (Parke *et al.*, 2002; Turner *et al.*, 2005). In infected tree bark, there is the potential for chlamydospores to be produced in infected phloem/cambial tissues. Brown and Brasier (2007) isolated *P. ramorum* from bark of a range of species. Mycelial colonisation (Brown and Brasier, 2007) and chlamydospore formation (Parke *et al.*, 2008) of the xylem tissue underlying infected bark has also been observed. The production of sporangia on attached, infected bark of tree hosts is considered not to occur, or to occur with such rarity as to be insignificant (Tjosvold *et al.*, 2002b; Garbelotto *et al.*, 2003; Davidson *et al.*, 2005, 2008; J. Webber, Forest Research, UK, *personal communication*). However, detached, infected bark has been observed to produce spores when floated in water (Davidson and Shaw, 2003).

Table 2. (a) Estimated prevalence on each commodity pathway at origin in relation to geographical source. Likely prevalence of the pathogen is ranked according to the following scheme: **VU**, Very unlikely; **U**, Unlikely; **ML**, Moderately likely; **L**, Likely; **VL**, Very Likely; (b) associated levels of uncertainty

(a) Estimated prevalence at origin							
	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]	Range
i	Plants for planting (Hosts)	Direct	**L**	**ML**	**L**	**ML**	**ML – L**
ii	Plants for planting (Non-Hosts) [c]	Direct	**L**	**ML**	**L**	**ML**	**ML – L**
iii	Soil/growing media as a commodity	Direct [c]	**ML**	**U**	**ML**	**U**	**U – ML**
iv	Soil as a contaminant	Direct	**ML**	**U**	**ML**	**U**	**U – ML**
v	Foliage/cut branches of susceptible hosts	Indirect	**L**	**ML**	**L**	**ML**	**ML – L**
vi	Seeds and *fruits*	Direct/*Indirect*	**U**	**U**	**U**	**U**	**U**
vii	Susceptible/isolated bark	Direct	**L**	**VU**	**L**	**VU**	**VU**
viii	Susceptible wood [d]	Indirect	**L**	**U**	**L**	**U**	**U – ML**

(b) Estimated levels of uncertainty for the estimates of prevalence at origin							
	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]	Range
i	Plants for planting (Hosts)	Direct	LOW	MEDIUM	HIGH	LOW	LOW TO HIGH
ii	Plants for planting (Non-Hosts) [c]	Direct	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM TO HIGH
iii	Soil/growing media as a commodity	Direct	HIGH	HIGH	HIGH	HIGH	HIGH
iv	Soil as a contaminant	Direct	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM TO HIGH
v	Foliage/cut branches of susceptible hosts	Indirect	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM TO HIGH
vi	Seeds and *fruits*	Direct/*Indirect*	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM TO HIGH
vii	Susceptible/isolated bark	Direct	LOW	MEDIUM	HIGH	MEDIUM	LOW TO HIGH
viii	Susceptible wood [d]	Indirect	LOW	MEDIUM	HIGH	MEDIUM	LOW TO HIGH

[a] Asia is speculated (Brasier *et al*., 2004; Goheen *et al*., 2005). [b] Norway & Switzerland; [c] Plants for planting (non-hosts) with contaminated growing media; [d] Susceptible wood prior to treatment (see *Question 1.10*)

With respect to bark and wood only the affected areas of the USA are likely to have the pathogen on the pathway at origin with a low level of uncertainty. It is assumed that trees are affected in the unknown area or areas of origin but this has a high level of uncertainty. No trees are affected in Canada, Norway or Switzerland and so *P. ramorum* is very unlikely to be associated with the pathway at origin with a low level of uncertainty.

With respect to *Rhododendron*, histological studies of inoculated twigs showed that *P. ramorum* was present in healthy (green) and unhealthy (discoloured) tissue but chlamydospores could be observed only in unhealthy tissue (Pogoda and Werres, 2004). Similar results were obtained with other tissue from the upper parts of *Rhododendron* (Riedel *et al*., 2008). In irrigation experiments with contaminated water *P. ramorum* could be detected in the root balls of asymptomatic *Rhododendron* and *Viburnum* at the beginning of the following year (Werres *et al.* 2007a). Riedel *et al*., 2008 also found chlamydospores in the epidermis of healthy-looking roots of *Rhododendron*, 2 weeks after inoculation. Kessel *et al.* (2007) showed visually healthy plants (above ground) also had visually healthy root symptoms but, despite the absence of symptoms, chlamydospores could be detected in these plants one week after inoculation. This phenomenon may be related to some of the reported incidences on latent infections in plant trade. It is however unknown if the occurrence of chlamydospores in the roots of otherwise symptom-free plants is a general phenomenon. Sporangia form freely on branching hyphae growing out of stomata on discoloured leaf surfaces of infected *Rhododendron* (e.g. Riedel *et al*., 2008).

Sporangia, zoospores/cysts and chlamydospores may also potentially be present as contaminants of growing media or soil, i.e.: with host plants, with non-host plants, in soil contaminating footwear/machinery/etc., or with growing media/soil as a commodity. Chlamydospores (which are almost always formed inside, rather than outside, infected plant tissues) have the potential to contaminate these substrates if infected debris is present; they have the potential to survive significant periods of time. Linderman and Davis (2006) suggest that chlamydospores can survive for up to 12 months in potting media or soil, and sporangia for up to 6 months; Colburn *et al.* (2005) and Jeffers (2005) also showed that *P. ramorum* can survive for several months in potting media, especially at low temperatures. Fichtner *et al*. (2005) suggest that *P. ramorum* can survive six months in leaf debris and can survive in this material over the summer in US forests. Experiments in the UK have shown that the pathogen can survive in artificially infected leaf debris buried in soil for at least two UK winters (Turner *et al*., 2005). Experiments in the Netherlands have shown that *P. ramorum* can survive in chipped *Rhododendron* for 2 years when the material was left *in situ* (Steeghs, 2008). Experiments in Oregon (McLaughlin *et al.*, 2006) also showed significant survival when infected leaves were buried outside, though survival was less in leaves on the soil surface in both shade and sun. Sporangia and zoospores/cysts, though less robust, can survive a range of environmental conditions for considerable periods (Davidson *et al.*, 2002; Turner *et al.*, 2005; Turner and Jennings, 2008). Sporangia have been shown to survive in potting media for up to six months (Linderman and Davis, 2006). Zoospores have been shown to survive for at least one month in water, but are killed rapidly under very dry conditions (Davidson *et al.*, 2002). Therefore, sporangial inoculum contaminating growing media, either accompanying plants or as a contaminated commodity, could enable the pathogen to be viable on the pathway at origin throughout the year, irrespective of any seasonality of inoculum production. The pathogen has been isolated from asymptomatic roots in laboratory-inoculated host plants (Shishkoff, 2007) and it has been suggested that this may be a route by which the pathogen could be spread in a cryptic manner (Shishkoff, 2007; Parke and Lewis, 2007). It has also been isolated from roots of naturally infected tanoak (*L. densiflorus*) (Parke *et al*., 2006). Shishkoff (2008) has also shown that artificial inoculation of *Viburnum tinus* led to the formation of chlamydospores in root tissue. Fitchner *et al.*, (2007, 2008a) reported *P. ramorum* from roots of rhododendron shrubs in UK woodlands.

Prevalence on some pathways at origin may vary with the season, reflecting seasonality in inoculum production or survival of propagules, e.g. in relation to the contamination of soil/growing media of non-hosts and machinery and footwear. In the USA, the pathogen is rarely isolated from mixed evergreen woodland soils during the hot, dry summer period in California (Davidson *et al.*, 2002 and 2005), although the pathogen can still survive in infected leaves in the soil or litter over the summer period, especially in redwood-tanoak woodlands (Fichtner *et al.*, 2006 and 2007). The pathogen can be isolated from leaf lesions on Californian bay laurel (*Umbellularia californica*) during the whole year, though the success of isolation declines gradually during the hot and dry summer period (Davidson *et al*., 2002 and 2003; Fitchner *et al.*, 2008). For host plants for planting (excluding seeds and fruit), it might be anticipated that the potential incidence of infected plants on the pathway might be higher during milder and wetter periods of the year in the country of origin since these conditions favour the pathogen. Although there may be some influence of season on all the commodities considered, there is still the potential for the pathogen to be present on the pathway at origin with host plant material or contaminated non-host commodities all year round.

The prevalence on the pathways at origin are estimated in Table 2, taking into account the prevalence of the pathogen at origin and the life stages of the pathogen in relation to the time of year and the commodity (e.g. seasonality of inoculum production and propagule survival). Since the pathogen can potentially enter all year round and factors such as 'life stage' and 'seasonality' are not considered to significantly affect this, 'origin' is therefore considered the main factor influencing prevalence on each commodity. The influence of treatments and cultural practices on the prevalence of the pathogen on each pathway is considered under *Question 1.5*, and the volume of trade under *Question 1.6* (excluding the influence of phytosanitary measures for both questions, which are not considered until *Question 1.10*).

Go to 1.5

1.5. How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?

Note: *these are practices mainly in the country of origin, such as pesticide application (including herbicides for plants), removal of substandard produce, kiln-drying of wood, cultural methods, sorting and cleaning of commodities. Note that cultivation practices may change over time.*

Phytosanitary measures are not considered in this question (see 1.10).

For the purposes of this PRA, this question is answered for each commodity based on the worst-case scenario, i.e. commodities are assumed to come from areas where the pathogen specifically occurs and no phytosanitary measures have been applied. The likelihood of the concentration of *P. ramorum* being high on the pathway at origin will depend on the commodity and the origin as well as any cultivation practices or treatments that have been applied (Table 3).

Table 3. (a) Estimated likelihood of the concentration of *P. ramorum* on the pathway at origin being high in relation to each commodity pathway and geographical source accounting for cultivation practices (but excluding phtyosanitary measures). The likelihood is ranked according to the following scheme: **VU**, Very unlikely; **U**, Unlikely; **ML**, Moderately likely; **L**, Likely; **VL**, Very Likely; (b) associated levels of uncertainty.

(a) Estimated likelihood of *P. ramorum* concentration being high at origin							
	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]	Range
i	Plants for planting (Hosts)	Direct	**L**	**ML**	**L**	**ML**	**L-ML**
ii	Plants for planting (Non-Hosts) [c]	Direct	**L**	**ML**	**L**	**U**	**U-L**
iii	Soil as a commodity	Direct	**ML**	**U**	**ML**	**U**	**U-ML**
iv	Soil as a contaminant	Direct	**ML**	**U**	**ML**	**U**	**U-ML**
v	Foliage/cut branches of susceptible hosts	Indirect	**L**	**ML**	**L**	**ML**	**L-ML**
vi	Seeds and *fruits*	Direct/*Indirect*	**U**	**U**	**U**	**U**	**U**
vii	Susceptible/isolated bark	Direct	**L**	**VU**	**L**	**VU**	**VU**
viii	Susceptible wood [d]	Indirect	**L**	**U**	**L**	**U**	**U-ML**

(b) Estimated levels of uncertainty for the *P. ramorum* concentration being high at origin							
(b)	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]	Range
i	Plants for planting (Hosts)	Direct	LOW	MEDIUM	HIGH	LOW	LOW-HIGH
ii	Plants for planting (Non-Hosts) [c]	Direct	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM-HIGH
iii	Soil as a commodity	Direct	HIGH	HIGH	HIGH	HIGH	HIGH
iv	Soil as a contaminant	Direct	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM-HIGH
v	Foliage/cut branches	Indirect	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM-HIGH
vi	Seeds and *fruits*	Direct/*Indirect*	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM-HIGH
vii	Susceptible/isolated bark	Direct	LOW	MEDIUM	HIGH	MEDIUM	LOW-HIGH
viii	Susceptible wood [d]	Indirect	LOW	MEDIUM	HIGH	MEDIUM	LOW-HIGH

[a] Asia is speculated (Brasier *et al*., 2004; Goheen *et al*., 2005). [b] Norway & Switzerland; [c] Plants for planting (non-hosts) with contaminated growing media; [d] Susceptible wood prior to treatment (see *Question 1.10*)

i. Plants for planting (excluding seeds and fruit) of host plant species: With respect to cultivation and treatment practices, the prevalence of the pathogen on nursery-grown host plants at origin may be affected negatively or positively by a variety of practices or other factors. It should also be noted that cultural and treatment practices vary from nursery to nursery and from country to country.

Cultural practices, treatments or other factors that might increase the prevalence of the pathogen on host plants for planting include:

- *Location of the nursery in woodland areas where the pathogen is well established.* Prevalence on the commodity may be increased if nurseries are located in woodland areas where the pathogen is established. In California, for example, nurseries can be located in woodland areas with high levels of infection on Californian bay laurel (*Umbellularia californica*). This host produces large quantities of both sporangia and chlamydospores. Host plants in such nurseries are therefore at higher risk from infection. Similarly, growing media of host plants are at a higher risk of contamination by sporangial inoculum from outside the nursery than those nurseries elsewhere, as well as contamination by infected leaf debris falling on to the surface of the growing media. There is also an increased risk if nurseries use contaminated irrigation water, either directly from contaminated streams (Tjosvold *et al.*, 2002, 2005), or from contaminated irrigation ponds or other water supplies, especially if over-head irrigation is used (Werres *et al*., 2007a).

- *Husbandry or cultural practices*: Over-head irrigation, if used, is likely to increase the dispersal and spread of the pathogen in infested nurseries since the pathogen is primarily splash-dispersed. Over-head irrigation with contaminated water outdoors on a nursery in Germany has led to infection of *Rhododendron* by *P. ramorum.* (Werres *et al*., 2007a). High humidity also favours disease development. Closely-spaced plants will favour disease spread and development due to their proximity to each other and due to the creation of higher humidities within the 'crop'. Poor hygiene practices will also favour the pathogen, especially poor or non-existent disinfection practices (tools, growing media, irrigation water, pots/trays, surfaces etc.). Pruning may increase the spread of the pathogen, either by the direct transfer of inoculum on contaminated tools, or by causing wounds which are more at risk from infection.

- *Use of fungicides*: Commercial nurseries often use fungicides against *Phytophthora* and *Pythium* species, especially root-infecting species. These are applied either as drenches to the soil/growing medium or as foliar sprays. Other fungicides may be used against specific foliar pathogens such as powdery mildews or leaf-spotting fungal pathogens. It is generally considered that fungicides applied against *Phytophthora* species are more fungistatic that fungitoxic, at least in relation to established infections. Routine fungicide applications are therefore unlikely to eradicate the pathogen post-infection; they may also not eradicate inoculum contaminating growing media, especially if their mode of action requires breakdown within the plant to an active compound. Furthermore, symptoms may be suppressed as a result of the use of these fungicides, increasing the risk of the pathogen being undetected prior to export. Over-use of some fungicides may also lead to the development of fungicide resistance, as has already been found for European isolates of *P. ramorum* with respect to metalaxyl (Wagner *et al.*, 2006; Turner *et al.*, 2008c).

Cultural practices or factors that may decrease (or not increase) the prevalence of the pathogen on plants for planting would typically include the opposite practices to those above: e.g.

- *Location of the nursery outside of woodland areas where the pathogen is well established.*

- *Husbandry or cultural practices*: Drip-irrigation from water sources known to be free of the pathogen, or that have been disinfected. Good plant spacing and measures to reduce humidity. Good hygiene practices. In Germany slow sand filtration (three different designs) and filtration with lava (pumice) grains have been adapted to commercial nursery practice (Ufer *et al*., 2008, 2008a, 2008b). Both filtration techniques successfully eliminated all (unspecified) *Phytophthora* species from water used for irrigation; Jennings *et al*. (2008) also showed the efficacy of slow sand filters.

- *Use of fungicides*: Judicious use of protectant fungicides, alternating active ingredients from different chemical groups or using them in mixtures to reduce the potential for resistance developing, might potentially reduce the prevalence of the pathogen on, or associated with, plants for planting. However, as mentioned above, *Phytophthora* fungicides are unlikely to eradicate the pathogen post-infection, or from contaminated growing media, and they could actually mask the presence of the pathogen.

As a general conclusion, the practices applied in nurseries might, at best, only partially reduce the prevalence level; at worst, they might mask the presence of the pathogen or they could increase it. It should also be noted that plants collected from the natural environment are unlikely to be subject to cultivation or treatment practices that might help reduce the prevalence level.

ii. Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media: The comments that apply to host plants above also apply here regarding practices which may increase or decrease prevalence of *P. ramorum* as a growing-media contaminant of non-host plants.

iii. Soil/growing media as a commodity. It is not known whether it is normal practice to sterilise soil/growing media other than compost using treatments such as heat or fumigation. If this was done it would eliminate or significantly reduce the potential prevalence of *P. ramorum* on this commodity from countries where importation into the EU is permitted.

iv. Soil as a contaminant (e.g. on machinery, footwear, etc.): There are no routine practices that are relevant to reducing the prevalence on this commodity, other than phytosanitary measures related to machinery and standard cleaning practices which are not accounted for here.

v. Foliage and cut branches: These are typically collected from the wild and are therefore not subject to any specific cultural or treatment practices, other than perhaps drying. Dried foliage or cut branches may still contain viable pathogen structures, especially if chlamydospores are formed within infected tissues, though drying (especially if using heat) is likely to reduce the viability of the pathogen in or on the plant tissue. Material may also be dyed, bleached or otherwise impregnated – the effect of this is uncertain – it may reduce the prevalence of the pathogen.

vi. Seeds and fruits: The prevalence on seed at origin is unknown. Assuming the pathogen can potentially be seed-borne (as a seed-coat contamination or seed-coat infection), certain cultural or harvesting practices might have an impact on reducing prevalence of the pathogen, but these will vary with seed type. They might, however, include: the use of any chemical seed extraction techniques for hosts with fleshy fruits; effective seed cleaning techniques to remove any debris; and fungicide seed dressings that have the ability to eradicate any contamination of the seed surface. Good hygiene and cultural practices that reduce the incidence of the pathogen on the mother plants will also have a concomitant impact on the likelihood of the pathogen being found associated with fruits or seeds.

vii. Isolated bark: It is likely that the prevalence of *P. ramorum* on susceptible isolated bark would be high at origin in the affected areas (parts of California, Oregon, and the unknown area/areas of origin, taking into account non-phytosanitary measures (cultivation practices, consignment treatments that are non-phytosanitary).

Bark is unlikely to be treated in any way prior to export except it might be composted. This would only be likely to be done for conifer bark as hardwood material would take longer to break down. (R. Burgess, Forestry Commission, UK, 2008, *personal communication*). Composting is not a sterilisation process and may not be effective in eradicating the pathogen if it is present in the form of chlamydospores (see 3.19).

viii. Wood: It is likely that the prevalence of *P. ramorum* on susceptible isolated wood will be high overall at origin in the affected areas (parts of California, Oregon, and the unknown area/areas of origin, taking into account non-phytosanitary measures (cultivation practices, consignment treatments that are non-phytosanitary). However, this will vary with the treatment.

The processing of wood in the form of roundwood pre-export depends on the customers requirements. If the logs are to be used for the production of veneer then it seems likely that the bark would not be removed to preserve the moisture content until processing. This would not affect the prevalence of the pathogen. For logs destined for the production of sawnwood, these are likely to be debarked. This would not necessarily remove the pathogen as it can be found in the xylem. However, sawnwood is likely to seasoned through air drying or kiln drying which would reduce the moisture content. Air dried or green (unseasoned) sawn wood would have a moisture content of > 20% and kiln-dried <20%. The latter treatment will reduce the prevalence of the pathogen more so than air drying. (R. Burgess, Forestry Commission, UK, *personal communication*, 2008). The efficacy of these treatments against *P. ramorum* is not known.

Go to 1.6

1.6. How large is the volume[10] of the movement along the pathway?

This varies with the commodity and the origin. Relative volume by origin is given in Table 12.

Eurostat data (Comext database) for the last 5 years on imports into the EU of the eight different commodity types from countries where *P. ramorum* is known to occur in the nursery trade and in the non-nursery environment (the USA, Canada, Norway, and Switzerland) as well as two of the countries which are speculated as possible origins *P. ramorum* (China and Taiwan) are relatively

[10] This refers to the commodity.

undetailed and in some cases are not available. This is presented below. (Data supplied by M. O'Donnell, Defra Plant Health Division, UK, *personal communication*, 2008)

Pathway (i) Plants for planting (hosts) (excluding fruits and seeds).
Eurostat data only gives details of imports into the EU for two known hosts of *P. ramorum*, namely rhododendrons (including azaleas) and roses. (CN Code 06023000).

Between 2003 and 2007 there were imports of 'rhododendrons and azaleas' from Canada, the United States, Norway, Switzerland and China but not from Taiwan as shown in Table 4.

Table 4. Weight (100 kg) of grafted/ungrafted rhododendrons and azaleas imported into the EU from six areas where *P. ramorum* occurs or may occur – 2003 to 2007 – Eurostat data.

EXPORTING COUNTRY	2003	2004	2005	2006	2007	TOTAL
Canada	0	0	0	2	0	**2**
USA	17	20	7	4	9	**57**
Norway	6	0	0	7	1	**14**
Switzerland	38	1	109	4	8	**160**
China	0	0	72	0	13	**85**
Taiwan	0	0	0	0	0	**0**

Within the time period, both the United States and Switzerland exported rhododendrons and azaleas to the EU every year. Switzerland was the biggest exporter by weight (total for the period), followed by China, the USA, Norway and Canada.

According to EUROSTAT there were no imports of roses from any of the six countries named (CN Code 06024000).

RAPRA Workpackage 5 year 2 report gave data on imports of ornamental nursery stock (Table 5 below) and for azalea and rhododendron (Table 6) from AIPH, International Statistics Flowers and Plants for 1999, 2002 and 2003. No genera were named for ornamental nursery stock but it is assumed that there are susceptible hosts included in these data.

Table 5. Weight (100 kg) of ornamental nursery stock imported into the EU – 1999, 2002 and 2003 - AIPH, International Statistics Flowers and Plants.

EXPORTING AREA	1999	2002	2003	TOTAL
Africa	630	340	630	**1600**
Asia excluding Middle East	4900	9020	8900	**22820**
Middle East	23530	48260	75500	**147290**
North America	750	1260	520	**2530**
Latin America	9470	20390	42990	**72850**
Europe excluding EU	41500	0	31510	**73010**

Table 6. Weight (100 kg) of azalea and rhododendron imported into the EU – 1999, 2002 and 2003 - AIPH, International Statistics Flowers and Plants.

EXPORTING AREA	1999	2002	2003	TOTAL
Africa	110	0	0	**110**
Asia excluding Middle East	10	100	90	**200**
Middle East	0	0	0	**0**
North America	70	50	20	**140**
Latin America	0	0	0	**0**
Europe excluding EU	2990	0	0	**2990**

Clearly Asia and North America both exported ornamental nursery stock to the EU in each of the three years with Asia exporting *ca*. ten times as much material by weight. However, non-EU countries exported three times more material than Asia. With respect to the data on azalea and rhododendron, comparing the data for 2003 with that sourced from Eurostat there are some discrepancies with zero imports from China and Taiwan (Eurostat, Table 4) compared to 9000 kg from 'Asia excluding the Middle East'. The 2003 figures for the USA and Canada (Table 4) (1700 kg) are similar to those for North America (Table 6) (2000 kg).

As no more up-to-date information has been obtained from this source, the Eurostat Comext database is used to compare import data for this and the remaining pathways of entry.

Because of the lack of detail in Eurostat, other hosts are likely to be included in 'Plants for planting, non-hosts' as described below.

Pathway (ii) Plants for planting (non-hosts) (excluding fruits and seeds). This category is difficult to define, because Eurostat data only name two of the known hosts of *P. ramorum*. Thus, generic data on imports of non-host plants from this source, is also likely to include known hosts of *P. ramorum*.

Table 7 lists the data on imports of plants for planting into the EU (other than rhododendrons and azaleas, roses and non-hosts including chicory) from the known and potential pathway origins for *P. ramorum* for 2003 to 2007.

All exporting countries have shipped plants to the EU over the past 5 years with China being the biggest exporter of live plants by weight (total for the period) (CN Code 060290) followed by the USA, Taiwan, Switzerland, Norway and Canada. Edible fruit or nut trees, shrubs and bushes (CN Code 06022) were exported from all the named countries except Taiwan with Switzerland being the biggest exporter (total weight for the period) followed by the USA, China, Canada and Norway. Fresh Christmas trees were only imported from Norway (most by weight), Switzerland and China (least).

Pathway (iii) Soil as a commodity. Council Directive 2000/29/EC (Anon., 2000) Annex IIIA (article 14) prohibits soil and growing media containing soil or solid organic matter (other than pure peat) imported from certain countries outside of the EU such that the only source of entry for *P. ramorum* would be from Norway and Switzerland. Data on imports for soil and growing media are not available from the Eurostat Comext database.

Pathway (iv) Soil as a contaminant. There are no data to evaluate.

Pathway (v) Foliage/cut branches of susceptible hosts. All data that are available on fresh plant material imported into the EU from the known and potential pathway origins for *P. ramorum* that are available from the Eurostat Comext database for 2003 to 2007 are presented in Table 8. Data are not broken-down by genera so they will include hosts and non-hosts of *P. ramorum*. All countries of origin or potential origin for *P. ramorum* exported foliage, branches and other parts of plants (without flowers or buds) suitable for bouquets or ornamental purposes to the EU between 2003 and 2007. The biggest exporter (by total weight for the period) was the USA, followed by China, Canada, Norway, Switzerland and Taiwan.

Pathway (vi) Seeds and fruits of susceptible hosts. All data that are available on fresh plant material imported into the EU from the known and potential pathway origins for *P. ramorum* that are available from the Eurostat Comext database for 2003 to 2007 are presented in Table 9. The only genera that are named in Eurostat which include known hosts of *P. ramorum* are *Corylus* spp., *Castanea* spp. and *Vaccinium* spp. *Corylus cornuta* (Californian hazelnut) is a ramorum dieback host in the USA. Seeds and fruit of this host could be potential pathways of entry if they become infected. *Castanea sativa* (sweet chestnut) is a foliar and dieback host in the UK only, so this is an unlikely pathway of entry from non-EU countries unless *Castanea* spp. are affected in the unknown areas of origin (potentially China or Taiwan) or become infected in areas where *P. ramorum* is known to occur. *Vaccinium ovatum* (Californian huckleberry) is a foliar and dieback host in the USA. It is cultivated as an ornamental plant rather than for its fruit (which are gathered from the wild) (USDA, 2001) so seeds and fruit are not likely to be a pathway of entry from the USA if they become infected. For all named genera, the biggest exporter by origin (total weight for the period) was the USA, followed by China and Taiwan (combined), Canada, and Norway and Switzerland (combined).

Pathway (vii) Susceptible isolated bark. The Eurostat Comext database does not have a specific category for bark. Data are consolidated under CN Code 440130 'Sawdust and wood waste and scrap, whether or not agglomerated in logs, briquettes, pellets or similar forms'; comprising CN Code 440130 10 00 – 'Sawdust' and CN Code 440130 90 00 – 'Other'. Data from the latter category will include bark of unnamed genera and are presented for Canada, the USA and China only in Table 10.

Data have been difficult to obtain but Norway, Switzerland and Canada do not have *P. ramorum* in their woods or forests so do not represent a pathway.

No data were provided for Taiwan.

Both the USA (and Canada) shipped large quantities of wood waste to the EU between 2003 and 2007 with China shipping less material. How much of his material was bark of known hosts of *P. ramorum* is not known.

However, with respect to imports from the USA, imports of bark of *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp. and *Taxus brevifolia* originating in the USA are banned under the EC emergency legislation for *P. ramorum* (Anon., 2002, 2004 and 2007). *A. macrophyllum* and *A. californica* are foliar hosts in North America and *A. californica* is also a dieback host – i.e. not canker hosts. However, these are regulated based upon other species being canker hosts. *Toxicodendron diversilobum* is a canker host in the USA but is not regulated as it is not a cultivated host. There are other hosts with susceptible bark but these all occur in the EU.

Council Directive 2000/29/EC Annex IIIA (Anon., 2000) prohibits isolated bark of *Castanea* from all third countries (*Castanea sativa*, sweet chestnut, is known as a UK host and suffers from foliar and dieback symptoms as well as bark cankers) and isolated bark of *Quercus* (other than the cork oak, *Quercus suber*) from North America which would include Canada.

There may be other hosts that occur in the potential country/countries of origin which are unknown and therefore cannot be accounted for here.

<u>Pathway (viii)</u> <u>Susceptible wood</u>. The Eurostat Comext database has an abundance of data on imports of wood and wood products into the EU with some named genera. Only data that are available on wood of named genera (*Quercus*, *Fagus* – both canker hosts; *Acer*, *Prunus* and *Fraxinus* – hosts of *P. ramorum* but not canker hosts) imported into the EU that are available from the Eurostat Comext database for 2003 to 2007 for Canada, the USA and China are presented in Table 11.

Currently, the importation of wood from Canada is not considered a pathway of entry because there are no findings of *P. ramorum* in woods or forests there. The same applies for Norway and Switzerland. No data were obtained for these European countries or for Taiwan.

Under the EC emergency legislation for *P. ramorum*, imports of wood of *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp. and *Taxus brevifolia* originating in the USA are only permitted entry into the EU if they come from a pest-free area for *P. ramorum* or if they have received a specific treatment for *P. ramorum* (Anon., 2002, 2004 and 2007). *A. macrophyllum* and *A. californica* are foliar hosts in North America and *A. californica* is also a dieback host – i.e. not canker hosts. However, these are regulated based upon other species being canker hosts. *Toxicodendron diversilobum* is a canker host in the USA but is not regulated as it is not a cultivated host. There are other hosts with susceptible bark but these all occur in the EU.

Council Directive 2000/29/EC Annex IVA (Anon., 2000) has specific requirements for the entry of wood or wood products of certain genera imported from outside the EU but their efficacy against *P. ramorum* is not known.

The main material imported into the EU from areas where *P. ramorum* is known to occur or may occur is wood of *Quercus* spp. (oak). The majority of this wood comes from the USA and Canada with reasonably large amounts also coming from China. *Quercus* spp. are the main canker hosts in the USA. Wood of *Fraxinus* spp. (ash) from the USA is a major import into the EU as well as *Acer* spp. from Canada and the USA. *F. latifolia* and *F. excelsior* are the only known hosts in the genus *Fraxinus* and these are both foliar hosts in the USA and the UK respectively, so are not likely to be carried in wood. Sycamore (*A. pseudoplatanus*) is a canker host in the UK but *Acer* spp. are only foliar hosts in North America. Wood of *Prunus* spp. comes mainly from the USA and Canada but in this genus the only known hosts are foliar hosts (*P. laurocerasus* in the USA and *P. lusitanica* in Canada; both nursery hosts) and so currently wood of this genus poses no risk. Wood of *Fagus* spp. (beech) is also imported, mainly from China but also from Canada and the USA. *Fagus sylvatica* (beech) is a canker host, but currently only in the UK.

Although there are data available in the Eurostat Comext database for six of the eight pathways the level of uncertainty surrounding the data is high for <u>Pathway (i) plants for planting (hosts)</u>, <u>Pathway (ii) plants for planting (non-hosts)</u> and <u>Pathway (v) foliage/cut branches of susceptible hosts</u> because the only named hosts in the database are rhododendron (including azalea) and roses and this is only for plants for planting. It is assumed that Pathway (ii) plants for planting (non-hosts) contains some susceptible hosts. The level of uncertainty for (iv) volume of soil as a contaminant is high because there are no data. The level of uncertainty for (vii) volume of susceptible bark is high because the data are part of a general wood waste category in Eurostat with no named genera. The level of uncertainty is high for Pathway (iii) volume of soil/growing media as a commodity from non-EU European countries (Norway and Switzerland) as no data are available in the Eurostat database, as well as for Pathway (vii) susceptible bark and Pathway (viii) susceptible wood from these countries too, as no data were obtained.

For Pathway (vi), the volume of seeds and fruits has medium to high uncertainty as only a few genera are named and these data refer to nuts and fruit only.

The only categories where the data on volumes of imports has low uncertainty are for (iii) soil as a commodity from Canada, USA, China and Taiwan as this is banned and (viii) susceptible wood from these countries as five of the host genera are named including *Quercus* spp.

In terms of volumes the 'massive' pathways are:

Pathway (vii) Susceptible bark (assuming that there are susceptible genera in this data) from Canada and the USA although the majority of hosts with susceptible bark in the USA are banned from entry into the EU under the emergency legislation for *P. ramorum* (Anon., 2002, 2004, 2007).

Pathway (viii) Susceptible wood from Canada and the USA although there are controls on both these pathways for *P. ramorum* where they originate in the USA (Anon., 2002, 2004, 2007) and *P. ramorum* does not occur in forests or woodlands in Canada where such material would be harvested.

Pathway (v) Susceptible foliage/cut branches from the USA (also assuming there are susceptible genera included in the data); there are no specific phytosanitary controls for *P. ramorum* on this material.

Major pathways are:

Pathway (ii) Plants for planting (non-hosts) (assuming this also contains natural hosts) from Asia (China/Taiwan, if *P. ramorum* is present there), the USA and non-EU European countries (Norway and Switzerland).

Pathway (v) Susceptible foliage/cut branches from Asia (China/Taiwan, if *P. ramorum* is present there), Canada, and non-EU European countries (Norway and Switzerland) (assuming there are susceptible genera included in these data).

Pathway (vi) Seeds and fruits from all the identified areas of origin.

Pathway (vii) Susceptible bark from Asia (China/Taiwan, if *P. ramorum* is present there) assuming that there are susceptible genera in these data.

Pathway (viii) Susceptible wood from Asia (China/Taiwan, if *P. ramorum* is present there) assuming that there are susceptible genera in this data.

Moderate pathways are:

Pathway (i) Plants for planting (hosts) from the USA, Asia (China/Taiwan, if *P. ramorum* is present there) and non-EU European countries (Norway and Switzerland).

Pathway (ii) Plants for planting (non-hosts) (we assume this also contains natural hosts) from Canada.

Minor pathways are:

Pathway (i) Plants for planting (hosts) from Canada.

Go to 1.7

Table 7. Weight (100 kg) of plants for planting (unnamed genera) by Eurostat category imported into the EU from six areas where *P. ramorum* occurs or may occur – 2003 to 2007.

PLANT CATEGORY & CN CODE	EXPORTING COUNTRY	2003	2004	2005	2006	2007	TOTAL
LIVE PLANTS, INCL. THEIR ROOTS, AND MUSHROOM SPAWN (EXCL. BULBS, TUBERS, TUBEROUS ROOTS, CORMS, CROWNS AND RHIZOMES, INCL. CHICORY PLANTS AND ROOTS, UNROOTED CUTTINGS AND SLIPS, FRUIT AND NUT TREES, RHODODENDRONS, AZALEAS AND ROSES)	CANADA	21	94	14	421	3	553
	USA	19,837	19,553	23,770	18,252	24,314	105,726
	NORWAY	1,770	1,415	1,349	950	556	6,040
	SWITZERLAND	1,562	2,849	2,404	3,303	2,974	13,092
	CHINA	112,253	131,020	155,180	180,125	201,370	779,948
	TAIWAN	21,350	22,791	13,518	11,513	20,044	89,216
1. CN CODE 060290 – master category.	**TOTAL**						**994,575**
OUTDOOR TREES, SHRUBS AND BUSHES, INCL. THEIR ROOTS (EXCL. CUTTINGS, SLIPS AND YOUNG PLANTS, AND FRUIT, NUT AND FOREST TREES)	CANADA	0	18	2	0	0	20
	USA	522	688	3,965	655	2,292	8,122
	NORWAY	83	112	350	142	150	837
	SWITZERLAND	274	1,071	842	537	643	3,367
	CHINA	6,593	6,146	10,053	10,341	13,743	46,876
	TAIWAN	0	0	30	24	99	153
2. CN CODE 06029049 – subset of 1.	**TOTAL**						**59,375**
EDIBLE FRUIT OR NUT TREES, SHRUBS AND BUSHES, WHETHER OR NOT GRAFTED	CANADA	6	11	0	223	15	255
	USA	876	306	4,680	691	473	7,026
	NORWAY	6	30	21	24	42	123
	SWITZERLAND	6,304	3,442	2,084	2,207	2,791	16,828
	CHINA	77	1	33	321	554	986
	TAIWAN	0	0	0	0	0	0
3. **CN CODE 06022 – master category**	**TOTAL**						**25,218**
TREES, SHRUBS AND BUSHES, GRAFTED OR NOT, OF KINDS WHICH BEAR EDIBLE FRUIT OR NUTS (EXCL. VINE SLIPS)	CANADA	6	11	0	223	1	241
	USA	876	296	4,680	691	473	7,016
	NORWAY	6	30	21	24	42	123
	SWITZERLAND	6,304	3,430	2,066	2,189	2,752	16,741
	CHINA	72	1	10	320	554	957
	TAIWAN	0	0	0	0	0	0
4. **CN CODE 06022090 – subset of 3.**	**TOTAL**						**25,078**
OUTDOOR ROOTED CUTTINGS AND YOUNG PLANTS OF TREES, SHRUBS AND BUSHES (EXCL. FRUIT, NUT AND FOREST TREES)	CANADA	20	0	0	0	0	20
	USA	176	234	208	164	776	1,558
	NORWAY	81	293	19	252	9	654
	SWITZERLAND	14	107	22	58	15	216
	CHINA	590	247	877	457	2,027	4,198
	TAIWAN	26	440	55	461	384	1,366
5. **CN CODE 06029045 – subset of 1.**	**TOTAL**						**8,012**
FRESH CHRISTMAS TREES	CANADA	0	0	0	0	0	0
	USA	0	0	0	0	0	0
	NORWAY			10	592	2,208	2,810
	SWITZERLAND				221	265	486
	CHINA			247	0	0	247
	TAIWAN	0	0	0	0	0	0
6. **CN CODE 06049120 – subset of 1, table 8.**	**TOTAL**						**3,543**
LIVE FOREST TREES	CANADA	0	73	0	0	0	73
	USA	117	0	123	0	0	240
	NORWAY	11	11	24	0	3	49
	SWITZERLAND	11	3	2	9	163	188
	CHINA	0	256	8	0	186	450
	TAIWAN	0	0	0	0	0	0
7. **CN CODE 06029041 –subset of 1.**	**TOTAL**						**1,000**

Table 8. Weight (100 kg) of foliage/cut branches of susceptible hosts (includes non-hosts) (unnamed genera) by Eurostat category imported into the EU from six areas where *P. ramorum* occurs or may occur – 2003 to 2007.

PLANT CATEGORY & CN CODE	**EXPORTING COUNTRY**	**2003**	**2004**	**2005**	**2006**	**2007**	**TOTAL**
FOLIAGE, BRANCHES AND OTHER PARTS OF PLANTS, WITHOUT FLOWERS OR FLOWER BUDS, AND GRASSES, MOSSES AND LICHENS, OF A KIND SUITABLE FOR BOUQUETS OR FOR ORNAMENTAL PURPOSES, FRESH, DRIED, DYED, BLEACHED, IMPREGNATED OR OTHERWISE PREPARED	CANADA	54,933	36,787	28,206	18,250	22,404	160,580
	UNITED STATES	219,036	246,603	239,184	280,365	289,586	1,274,774
	NORWAY	1,406	1,605	1,135	2,049	3,487	9,682
	SWITZERLAND	303	210	128	427	557	1,625
	CHINA	32,339	38,939	42,917	55,816	53,195	223,206
	TAIWAN	147	110	91	69	98	515
1. CN CODE 0604 – master category	**TOTAL**						**1,670,382**
FOLIAGE, BRANCHES AND OTHER PARTS OF PLANTS, WITHOUT FLOWERS OR FLOWER BUDS, GRASSES, FRESH, FOR BOUQUETS OR ORNAMENTAL PURPOSES	CANADA	54,778	36,529	28,187	18,184	22,193	159,871
	UNITED STATES	216,953	244,322	237,249	278,806	287,651	1,264,981
	NORWAY	282	118	14	696	2,341	3,451
	SWITZERLAND	172	56	8	233	547	1,016
	CHINA	4,382	474	889	1,755	2,491	9,991
	TAIWAN	85	51	40	44	53	273
2. CN CODE 060491 – subset of 1	**TOTAL**						**1,439,583**
FOLIAGE, BRANCHES AND OTHER PARTS OF PLANTS, WITHOUT FLOWERS OR FLOWER BUDS, GRASSES, FRESH, FOR BOUQUETS OR ORNAMENTAL PURPOSES (EXCL. CHRISTMAS TREES AND CONIFER BRANCHES)	CANADA	54,778	36,529	28,187	18,182	22,193	159,869
	UNITED STATES	216,952	244,319	237,249	278,806	287,651	1,264,977
	NORWAY	272	3	4	4	3	286
	SWITZERLAND	141	2	8	0	255	406
	CHINA	4,382	279	642	1,755	2,491	9,549
	TAIWAN	85	51	40	44	53	273
3. CN CODE 06049190 – subset of 1	**TOTAL**						**1,435,360**
FRESH CONIFER BRANCHES, FOR BOUQUETS OR ORNAMENTAL PURPOSES	CANADA	0	0	0	2	0	2
	UNITED STATES	0	0	0	0	0	0
	NORWAY	0	0	0	100	130	230
	SWITZERLAND	0	0	0	12	27	39
	CHINA	0	0	0	0	0	0
	TAIWAN	0	0	0	0	0	0
4. CN CODE 06049140 – subset of 1	**TOTAL**						**271**

NB: Foliage, branches and other parts of plants, without flowers or flower buds, grasses, for bouquets or ornamental purposes, dried, dyed, bleached, impregnated or otherwise prepared are considered to be much lower risk pathways of entry for *P. ramorum* and so no data are presented here.

Table 9. Weight (100 kg) of seeds and fruits of susceptible hosts (named genera) by Eurostat category imported into the EU from six areas where *P. ramorum* occurs or may occur – 2003 to 2007.

PLANT CATEGORY & CN CODE	EXPORTING COUNTRY	2003	2004	2005	2006	2007	TOTAL
FRESH OR DRIED HAZELNUTS OR FILBERTS "*CORYLUS* SPP.", IN SHELL	CANADA	0	387	599	0	0	986
	UNITED STATES	39,782	41,082	39,347	38,500	36,166	194,877
	NORWAY	0	0	0	0	0	0
	SWITZERLAND	20	0	0	0	0	20
	CHINA	454	800	963	1,222		3,439
	TAIWAN	0	0	0	0	0	0
1. CN CODE 08022100	**TOTAL**						**199,322**
FRESH OR DRIED HAZELNUTS OR FILBERTS "*CORYLUS* SPP.", SHELLED AND PEELED	CANADA	0	0	0	0	0	0
	UNITED STATES	828	3,070	6,576	2,864	2,070	15,408
	NORWAY	92	47	29	31	233	432
	SWITZERLAND	714	895	9	340	370	2,328
	CHINA	1,013	2,498	3,222	3,597	1,032	11,362
	TAIWAN	0	0	0	0	0	0
2. CN CODE 08022200	**TOTAL**						**29,530**
FRESH OR DRIED CHESTNUTS "*CASTANEA* SPP.", WHETHER OR NOT SHELLED OR PEELED	CANADA	583	228	890	480	0	2,181
	UNITED STATES	1,140	1,053	3,221	464	1,604	7,482
	NORWAY	0	0	0	0	0	0
	SWITZERLAND	936	404	412	445	642	2,839
	CHINA	1,557	12,447	13,116	25,251	55,748	108,119
	TAIWAN	0	0	197	0	0	197
3. CN CODE 08024000	**TOTAL**						**120,818**
FRESH CRANBERRIES, BILBERRIES AND OTHER FRUITS OF THE GENUS VACCINIUM	CANADA	1,287	425	360	2,400	3,216	7,688
	UNITED STATES	9,896	9,741	15,229	19,108	17,200	71,174
	NORWAY	80	279	114	265	63	801
	SWITZERLAND	4	118	18	27	253	420
	CHINA	0	1	290	53	64	408
	TAIWAN	0	0	0	0	0	0
4. CN CODE 081040 – master code	**TOTAL**						**80,491**
FRESH COWBERRIES, FOXBERRIES OR MOUNTAIN CRANBERRIES "FRUIT OF THE SPECIES *VACCINIUM VITIS-IDAEA*"	CANADA	208	0	12	0	0	220
	UNITED STATES	1,896	1,604	2,005	1,911	4,428	11,844
	NORWAY		249	97	256	54	656
	SWITZERLAND	0	118	3	0	250	371
	CHINA	0	0	260	0	0	260
	TAIWAN	0	0	0	0	0	0
5. CN CODE 08104010 - subset of 4	**TOTAL**						**13,351**
FRESH FRUIT OF SPECIES *VACCINIUM MYRTILLUS*	CANADA	29	43	0	4	6	82
	UNITED STATES	304	76	71	206	31	688
	NORWAY	0	0	0	1	5	6
	SWITZERLAND	4		9	27		40
	CHINA	0	0			1	1
	TAIWAN	0	0	0	0	0	0
6. CN CODE 08104030 – subset of 4	**TOTAL**						**817**
FRESH FRUIT OF SPECIES *VACCINIUM MACROCARPUM* AND *VACCINIUM CORYMBOSUM*	CANADA	1,050	380	344	2,284	3,210	7,268
	UNITED STATES	7,683	8,039	13,115	16,943	12,732	58,512
	NORWAY	0	0	13	0	0	13
	SWITZERLAND	0	0	6	0	3	9
	CHINA	0	0	0	0	0	0
	TAIWAN	0	0	0	0	0	0
7. CN CODE 08104050- subset of 4	**TOTAL**						**65,802**

Table 10. Weight (100 kg) of wood waste 'other' by Eurostat category imported into the EU from six areas where *P. ramorum* occurs or may occur – 2003 to 2007.

PLANT CATEGORY & CN CODE	EXPORTING COUNTRY	2003	2004	2005	2006	2007	TOTAL
SAWDUST AND WOOD WASTE AND SCRAP, WHETHER OR NOT AGGLOMERATED IN LOGS, BRIQUETTES, PELLETS OR SIMILAR FORMS	CANADA	2,543,741	3,647,842	4,961,482	5,333,797	6,122,088	22,608,950
	UNITED STATES	55,791	2,542,846	3,375,920	29,420	77,313	6,081,290
	NORWAY	ND	ND	ND	ND	ND	ND
	SWITZERLAND	ND	ND	ND	ND	ND	ND
	CHINA	840	237	2,098	14,806	27,400	45,381
	TAIWAN	ND	ND	ND	ND	ND	ND
CN CODE 44013090	**TOTAL**						**28,735,621**

ND = No data received or available

Table 11. Weight (100 Kg) of wood by Eurostat category (named genera only) imported into the EU from three of the six areas where *P. ramorum* occurs or may occur – 2003 to 2007.

PLANT CATEGORY and CN CODE	EXPORTING COUNTRY	2003	2004	2005	2006	2007	TOTAL
OAK '*QUERCUS* SPP.' IN THE ROUGH, WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED	CANADA	4,636	11,691	10,116	10,627	5,867	42,937
	UNITED STATES	243,631	355,886	294,054	328,286	369,162	1,591,019
	CHINA	341	1,068	3,060	1,762	7,283	13,514
1. CN CODE 440391	**TOTAL**						**1,633,956**
BEECH '*FAGUS* SPP.' IN THE ROUGH, WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED	CANADA	140		378	211	278	1,007
	UNITED STATES	2,073	1,284	229	417	257	4,260
	CHINA	225	0	1	0	250	476
2. CN CODE 440392	**TOTAL**						**5743**
OAK *QUERCU*S SPP., SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR END-JOINTED, > 6 MM THICK	CANADA	228,903	232,981	228,907	174,083	145,327	1,010,201
	UNITED STATES	2,833,831	2,934,088	3,037,180	3,091,546	3,310,934	15,207,579
	CHINA	72,783	104,531	94,021	100,154	144,868	516,357
3. CN CODE 440791	**TOTAL**						**16,734,137**
BEECH 'FAGUS SPP.', SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR END-JOINTED, > 6 MM THICK	CANADA	784	1,186	4,356	4,364	2,712	13,402
	UNITED STATES	3,670	400	2,114	1,343	3,265	10,792
	CHINA	317	4,456	13,955	8,510	5,488	32,726
4. CN CODE 440792	**TOTAL**						**56,920**
MAPLE '*ACER* SPP.', SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR END-JOINTED, > 6 MM THICK	CANADA	0	0	0	0	134,826	134,826
	UNITED STATES	0	0	0	0	89,341	89,341
	CHINA	0	0	0	0	369	369
5. CN CODE 440793	**TOTAL**						**224,536**
CHERRY '*PRUNUS* SPP.', SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR END-JOINTED, > 6 MM THICK	CANADA	0	0	0	0	42,600	42,600
	UNITED STATES	0	0	0	0	85,486	85,486
	CHINA	0	0	0	0	354	354
6. CN CODE 440794	**TOTAL**						**128,440**
ASH '*FRAXINUS* SPP.', SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR END-JOINTED, > 6 MM THICK	CANADA	0	0	0	0	51,804	51,804
	UNITED STATES	0	0	0	0	256,992	256,992
	CHINA	0	0	0	0	441	441
7. CN CODE 440795	**TOTAL**						**309,237**

NB. No data were available for Norway, Switzerland or Taiwan**.**

Table 12. (a) Estimated relative volume of each commodity imported into the EU in relation to geographic source – 2002 to 2007, based upon total weights (100 kg) from Eurostat Comext database. Commodity volume is categorised according to the following scheme: *Minimal; Minor; Moderate; Major; Massive.* (b) Associated levels of uncertainty.

(a) Estimated relative volume (100kg) and ranking of imports into the EU by geographic source							
	Commodity	**Pathway type**	**Canada**	**USA**	**Unknown area/s of origin** [a]	**Europe (Non-EU)** [b]	**Range**
i	**Plants for planting (Hosts)** [c]	Direct	2 Minor	57 Moderate	85 Moderate	245 Moderate	Minor to Moderate
ii	**Plants for planting (Non-Hosts –includes hosts)** [d]	Direct	808 Moderate	112,752 Major	870,150 Major	23,336 Major	Moderate to Major
iii	**Soil as a commodity** [e]	Direct	**Banned**	**Banned**	**Banned**	**No data – assumed minimal**	Minimal
iv	**Soil as a contaminant** [f]	Direct	**No data**	**No data**	**No data**	**No data**	No data
v	**Foliage/cut branches of susceptible hosts** [g]	Indirect	160,580 Major	**1,274,774** **Massive**	223,721 Major	11,307 Major	Major to Massive
vi	**Seeds and *fruits*** [h]	Direct/*Indirect*	11075 Major	300,785 Major	123,785 Major	5,539 Major	Major
vii	**Susceptible/isolated bark** [i]	Direct	**22,608,950** **Massive**	**6,081,290** **Massive**	45,381 Major	**No data**	Major to Massive
viii	**Susceptible wood** [j]	Indirect	**1,296,777** **Massive**	**17,245,469** **Massive**	564,237 Major	**No data**	Major to Massive

(b) Estimated levels of uncertainty for the estimates of relative volume of imports into the EU by geographic source							
	Commodity	**Pathway type**	**Canada**	**USA**	**Unknown area/s of origin** [a]	**Europe (Non-EU)** [b]	**Range**
i	**Plants for planting (Hosts)** [c]	Direct	**HIGH**	**HIGH**	**HIGH**	**HIGH**	HIGH
ii	**Plants for planting (Non-Hosts)** [d]	Direct	**HIGH**	**HIGH**	**HIGH**	**HIGH**	HIGH
iii	**Soil as a commodity** [e]	Direct	LOW	LOW	LOW	**HIGH**	LOW TO HIGH
iv	**Soil as a contaminant** [f]	Direct	**HIGH**	**HIGH**	**HIGH**	**HIGH**	HIGH
v	**Foliage/cut branches of susceptible hosts** [g]	Indirect	**HIGH**	**HIGH**	**HIGH**	**HIGH**	HIGH
vi	**Seeds and *fruits*** [h]	Direct/*Indirect*	MEDIUM TO HIGH	MEDIUM TO HIGH	MEDIUM TO HIGH	MEDIUM TO HIGH	MEDIUM TO HIGH
vii	**Susceptible/isolated bark** [i]	Direct	**HIGH**	**HIGH**	**HIGH**	**HIGH**	HIGH
viii	**Susceptible wood** [j]	Indirect	LOW	LOW	LOW	**HIGH**	LOW TO HIGH

[a]Asia is speculated, Eurostat data from China & Taiwan used except for 'bark' and 'wood' which is China only; [b] Norway & Switzerland; [c]Eurostat data for rhododendron (including azalea) only; [d]Eurostat data for all plants other than rhododendron (including azalea) so includes hosts and non-hosts, [e]Banned from Canada, USA, China and Taiwan, [f]No data; [g]Eurostat data for unspecified genera so includes hosts and non-hosts – fresh material only [h]Eurostat data for nuts of *Corylus* spp. and *Castanea* spp. and fruits of *Vaccinium* spp; [i]Eurostat data on total imports by weight (2002 to 2007) of wood waste 'other'; Bark of *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp., and *Taxus brevifolia* from the USA is prohibited under EC emergency legislation for *P. ramorum* (Anon., 2002, 2004 and 2007) and bark of *Quercus* spp. other than *Q. suber* is banned from North America under the EC Plant Health Directive (Anon., 2000) as well as bark of *Castanea* from non-European countries [j]Eurostat data on total imports by weight (2002 to 2007) for canker hosts *Quercus* and *Fagus* spp., as well as non-canker hosts *Acer*, *Fraxinus* and *Prunus* spp.; wood of *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp., and *Taxus brevifolia* from the USA is only permitted entry into the EU if it comes from a pest-free area for *P. ramorum* or if it has received a specific treatment for *P. ramorum* (Anon., 2002, 2004 and 2007); Council Directive 2000/29/EC Annex IVAI (Anon., 2000) has specific requirements for the entry of wood or wood products of certain genera imported from outside the EU but their efficacy against *P. ramorum* is not known.

1.7. How frequent is the movement[11] along the pathway?

Very rarely, rarely, occasionally, often, **very often**

Very often

Level of uncertainty: Medium

Plants for planting (excluding seeds) of host plants and non-host plants with soil or growing media attached can enter the PRA area at all times of year (see *Question 1.10* for phytosanitary requirements), as can soil as a contaminant of footwear, machinery, etc. These represent the most likely pathways of entry. For plants for planting, the number of hosts of susceptible hardy ornamental nursery stock is very large and therefore there is potentially a very large and frequent movement along this general pathway.

However, the frequency of movement of the commodities is not particularly relevant to the assessment of the risk of entry because of the potential longevity of the pathogen's spores, especially chlamydospores.

Go to 1.8

Probability of survival during transport or storage

1.8. How likely is the pest to survive during transport /storage?

Very unlikely, unlikely, moderately likely, likely, **very likely**

Very likely

Level of uncertainty: Low

The pathogen is primarily moved in trade via infected host plants for planting, on which sporangia and chlamydospores may also be formed depending on the host species, the stage of disease development and environmental conditions prior to, or during, transport. In such cases, the pathogen is very likely to survive during transport and storage since the primary conditions for survival are fulfilled by the presence of the live host plant and associated environmental conditions. It is also likely that sporangia on foliar lesions will survive under most transport conditions since they are able to survive a range of temperatures between 0°C and 25°C (Turner *et al.*, 2005; Turner and Jennings, 2008). Although sporangia are vulnerable to desiccation and did not survive extreme desiccation for longer than 24 hours in UK experiments (Turner *et al.*, 2005), they are likely to survive for much longer periods at more ambient relative humidities during transport. Chlamydospores within infected tissues are also very likely to survive since they are robust, thick-walled structures adapted for survival. They are very likely to survive the range of temperatures that plant material is subjected to during transport or storage (see below).

The pathogen is also very likely to survive during transport in contaminated soil/growing media associated with non-host plants, with footwear or machinery, or contaminated soil/growing media as a commodity; however, survival in soil contaminating footwear or machinery is likely to be reduced on drying (Cushman *et al.*, 2008). Sporangia inoculated into a range of growing media components survived for up to 6 months (Linderman and Davis, 2006); in the same experiment chlamydospores survived for up to 12 months. Colburn *et al.* (2005) showed no decline in chlamydospore populations after 4 months in sand, potting soil mix or forest soil held

[11] This refers to the commodity.

at 4°C. Jeffers (2005) also showed that *P. ramorum* could survive for several months in potting media shipped with plants from California to South Carolina after storage at 4°C. Shishkoff and Tooley (2004) reported survival of *P. ramorum* in infected *Rhododendron* leaf tissue containing chlamydospores buried in mesh bags in pots containing nursery stock for up to 155 days after burial. Additionally, Shishkoff (2007) recovered *P. ramorum* from moist potting mix or sand for many months, whether buried as infected plant leaf tissue or as mycelium bearing chlamydospores. In laboratory experiments in the UK, chlamydospores survived a range of temperatures and pH (Turner *et al.*, 2005; Turner *et al.*, 2008a): chlamydospore survival in culture was not affected by temperatures between 0°C and 20°C; approximately 60% of chlamydospores survived 24 hours at -2°C or 25°C; whilst all chlamydospores were killed within 24 hours by -25°C or 40°C extremes. Chlamydospores produced in culture also survived a pH range between pH2 and pH9.

With respect to survival in seed and fruit, although there is no evidence that *P. ramorum* is truly seed transmitted, it is possible that the organism could be seed-borne (e.g. through colonisation of the outer seed coat, or through infected debris accompanying seed, especially if chlamydospores are formed in these tissues); if this occurs then the pathogen could survive transportation in seed. Fruits of some susceptible plant species have been shown to be infected by *P. ramorum* (Moralejo *et al.*, 2006, 2006a; Denman *et al.*, 2008; Inman *et al.*, 2005; Moralejo *et al.*, 2007), so fruits and any seeds contained therein could potentially be infected/ contaminated. The form in which it might survive in fruit is unknown.

With respect to survival in bark, there is the potential for chlamydospores to be produced in infected phloem/cambial tissues. Brown and Brasier (2007) isolated *P. ramorum* from the bark of a range of tree species but considered that there was little evidence to suggest that sporangia were formed in bark. However, it is thought likely that chlamydospores are formed in tree bark following infection although no microscopy studies have been conducted to try and detect these structures in infected bark.

With respect to survival in wood, infection has been reported in the xylem (Rizzo *et al.*, 2002; Brown and Brasier, 2007; Parke *et al.*, 2008) of some tree species. Chlamydospores, which are potentially relatively long lived, have been reported in sapwood (xylem vessels) of tanoak (*L. densiflorus*) (Parke *et al.*, 2008). Preliminary data suggests that *P. ramorum* spores can survive in firewood from susceptible host trees for at least 6 months (Shelly *et al.*, 2005). Brown and Brasier (2007) also found that *P. ramorum* could survive in exposed wood of trees for up to two years and, although they did not specify in what form extended survival occurred (i.e. spores or mycelium), chlamydospores are the most likely survival stages for extended persistence in wood.

In conclusion, it is very likely that the pathogen can survive transport and storage on a range of commodity types. Interception data for traded plants and other publications support this view, including the following:

- Interceptions of *P. ramorum* on plant passported material moved between EU Member States (Slawson *et al*, 2008).
- The movement of *P. ramorum* between Californian Nurseries and to other US nurseries in Oregon and Washington State in 2003 (Frankel, 2008).
- The movement of *P. ramorum* from a large Californian nursery (Monrovia Nursery, Azusa, CA), directly or indirectly to 39 other US states in 2004, of which 20 states subsequently confirmed *P. ramorum* on shipped plants in 171 nursery-related detections (Frankel, 2008).
- The finding of isolates of the European (EU1) lineage on plant material in nurseries in California, Oregon, Washington (USA) and British Columbia (Canada) (COMTF, 2008;

Ivors *et al.*, 2006; Cave *et al.*, 2005; Grunwald *et al.*, 2008). This suggests the potential introduction on plant material imported from Europe or from the unknown area/s of origin.

- Interceptions by Canada of *P. ramorum* on US plant material in 2003 and 2004 (Frankel, 2008; Wong, 2008)
- The separate original introductions of the pathogen into both the USA and Europe from its (as yet) unknown area/s of origin during, or prior to, the early-1990s. The North American and European lineages appear to be evolutionally separated over a period of many thousand years and are likely to have originated from separate geographic locations (Goss and Grünwald, 2008; Goss *et al.*, 2009).

Go to 1.9

1.9. How likely is the pest to multiply/increase in prevalence during transport/ storage?
Impossible/Very unlikely, unlikely, **moderately likely**, likely, very likely

Moderately likely

Level of uncertainty: Low

The pathogen has a minimum and maximum growth temperature of 2°C and 30°C respectively; the optimum for growth is about 20°C, but growth is only marginally slower at 15°C and 25°C. Growth is therefore likely to continue during transport within infected plant tissues.

Prevalence is only moderately likely to increase during transport as the pathogen is primarily dispersed by rain-splash. Sporangia produced before, or during, transport or storage could still liberate zoospores if conditions are suitable (cool temperatures and the availability of free moisture on plant surfaces), resulting in new infections.

Multiplication through the production of sporangia during transport and storage will depend on a variety of factors, including the host species, the plant part infected, temperature, light and humidity. Sporangial production occurs at a broad range of temperatures with the optimal temperature being between 16 and 22°C (Englander *et al.*, 2006). Maximum production and release of zoospores occurs between 15 and 20°C (Davidson *et al.* 2005). Turner and Jennings (2006) reported that optimum temperature for sporulation and germination ranged from 20 to 30°C depending upon experimental conditions. Turner and Jennings (2006) found that differences in humidity had the most effect on sporangial production and zoospore germination *in vitro*, whereas sporangial germination was less sensitive. Maximum levels of sporangial production and zoospore germination occurred at 100% humidity; continuous light or alternating light/dark cycles is also required for sporangial production (Turner and Jennings, 2008). Sporangial production therefore has the potential to occur during transport and storage, but only moderately so.

Go to 1.10

Probability of the pest surviving existing pest management procedures

1.10. How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?

Very unlikely, unlikely, moderately likely, likely, very likely

Very unlikely to **Very likely**, depending on the commodity (see Table 13)

Level of uncertainty: Low

The likelihood will vary with the commodity and the phytosanitary measures applied. The estimated likelihood of the pathogen surviving or remaining undetected is given in Table 13, and explanations are given below for each commodity type. Current EU emergency measures for *P. ramorum* (2002/757/EC, as amended 2004, 2007) (Anon, 2002, 2004, 2007) are referred to here for each commodity type (where applicable), together with any other relevant EU Plant Health Directive requirements (2000/29/EC) (Anon, 2000).

In the case of all origins, the ability for the pathogen to remain undetected will be affected by the method of inspection and/or testing by the exporting country's NPPO for each commodity, if required by EU regulations. Similarly, the likelihood of the pathogen surviving any phytosanitary treatments required by EU legislation will depend on the effectiveness of their application and their efficacy.

i. Plants for planting (excluding seeds and fruit) of host plant species: EU emergency legislation for *P. ramorum* has measures related to imports from third countries as well as internal movements within the Community. Anon. (2002; *Article 3*) requires that susceptible plants (listed in paragraph 2, *Article* 1, Anon., 2007) originating in the USA that are allowed entry into the EU (i.e. without prejudice to specified provisions in Annex III and IV of the EC Plant Health directive, 2000/29/EC[12]), are accompanied by a phytosanitary certificate stating that:

(a) *they originate in areas in which non-European isolates of* P. ramorum *are known not to occur; or*

(b) *that no signs of non-European isolates of* P. ramorum *have been observed on any susceptible plants at the place of production during official inspections, including laboratory testing of any suspicious symptoms carried out since the beginning of the last complete growing cycle of vegetation.*

Furthermore, the certificate shall only be issued after representative samples of the plants have been taken prior to shipment and have been inspected and found free from non-European isolates of P. ramorum *in these inspections.*

Introduced plants of susceptible species from the USA may only be moved within the Community if they are accompanied by a plant passport.

Also:

[12] 2000/29/EC: Annex IIIA prohibits certain plants for planting that are known hosts of *P. ramorum*; Annex IVAI lists requirements relating to trees, shrubs and herbaceous plants from various third countries intended for planting (e.g. *Article 39* for trees and shrubs; *Article 40* for deciduous trees and shrubs; *Article 41* for annual/biennial plants; *Article 43* for dwarf plants; *Article 44* for herbaceous perennial plants)

Plants intended for planting of Viburnum *spp.*, Camellia *spp. and* Rhododendron *spp., other than* Rhododendron simsii *Planch, other than seeds*[13]*, originating in third countries*[14]*, other than the USA, introduced into the Community may only be moved in the Community if they are accompanied by a plant passport.*

The pathogen is moderately likely to remain undetected in plants for planting of host species in areas where the pathogen occurs in the USA, Canada, Norway, Switzerland or from its unknown area or areas of origin. Detection, either to determine 'area freedom', 'place of production freedom' or pre-shipment freedom, may be affected by a variety of factors as follows:

- Aerial symptoms are not unique to *P. ramorum* and similar leaf, shoot or stem symptoms can be caused by other plant pathogens (including other *Phytophthora* species) or by physiological conditions.

- Although the incubation period (the period from infection to the development of symptoms) for *P. ramorum* on leaves is generally only a few days (Turner *et al.*, 2005), even at low temperature, this incubation period may be longer for other plant parts (e.g. woody stems) or under certain environmental conditions. Symptom onset occurred 8 to 6 days respectively after *Rhododendron* plants were irrigated with contaminated water in June (Ufer *et al.*, 2008, 2008a, 2008b). Kessel *et al.* (2007) reported that when the root systems of *Rhododendron* were inoculated by applying a zoospore suspension, symptoms developed from 12 days post-inoculation onwards and included wilting and brown colouration of the stem base and roots. However, symptoms did not always develop following inoculation. Inoculated, visually healthy plants (above-ground) also had visually healthy root symptoms but, despite the absence of symptoms, chlamydospores could be detected in these plants one week after inoculation. *P. ramorum* survival structures were thus found in inoculated but visually healthy plants. This phenomenon may be related to some of the reported incidences on latent infections in plant trade. It is however unknown if the occurrence of chlamydospores in the roots of otherwise symptom free plants is a general phenomenon. This indicates that symptomless infections may play a role in spreading *P. ramorum* in trade. The pathogen may therefore be moved through pre-symptomatic infections on aerial plant parts, or on roots. This would not be detected at the time of inspection. Also, recently, sporulation from naturally infected but asymptomatic foliage on plants (*Rhododendron* and *Quercus ilex*) has been reported (Denman *et al.*, 2008) which may compound the problem.

- Although treatments are not required as specific phytosanitary measures in relation to plants for planting and *P. ramorum*, symptoms may be masked by the use of fungicides that may suppress disease development without eradicating the pathogen.

- Detection will also be affected by the method of inspection, the experience of the inspector and the approach to sampling.

- Detection will also be affected by the method of testing for suspect symptoms. Diagnosis of the pathogen from suspect symptoms can be done using a variety of different diagnostic methods, none of which are totally reliable and false negatives can occur with any method (EPPO, 2006; Bulluck *et al.*, 2006; Hayden *et al.*, 2002, 2004, 2006; Hughes *et al.*, 2005 and 2006; Inghelbrecht *et al.*, 2008; Kox *et al.*, 2007; Lane *et al.*, 2006, 2007;Martin *et al.*, 2004; Ufer *et al.*, 2007; Wagner and Werres, 2003; Zeller *et al.* 2008). The principal

[13] Fruits are not excluded

[14] Third countries include Canada. No specific measures have been produced specifically in relation to imports from Canada.

laboratory-based methods include: immunological methods, principally ELISA using antibodies able to detect the genus *Phytophthora*, used as a pre-screen for suspect samples; DNA-based methods (traditional PCR or real-time PCR); and isolation and culturing. These methods vary in their sensitivity and specificity (Lane *et al.*, 2006, 2007). Host factors (plant species and plant part) and seasonality can also influence the reliability of the diagnostic assay. For example, the pathogen can be difficult to isolate from certain hosts, from some plant parts more than others, and from symptomatic tissue during certain times of year (e.g. during the summer in California) (Hayden *et al*, 2002, 2004, 2006). In the USA, APHIS have approved a variety of methods in a pyrimidal structure that enables APHIS-approved diagnostic laboratories to select the diagnostic routes most appropriate to their resources and expertise. APHIS strongly recommend using ELISA as a pre-screen to reduce the number of samples requiring confirmatory testing. The ELISA method is not as sensitive as DNA-based PCR tests, though sufficiently sensitive for use with symptomatic material. However, no data are available on how the ELISA method performs in comparative tests with PCR or isolation for a range of plant species, matrices (substrate, i.e. herbaceous tissue versus woody tissue or water and soil) or seasons. It is therefore possible that false negatives may result for certain plant samples, especially as negative samples are not tested further by other methods. However, samples need not be screened initially by ELISA but can be tested directly by either isolation or by PCR. Samples that are negative by isolation have to be tested by PCR thereby reducing the potential for false negatives from isolations that result from host or matrix type, or seasonal influences. Samples tested first by PCR do not require testing by secondary testing by isolation since PCR is considered the more reliable technique. Details of the APHIS diagnostic protocols can be found at:
http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/downloads/pdf_files/diagnosticssummary6-07.pdf

- The pathogen may also go undetected if present as inoculum contaminating growing media (Linderman and Davis, 2006) or as asymptomatic (but potentially sporulating) root infections on susceptible hosts (Lewis *et al.*, 2004; Riedel *et al.*, 2008; Shishkoff, 2007, 2008; Fitchner *et al.*, 2008a;Kessel *et al.*, 2007). EU legislation (Anon., 2000) has requirements for '*soil and growing media, attached to or associated with plants, consisting whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark or consisting in part of any solid inorganic substance, intended to maintain the vitality of the plants'* coming from non-European countries (other than certain non-European Mediterranean countries) as follows:

(a) *The growing medium, at the time of planting, was:*
- *Either free from soil, and organic matter, or*
  Found free from insects and harmful nematodes and subjected to appropriate examination or heat treatment or fumigation to ensure it was free from other harmful organisms, or
  Subjected to appropriate heat treatment or fumigation to ensure freedom from harmful organisms, and

(b) *Since planting:*
- *either appropriate measures have been taken to ensure the growing medium has been maintained free from harmful organisms, or*
- *within 2-weeks prior to despatch, the plants were shaken free from the medium leaving the minimum amount necessary to sustain vitality during transport, and, if replanted, the growing medium used for that purpose meets the requirements laid down in* (a).

It is therefore possible that growing media accompanying plants for planting from the USA, Canada, Norway, Switzerland or from its unknown area or areas of origin could unknowingly be contaminated with *P. ramorum*; such contamination would likely survive transport (see *Question 1.8*) and has the potential to infect above ground parts (Parke *et al.*, 2002a; Lewis and Parke, 2005; Parke and Lewis, 2007). It is possible that plants could have asymptomatic root infections that would go undetected though the significance of root infections in movement of the pathogen in trade is currently uncertain. Roots have been shown to be infected by *P. ramorum* in laboratory studies (Lewis and Parke, 2005; Parke and Lewis, 2007; Fitchner *et al.*, 2008a; Shishkoff, 2007, 2008; Riedel *et al.*, 2008; Kessel *et al.*, 2007). Mycelium colonises roots without typically causing any symptoms, though chlamydospores have been observed to form with the tissue in various studies (e.g. Kessel *et al.*, 2007); there is also evidence that colonised roots can sporulate (Shishkoff, 2008).

In conclusion, it is moderately likely that the pathogen may be present on plants for planting coming from areas considered ‘known to be free’ from *P. ramorum*. In the USA, infected material has been found several times on material shipped intra- or inter-state from Californian nurseries outside regulated Californian counties. It is also moderately likely that the pathogen could remain undetected on plants for planting that are inspected and tested prior to export to the EU from nurseries in areas where the pathogen occurs.

In relation to internal movements within the community plants (excluding seeds) of *Camellia*, *Viburnum* and *Rhododendron* (excluding *Rhododendron simsii*) are included in the plant passporting regime, and material from these species requires a plant passport to facilitate its movement at all stages down to the final retailer. The passport is needed both for movements within and between Member States. Factors relating to detection of the pathogen are the same as those detailed above. In addition, it should be noted that only the three most important genera (*Camellia*, *Rhododendron*, excluding *R. simsii*; and *Viburnum*) have plant passporting requirements; other known hosts are not specifically included in the plant passporting requirements for *P. ramorum* and this may facilitate internal movement of *P. ramorum* on these plants.

ii. <u>Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media:</u> The comments that apply to host plants immediately above also apply here regarding the likelihood of the pathogen being present but undetected as a contaminant of growing media attached to or associated with non-host plants for planting.

iii. <u>Soil and growing media as a commodity</u>: Soil and growing media are prohibited from third countries not belonging to continental Europe (other than certain Mediterranean countries) (Annex III of EC Plant Health Directive 2000/29/EC; Anon., 2000). Soil and growing media permitted entry from third countries where the pathogen occurs (i.e. Norway and Switzerland) would require a phytosanitary examination (Annex VB of 2000/29/EC; Anon., 2000); the pathogen, if present in the commodity, would be unlikely to be detected.

iv. <u>Soil as a contaminant</u> (e.g. on machinery, footwear, etc.): It is unlikely that soil, either contaminated or uncontaminated with *P. ramorum*, would be found associated with machinery imported from non-European third countries. It is more likely that footwear could introduce soil contaminated with *P. ramorum* since these articles would not be subjected to official inspection by NPPOs in third countries.

v. <u>Foliage and cut branches</u>: EC emergency measures for *P. ramorum* (2002/757/EC, as amended) (Anon., 2002, 2004, 2007) have no specific requirements in relation to foliage or cut branches belonging to hosts of *P. ramorum* since these commodities were considered indirect pathways for entry (see *Question 1.3*). If *P. ramorum* were present on such host material it would therefore not be constrained by any phytosanitary measures and would not be detected by NPPOs prior to export.

vi. Seed and fruits: EC emergency measures for *P. ramorum* (2002/757/EC, as amended) (Anon., 2002, 2004, 2007) have no specific requirements in relation to seeds or fruits of *P. ramorum* hosts since these are not known to be a pathway. If *P. ramorum* were present on, or contaminating, such host material it would therefore not be constrained by any phytosanitary measures and would be undetected prior to export.

vii. Susceptible/isolated bark: EC emergency measures for *P. ramorum* (2002/757/EC, as amended) (Anon., 2002, 2004, 2007) define susceptible bark in relation to certain known tree hosts in the USA, bark of which is prohibited. These are *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp. and *Taxus brevifolia*. *A. macrophyllum* and *A. californica* are foliar hosts in North America and *A. californica* is also a dieback host – i.e. not canker hosts. However, these are regulated based upon other species being canker hosts. *Toxicodendron diversilobum* is a canker host in the USA but is not regulated as it is not a cultivated host. There are other hosts with susceptible bark but these all occur in the EU.

Council Directive 2000/29/EC (Anon., 2000) Annex IIIA prohibits isolated bark of *Castanea* from all third countries and isolated bark of *Quercus* from North America; Annex IVAI has requirements related to isolated bark of conifers originating in non-European countries.

Thus *P. ramorum* is constrained from entering on bark from the USA on the majority of canker hosts. It is also constrained from entering on oak bark from Canada. However, *P. ramorum* is not present in forests and woods in Canada so this is not currently a pathway of entry. *Castanea sativa* (sweet chestnut) is a bark host as well as a foliar and dieback host in the UK, so this is a theoretical pathway of entry from non-EU countries. However, the prohibition on entry on bark of *Castanea* into the EU would constrain this theoretical pathway. The tree hosts that occur in the country or countries of origin are not known so it is possible, with the exception of EC requirements for bark of conifers, that the pathogen could enter undetected on bark of tree hosts from this source. *P. ramorum* does not occur in forests or woods in Norway or Switzerland currently so there is no risk of it remaining undetected on bark entering from this source.

viii. Susceptible wood: EC emergency measures for *P. ramorum* (2002/757/EC, as amended) (Anon., 2002, 2004, 2007) define susceptible wood in relation to certain known tree hosts in the USA. These are *Acer macrophyllum*, *Aesculus californica*, *Lithocarpus densiflorus*, *Quercus* spp. and *Taxus brevifolia. A. macrophyllum* and *A. californica* are foliar hosts in North America and *A. californica* is also a dieback host – i.e. not canker hosts. However, these are regulated based upon other species being canker hosts. *Toxicodendron diversilobum* is a canker host in the USA but is not regulated as it is not a cultivated host. Susceptible wood, may only be imported into the EU from the USA if it is accompanied by a phytosanitary certificate stating that

(a) *It originates in areas in which non-European isolates of* P. ramorum *is known not to occur;* or

(b) *The wood has been stripped of its bark and:*
(i) It has been squared so as to remove entirely its rounded surface or

(ii) That the water content does not exceed 20% expressed as a percentage of the dry matter; or
(iii) That the wood has been disinfected by an appropriate hot water treatment;
or

(c) *In the case of sawn wood with or without residual bark attached, it has undergone kiln-drying to below 20% moisture as a percentage of the dry matter*

This should ensure that the risk of *P. ramorum* on wood entering from the USA remaining undetected is nil with the exception of *Toxicodendron diversilobum* which is not listed in the legislation although it is a canker host but it would not be harvested for wood.

The only other route of entry on wood is from the country/countries of origin so it is possible, with the exception of EC requirements in Council Directive 2000/29/EC Annex IVAI (Anon., 2000) which has specific requirements for the entry of wood or wood products of certain genera imported from outside the community that the pathogen may enter via this route.

Table 13. (a) Estimated likelihood of *P. ramorum* surviving or remaining undetected during existing phytosanitary measures for each commodity type and potential origin (which assumes the worst-case scenario and that the plants come from an area where the pathogen is known to occur). The likelihood is ranked according to the following scheme: **VU**, Very unlikely; **U**, Unlikely; **ML**, Moderately likely; **L**, Likely; **VL**, Very Likely; (b) Levels of uncertainty.

(a) Estimated likelihood of *P. ramorum* surviving or remaining undetected during existing phytosanitary measures							
	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]	Range
i	Plants for planting (Hosts)	Direct	**ML**	**ML**	**ML**	**ML**	**ML**
ii	Plants for planting (Non-Hosts)	Direct	**ML**	**ML**	**ML**	**ML**	**ML**
iii	Soil as a commodity	Direct	**BANNED**	**BANNED**	**BANNED**	**L**	**L**
iv	Soil as a contaminant [c]	Direct	**U**	**U**	**U**	**U**	**U**
v	Foliage/cut branches of susceptible hosts	Indirect	**VL**	**VL**	**VL**	**VL**	**VL**
vi	Seeds and *fruits*	Direct/*Indirect*	**VL**	**VL**	**VL**	**VL**	**VL**
vii	Susceptible/isolated bark	Direct	**VU**	**VU**	**ML**	**VU**	**VU-ML**
viii	Susceptible wood [d]	Indirect	**VU**	**VU**	**ML**	**VU**	**VU-ML**

(b) Estimated uncertainty for assessed likelihood of *P. ramorum* surviving or remaining undetected during existing phytosanitary measures							
(b)	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]	Range
i	Plants for planting (Hosts)	Direct	LOW	LOW	LOW	LOW	LOW
ii	Plants for planting (Non-Hosts)	Direct	LOW	LOW	LOW	LOW	LOW
iii	Soil as a commodity [c]	Direct	LOW	LOW	LOW	LOW	LOW
iv	Soil as a contaminant	Direct	LOW	LOW	LOW	LOW	LOW
v	Foliage/cut branches	Indirect	LOW	LOW	LOW	LOW	LOW
vi	Seeds and *fruits*	Direct/*Indirect*	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
vii	Susceptible/isolated bark	Direct	LOW	LOW	MEDIUM	LOW	LOW
viii	Susceptible wood [d]	Indirect	LOW	LOW	MEDIUM	LOW	LOW

[a] Asia is speculated (Brasier *et al*., 2004; Goheen *et al*., 2005). [b] Norway & Switzerland

Go to 1.11

Probability of transfer to a suitable host or habitat

1.11. In the case of a commodity pathway, how widely is the commodity to be distributed throughout the PRA area?
Is the distribution of the commodity in the PRA area:

Very limited, limited, moderately widely, widely, **very widely**

Very widely

Level of uncertainty: Low

Plants for planting imported into the PRA area will be very widely distributed to retail outlets or production nurseries. Plants then sold to the final consumer could be further widely distributed outside of nurseries. Movement of *P. ramorum* in the nursery trade is considered the primary means for long-distance dispersal of the pathogen.

For commodities considered as less significant pathways (soil and growing media; soil as a contaminant; foliage and cut branches; seeds and fruits; isolated bark; wood), these would also potentially be widely distributed throughout the PRA area.

Go to 1.12

1.12. In the case of a commodity pathway, do consignments arrive at a suitable time of year for pest establishment?

Yes.

Consignments can arrive all year round. For plants for planting, nursery conditions are highly likely to support further disease development and spread within the nursery environment at all times of year, though the degree to which this occurs will vary between each country and on local environmental conditions. Even in nurseries, climates or times of the year that are milder and wetter will favour establishment more than climates or times of the year that are either hot and dry or very cold. However, the pathogen is likely to survive in infected plant tissue at all times of the year in European climates and therefore the timing of arrival is not considered significant in affecting the potential for establishment.

If yes **Go to 1.13**
If no Go to 1.15

1.13. How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Very unlikely, **unlikely, moderately likely**, likely, **very likely**

Very likely for transfer from infected plants for planting (and **moderately likely** for non-host plants with contaminated growing media attached) to other susceptible hosts in nurseries. *P. ramorum* has a very wide host range and conditions in nurseries are very likely to favour the dispersal of the pathogen and infection of new host plants within nurseries, e.g. close spacing of plants, irrigation practices, and pruning activities. This is evidenced by the continued findings of *P. ramorum* within the nursery trade in Europe and the increasing range of nursery species becoming infected year on year. The emergency legislation for *P. ramorum* (Anon., 2002, 2004, 2007) requires that EU Member States conduct official surveys for the pathogen. Since 2004 this has included both cultivated and uncultivated/unmanaged plants. As a result of these and other surveys *P. ramorum* has been found on nurseries in Belgium, Czech Republic (eradicated), Denmark, Estonia, Finland, France, Germany, Ireland, Italy (EPPO, 2004), Latvia, Lithuania, the

Netherlands, Poland, Portugal, Slovenia, Spain, Sweden and the UK. In European countries outside of the EU the pathogen has been found on nurseries in Norway and Switzerland (see RAPRA database): http://rapra.csl.gov.uk/objectives/wp1/naturalhostresults.cfm.

Natural host records and experimental data have shown that there is a large range of potential ornamental hosts in both northern Europe and in southern Europe.

P. ramorum is **very likely** to transfer to a suitable environment on plants for planting (or **moderately likely** for non-host plants with contaminated growing media attached) after nursery plants are sold to the consumer since domestic garden environments are likely to support the pathogen.

P. ramorum is **moderately likely** to transfer from plants for planting (or non-host plants with contaminated growing media attached) to the various semi-managed or natural environments that are of direct concern to the EU (e.g. woodland habitats, heathland/maquis habitats, public parks/ gardens). As a result of the official EU surveys and other surveys *P. ramorum* has been found outside of nurseries (either parks, gardens, public greens or 'forestry sites') in various European countries across a range of climatic regions. By the end of 2007, the findings were as follows: Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Slovenia, Spain, and the UK. In Poland, the pathogen has been found in two rivers, the Rawka (in 2006 and 2007) and the Ner (in 2007) (Orlikowski *et al*., 2007) with no reports on plants outside of nurseries. Outside of the EU the pathogen has also been found outside of nurseries in Norway (Herrero *et al*., 2008) and Switzerland: http://rapra.csl.gov.uk/objectives/wp1/naturalhostresults.cfm.

The routes by which transfer has occurred to the semi-managed or natural environment are not always known. However, in some cases infected nursery plants have clearly been planted out into gardens or other landscapes. In other cases, there is the potential that plants in non-nursery environments have become infected through dispersal of inoculum from nearby adjoining nurseries to plants in the environment, either naturally or through human activity (e.g. potentially on footwear or equipment).

The rate of transfer will depend on a variety of factors, including: the commodity; the proximity of nurseries to these habitats of concern; the presence and susceptibility/infectivity of host plants in the local environment (Condeso and Meentemeyer, 2008; Meentemeyer *et al.,* 2008, 2008a); degree of human activity in these habitats (Cushman *et al.*, 2008); climatic and seasonal factors favouring natural dispersal and spread, principally rainfall; the natural dispersal potential of the pathogen or whether infected plants are directly planted into the managed or natural environment. In California, approximately 80% of potentially susceptible habitats are still uninfected (Meentemeyer, 2008a), most likely reflecting the relatively low natural dispersal potential. Although sporangia are deciduous, they are not readily released in the absence of rain/water (Moralejo *et al*., 2006) and most dispersal in limited to short-distance splash dispersal (Davidson *et al.*, 2005; Chastagner *et al.*, 2008; Swieckie and Bernhardt, 2008; Turner, 2007), typically within 5–10m of the source. However, there is evidence that longer-distance dispersal may occur naturally with wind-driven rain and, potentially, mists: Turner (2007) showed that *P. ramorum* could be detected in rain traps about 50m from a known source of inoculum; Davidson *et al.* (2005) hypothesised that strong winds associated with rare storm events could disperse spores over long distances; and Hansen (2008) suggested that landscape-level aerial dispersal of sporangia could occur in Oregon over hundreds of metres or several kilometres via so-called 'turbulent' dispersal potentially associated with certain weather events. Other dispersal pathways also exist for *P. ramorum* to be transferred to the semi-managed or natural environment. Inoculum can be spread via contaminated footwear (Tjosvold *et al.*, 2002a; Cushman and Meentemeyer, 2005; Cushman *et al*., 2008; Webber and Rose, 2008), animals (J. Arnold and H. Cushman, 2004, *personal communication*) or vehicles/machinery. *P. ramorum* has also been found in water-courses several kilometres downstream of areas of known plant infections (Davidson *et al.*, 2005; Beales, 2007; Tjosvold *et al.*, 2002); the epidemiological significance of this as a pathway for introducing the pathogen to new areas is unknown.

Transfer from contaminated soil/growing media as a commodity is **moderately likely** but will only potentially occur if susceptible hosts are planted in the contaminated material.

Transfer from contaminated footwear of travellers from outside the EU is possible but **unlikely**, especially as the pathogen tends not to survive so well in soil/debris on footwear that is not kept moist (Cushman *et al*., 2008); to date, there has been no evidence that *P. ramorum* has been introduced, for example, from the California/Oregon in the USA (North American lineages) to Europe or elsewhere in the USA via contaminated footwear.

The pathogen is **unlikely** to be transferred to suitable hosts or potentially at-risk habitats via commodities that are processed or are not for planting, i.e. cut foliage/branches, fruits infected/contaminated timber. Transfer will only occur if infected material is composted and the pathogen survives the process with the compost being used to plant susceptible hosts.

Seeds are **unlikely** to transfer the pathogen as based on the current evidence there is no indication that *P. ramorum* is either seed-borne or seed-transmitted. Fruit will only potentially transfer the pathogen if it is composted, survives the process and if the compost is used for planting susceptible hosts.

There are no data to support spread via contaminated bark chippings imported from outside the EU. This may occur (**moderately likely**) if susceptible hosts are planted in the contaminated material.

The UK, and the Netherlands have, to date, been the only European countries experiencing significant spread to and within semi-natural or natural habitats. In the Netherlands, this has been almost exclusively 'public greens' where rhododendron has been the key foliar host on which *P. ramorum* is found. In the UK, semi-natural habitats affected (excluding historic gardens and parks) have primarily been areas of woodland containing *R. ponticum* in the SW of England (i.e. Cornwall). However, *P. ramorum* has also been transferred to, and caused significant disease in, naturalised rhododendron in woodlands in some parks and managed estate gardens in western areas of England (e.g. Cheshire, Cumbria, Gloucestershire, Staffordshire) and in Wales, Scotland and Northern Ireland. Inoculum produced by the foliar rhododendron host in the UK and the Netherlands has also been shown to transfer to tree hosts and give rise to bleeding cankers. In the UK to date, 28 trees have been found with bleeding bark cankers (mainly in the Fagaceae, principally *Fagus sylvaticus* and various *Quercus* species). At least 17 trees have been found with bleeding cankers in the Netherlands (*F. sylvaticus* and *Quercus rubra*). In both the UK and the Netherlands, all infected trees are in close proximity to infected rhododendron (Brasier and Jung, 2006; M. Steeghs, Plant Protection Service, Netherlands, *personal communication*). In terms of transfer to at-risk woodland habitats, the presence and abundance of a key foliar host/s, such as rhododendron (in northern Europe) or *Quercus ilex* or various other shrub hosts (e.g. *Arbutus unedo, Rhamnus alaternus, Viburnum tinus, Pistacea lentiscusa*) in the Mediterranean or southern Europe holm oak forests, is a critical factor.

Level of uncertainty: Low

Go to 1.14

1.14. In the case of a commodity pathway, how likely is the intended use of the commodity

(e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?

N/A, very unlikely, **unlikely, moderately likely,** likely, **very likely**

Very likely for plants for planting of host species. Infected plants can transfer the pathogen to other hosts in nurseries or in non-nursery environments where they are subsequently planted out.

Level of uncertainty: Low

Moderately likely for plants for planting of non-hosts with associated contaminated growing media. However, there is currently no firm evidence that such a pathway can result in subsequent host plant infection. Evidence for likelihood comes purely from observations and experimental work on survival in growing media: in the USA, infected California bay laurel leaves have been found on the surface of pots of non-host plants; sporangia/zoospores can survival significant periods of time in growing media (Linderman and Davis, 2006). Experimental work has shown that *P. ramorum* can colonise roots asymptomatically (Lewis *et al.*, 2004; Shishkoff, 2007; Riedel *et al*., 2008) and, that chlamydospores can form in root tissue (Riedel *et al*., 2008; Shishkoff, 2008). These studies showed that inoculum placed in growing media could result in infections on the aerial parts of plants, though a systemic spread internally from the roots into the stem has not been reported. In RAPRA studies, asymptomatic root colonisation has also been shown (Kessel *et al.*, 2007). In this study, zoospore inoculum placed either in the saucers of plant pots, or onto the surface of the compost away from the stem base, did not result in any above ground symptoms of rhododendron plants; however, zoospore inoculum placed around the stem base did result in some stem and leaf infections, presumably due to stem base infections via leaf scars or wounds.

Level of uncertainty: Medium

Moderately likely for soil/growing media as a commodity if this is planted with susceptible host plants.

Level of uncertainty: Low

Unlikely for soil as a contaminant. There is substantial direct and indirect evidence for the pathogen being able to spread via contaminated footwear locally. However, there is no direct evidence for *P. ramorum* being dispersed long distances on footwear etc. nor into the EU from areas outside the EU.

Level of uncertainty: Medium

Unlikely for foliage/cut branches and for seeds/fruits of susceptible plants. Again, not a proven pathway, only a potential pathway. However, if material is recycled via composting there is a possibility that the pathogen could survive and be transferred to susceptible plant material.

Level of uncertainty: Medium

Moderately likely for susceptible/isolated bark where this is used as a mulch around susceptible host plants.

Level of uncertainty: Medium

Unlikely for susceptible wood where this is used for furniture production, construction or other purposes which do not involve planting material.

Level of uncertainty: Medium

Go to 1.15

Consideration of further pathways

1.15. Do other pathways need to be considered?

No

If yes — Go back to 1.3

If no — Go to conclusion on probability of entry and then go to 1.16

Conclusion on the probability of entry

The overall probability of entry should be described and risks presented by different pathways should be identified.

The estimated probability of entry associated with each pathway is given in Table 14. Probability and risks are based on scenarios where there are **no phytosanitary controls** and on other factors, including: the volume of the trade; the likelihood of *P. ramorum* being associated with the commodity at origin and to survive existing pest management practices and during transport/storage; the likelihood of transfer to a suitable host/habitat and the end use of the commodity.

Plants for planting: These represent the greatest potential risk of entry from countries where *P. ramorum* exists. Host plants are clearly a high risk. Non-host plants for planting represent a lower risk, though there is the potential for inoculum to be present in any accompanying growing media or even roots.

Soil/growing media: Soil or growing media as a commodity in the absence of any controls is likely to be a moderate risk, depending on the country of origin, where the soil is sourced from, normal treatment practices and whether susceptible host plants are planted in the commodity as the end use. Soil as a contaminant (e.g. attached to footwear etc) is likely to be only a low or very low risk.

Cut foliage/branches of hosts, seeds and fruits of susceptible hosts represent a much lower risk. Cut foliage and branches of susceptible hosts are likely to be used for ornamental use. If the material is fresh there is the potential for the pathogen to be present. Should the material be composted there is a risk that *P. ramorum* could survive the composting process and be transferred to a susceptible host where the compost is used for planting such material. Seed infection has not been demonstrated for *P. ramorum*, though fruits of some hosts can become infected (Moralejo *et al*, 2007), and there is therefore the (low) risk that *P. ramorum* could be seed-borne, if not actually seed transmitted. Fruits themselves are also a low risk based on the likely end use of fruits from susceptible trees/shrubs although composted fruit, like other composted material poses a potential risk.

Bark and wood: Isolated bark of tree hosts in those countries with *P. ramorum* represent a moderate risk since *P. ramorum* can colonise phloem and cambial tissues and may produce spores in or on these tissues; the likely end use may also increase the relative risk. Wood itself represents a lower risk though *P. ramorum* has been shown to be able to colonise sapwood underlying bark lesions and xylem can support the production of chlamydospores; the likely end uses of wood and likely treatments (e.g. kiln drying) might mitigate against a high risk.

Table 14. (a) Estimated overall probability of entry for *P. ramorum* per pathway in the absence of phytosanitary controls. The probability and level of risk ranked according to the following scheme: **VL**, Very Low; **L**, Low; **M**, Medium; **H**, High; **VH**, Very High; (b) Levels of uncertainty.

(a) Overall probability of entry						
	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]
i	Plants for planting (Hosts)	Direct	**H**	**M**	**H**	**M**
ii	Plants for planting (Non-Hosts)	Direct	**L**	**L**	**L**	**L**
iii	Soil as a commodity	Direct	**M**	**M**	**M**	**M**
iv	Soil as a contaminant	Direct	**L**	**VL**	**L**	**VL**
v	Foliage/cut branches of susceptible hosts	Indirect	**VL**	**VL**	**VL**	**VL**
vi	Seeds and *fruits*	Direct/*Indirect*	**VL**	**VL**	**VL**	**VL**
vii	Susceptible/isolated bark	Direct	**M**	**VL**	**M**	**VL**
viii	Susceptible wood	Indirect	**L**	**VL**	**L**	**VL**

(b) Estimated uncertainty for estimated overall probability of entry						
	Commodity	Pathway type	USA	Canada	Unknown area/s of origin [a]	Europe (Non-EU) [b]
i	Plants for planting (Hosts)	Direct	LOW	LOW	MEDIUM	LOW
ii	Plants for planting (Non-Hosts)	Direct	LOW	LOW	LOW	LOW
iii	Soil as a commodity	Direct	LOW	LOW	LOW	LOW
iv	Soil as a contaminant	Direct	LOW	LOW	LOW	LOW
v	Foliage/cut branches of susceptible hosts	Indirect	LOW	LOW	LOW	LOW
vi	Seeds and *fruits*	Direct/*Indirect*	LOW	LOW	LOW	LOW
vii	Susceptible/isolated bark	Direct	LOW	LOW	LOW	LOW
viii	Susceptible wood	Indirect	LOW	LOW	LOW	LOW

[a] Asia is speculated (Brasier *et al*., 2004; Goheen *et al*., 2005). [b] Norway & Switzerland.

Probability of Establishment

<u>Availability of suitable hosts or suitable habitats, alternate hosts and vectors in the PRA area</u>

1.16. Estimate the number of host plant species or suitable habitats in the PRA area (see question 6).

Very few, Few, Moderate number, Many, **Very many**

<u>Very Many</u>

Level of uncertainty: <u>Low</u>

P. ramorum has a very large and expanding host range (Sansford and Woodhall, 2007) across a wide range of plant types (trees, shrubs and, to a lesser extent, herbaceous plants); see also RAPRA databases of hosts and potential hosts (http://rapra.csl.gov.uk/). To date *P. ramorum* has been found on numerous plant species (over 130) from over 75 plant genera and over 37 plant families. Such broad infection capacities might indicate that the pathogen has a multiple-host strategy that predates its recent introduction and the existence of common basal defence systems in woody plants that *P. ramorum* is adapted to overcome (Moralejo *et al*., 2006, 2006a); alternatively, it is possible that *P. ramorum* has simply been introduced into naive host populations that have do not have any evolved resistance mechanisms to it. Natural hosts are listed in Appendix II and experimental hosts in Appendix III.

There are many suitable habitats and the principal at-risk types include: woodland (managed, semi-natural, or natural habitats), heathland, maquis (macchia) shrubland, and managed gardens/parks/public greens, especially those that have a heritage or historic value (Wright, 2008; Sansford and Woodhall, 2007). Many of the potentially at-risk natural habitats are covered by the EC Habitats Directives (Anon., 1992).

Determination of what constitutes a suitable habitat can be based on the suitability of the climate for the pathogen, the types and susceptibility of the plant species present, the biology of the pathogen, and knowledge of how the pathogen behaves in habitats that are currently affected. In California, for example, epidemics occur in two coastal forest ecosystems: mixed evergreen woodlands (which tend to be drier habitats); and in (moister) redwood-tanoak woodlands (Rizzo *et al*., 2002). Both these woodland types have rich and diverse plant communities and the pathogen causes different types of disease on different species (Hansen *et al.*, 2002). It is the evergreen foliar hosts that support sporulation of the pathogen and which drive the epidemics. California bay laurel *(U. californica*) is the most significant of these (, Swiecki and Bernhardt 2003; Anacker *et al*., 2008); it supports only non-lethal foliar infections that generate abundant amounts of sporangia and chlamydospores compared to other foliar hosts; the foliage (leaves and shoots) of tanoak (*L. densiflorus*) also generates inoculum, but this species also develops bleeding bark cankers which result in mortality. In the case of *Quercus* species, these are dead-end hosts which only develop bleeding bark cankers; they do not generate inoculum and infection relies on the very close proximity (<2.5–10 m) of infected foliar hosts (Rizzo *et al.*, 2005; Davidson *et al.*, 2005; Swiecki and Bernhardt, 2008).

In Europe, evergreen foliar hosts are similarly important in generating inoculum which may then spread to susceptible trees and cause infection, resulting in bleeding bark cankers and mortality of some trees. In northern Europe, *Rhododendron* has so far been the most important host in this respect, though *Q. ilex* (holm oak) and *Castanea sativa* (sweet chestnut) have the potential to be a significant source of inoculum for trees, as could *V. myrtillus* (bilberry) (deciduous rather than evergreen) where it occurs in woodlands (Inman *et al.*, 2005). In southern Europe, epidemics in Mediterranean forests and in maquis (macchia) shrubland are most likely to also depend on the presence of susceptible (especially evergreen) foliar hosts, such as *Q. ilex*, *Rhamnus alaternus* and *Pistacia lentiscus,* that can support significant amounts of sporulation (Moralejo *et al*., 2007).

More details on the types of susceptible hosts and habitats that are available in the PRA area are given below.

<u>Trees and shrubs in the natural environment</u>

In the case of trees that could suffer mortality due to bark susceptibility, these are only at high risk if they are in close proximity to foliar hosts on which the pathogen can generate inoculum, or if they are foliar hosts themselves. To date in Europe, trees with bleeding bark cankers have only been found in the UK and the Netherlands and in all cases these were in close association with infected *Rhododendron*, especially *R. ponticum* (Brasier and Jung, 2006; Sansford and Woodhall, 2007; Brown *et al.*, 2006; Webber, 2008; M. Steeghs, Plant Protection Service, Netherlands, *personal communication*). However, in ecosystems in Europe where rhododendron is less abundant or absent, other plant species may take on the equivalent role and support abundant or epidemiological significant sporulation by *P. ramorum*. Some of the most important ecosystems at risk probably include the holm oak forest and laurel-type forests (laurisilva) of southern Europe and the Atlantic islands of Portugal and Spain. These are home to several other tree and understorey species such as *Q. ilex*, *Rhamnus alaternus*, *Viburnum tinus,* and *Arbutus unedo,* as well as species of the laurel family (*Laurus canariensis, Persea indica, Ocotea foetens, Apollonias barbujana*), all of which have the potential to support moderate to high levels of sporulation (Morelejo *et al.*, 2006, 2007, 2007a). Of these, *Q .ilex* is of most potential significance (Morelejo *et al.*, 2006b; Denman *et al.*, 2006). Areas of broad-leaf woodland in Europe have been mapped (Päivinen *et al.*, 2001; Schuck *et al.*, 2002) and are shown in Figure 2. Broadleaved trees are considered most at risk from *P. ramorum* depending on the plant species composition of the woodlands in which they occur (i.e. susceptible trees associated susceptible foliar hosts with significant sporulation potential) and conducive climatic factors. It is notable that many of the areas with broadleaved woodland also have a potentially suitable climate (See *Section 1.19* and Figures 5–11). Broadleaved trees will also occur in mixed woodlands and in other wooded land (OWL). The European distribution of mixed forest and OWL can be obtained from Päivinen *et al.* (2001) and Schuck *et al.* (2002); it is notable that the OWL classification occurs predominantly in the Mediterranean area.

Northern/Central Europe:

Log tests investigating bark susceptibility using wound-inoculation methods have predicted the northern European tree species at highest risk from *P. ramorum*. Those at highest risk include many trees in the family Fagaceae, of which the following are considered most economically and/or environmentally significant: European beech (*Fagus sylvatica*), various oak species (*Quercus cerris, Q. ilex, Q. petraea, Q. rubra*) and sweet chestnut (*Castanea sativa*). These are all natural hosts with all except *Q. ilex* displaying bark cankers. Other Fagaceae that have been found to be natural hosts (e.g. *Q. falcata*, *Nothofagus obliqua*) (with bark cankers) are minor ornamental or specimen species. Some non-Fagaceae are also predicted to be at higher to moderate risk, e.g. horse chestnut (*Aesculus hippocastanum, Acer pseudoplatanus*) (bark cankers) and several conifer species (*Abies procera, Abies grandis, Pseudotsuga menziesii, Tsuga heterophylla*), though natural bark infections have not been reported for these conifers. Although laboratory tests on bark susceptibility have been largely supported by natural records, some care should be taken when interpreting laboratory tests involving wound inoculations since field susceptibility can be affected by bark thickness (thinner-barked species are generally more easily infected in the absence of wounding), resin production and provenance (Webber, 2004). Log tests on various oak species using trees of different provenance, have shown that susceptibility can vary significantly between individuals (Brasier and Jung, 2006). Results from *P. ramorum* log tests with unwounded bark were reported in Turner *et al.* (2005) and Webber (2004): infection occurred without wounding on *F. sylvatica, Q. robur, Q. rubra, C. sativa, P. sitchensis* (sitka spruce) and *P. menziesii* (Douglas fir). Brown *et al.* (2005; 2006) also concluded that intact bark of beech could be infected based on field observation and experimentation.

Results from testing saplings of various northern European tree species has also been reported (Turner *et al*., 2005; Moralejo *et al*., 2008). In general, results supported the host susceptibilities found in log tests, with only a few exceptions. However, saplings were only infected by *P. ramorum* when wounded; susceptibility varied with season. Beech and sweet chestnut saplings were consistently highly susceptible to *P. ramorum* in wound-inoculation tests. Bark of saplings of many tree hosts appears to be less susceptible (or resistant) to direct bark infection than bark of mature trees.

Southern Europe:
For southern European tree species, those at higher to moderate risk, based on wound inoculation of logs, include the following: *Arbutus unedo*, *Pinus halepensis*, *Pinus pinea*, *Quercus canariensis, Q, faginea, Q. humilis* (=*Q. pubescens), Q. ilex*, *Q. pyrenaica*, and potentially *Q. suber* and *Eucalyptus* spp. (Moralejo *et al*., 2006, 2008, 2008a). In log inoculations, the inner bark of some Iberian oaks such as *Q. canariensis* and *Q. pyrenaica* developed necrotic lesions as large as those reported for tan oak and European beach (Moralejo *et al*; 2008, 2008a). As reported in other log inoculations, there was evidence of genetic variation in susceptibility within host populations, and of significant seasonal variation in host susceptibility in Iberian *Quercus* species. Wound inoculations with mycelial plugs on detached twigs (in winter) gave the following results 10 days after inoculation: large lesions (>30 mm) on *C. sativa*, *V. tinus* and *Ilex aquifolium*; moderately large lesions on *A. unedo*, *P. lentiscus*, *Q. pyrenaica* and *Q. pubescens*; and small lesions on *Q. canariensis* and *Q. faginea*. Susceptibility seemed to vary with season as well. All the twigs of Iberian pine species inoculated formed small lesions. Among the susceptible oaks, *Q. ilex*, *Q. suber, Q. canariensis* and *Q. pubescens*, and to a lesser extent *Q. faginea* and *Q. pyrenaica*, thrive in areas of Spain, Portugal, and southeast France where climatic conditions might be conducive to disease (Kluza *et al*., 2007; see *Question 1.19*). Cork oak (*Q. suber*) and *Q. canariensis*, in particular, commonly live on siliceous substrates in subhumid to humid habitats near coastal areas, where environmental conditions are similar to those encountered in the geographical range of *Q. agrifolia* in California. At the local scale, forest ecosystems in southern Spain are at high risk (e.g. Los Alcornocales Natural Park), where relict populations of *Q. canariensis* surrounded by cork oak woodlands exist alongside *Rhododendron ponticum*, *Viburnum tinus* and other potentially susceptible host species in the understorey.

Evergreen oak forests and woodlands are among the most widespread forest ecosystems in the Mediterranean basin and are potentially most at risk. In particular, the Mediterranean holm oak woodlands/forests occupy an equivalent habitat to California mixed evergreen oak woodlands (Moralejo and Descals, 2003;) and have a similar canopy structure and understory shrubs belonging to the laurophyllous and sclerophyllous type of vegetation (Moralejo and Descals, 2003; Moralejo *et al.*, 2006b; Moralejo *et al.*, 2007; Dallman, 1998). In California, the key sporulating foliar hosts are California bay laurel (*U. californica* – family Lauraceae) and tanoak (*L. densiflorus* – family Fagaceae) (Davidson *et al*. 2005; Maloney *et al*., 2002; Anacker *et al*., 2008). In comparison to the Mediterranean holm oak woodlands, *Laurus nobilus* (family Lauraceae) is unlikely to be a significant host epidemiologically since its foliage is resistant; instead, *Q. Ilex* (family Fagaceae) is likely to be the most epidemiologically significant host since it has susceptible foliage that supports sporulation, and also high experimental bark susceptibility, although no natural bark infections have been found to date.

Transitions from Mediterranean to sub-Mediterranean and temperate forest domains are not linear, exhibiting complex patterns associated with topography, substrate and microclimate. They often show mixed overlaps and species substitutions, especially in the north and northeast of Iberia (Ruiz de la Torre, 2002), south of France, Italy and from the Dalmatian coast to Greece. Due to the ecological amplitude exhibited by *Q. ilex*, in its northern range in temperate and sub-Mediterranean zones it frequently forms mosaics of mixed forests with beech, chestnut, *Q. pubescens* and *Q. pyrenaica* (Ruiz de la Torre, 2002). In these mixed hardwood forests, infected *Q. ilex* foliage could act as a source of inoculum, leading to trunk infections on chestnut and beech for example, chestnut being moderately and beech highly susceptible to *P. ramorum* (Brasier and Jung, 2006; Moralejo *et al.*, 2008, 2008a). As in the area affected by SOD in California, a diversity of forest and vegetational types occurs in Catalonia (NE Spain) forming intricate mosaics along short transects (30 kms) from the coast to the nearby mountain ranges. For example, in the Montseny Park near the coast, mixed populations can be found of *Q. ilex*, *Q. suber*, *Q. canariensis*, *Q. pubescens*, *Q. faginea*, *Castanea sativa* and *Fagus sylvatica*. In coastal areas in NE Spain and the Balearic Islands and south-eastern France, holm oak also often forms part of a succession of mixed evergreen forests with *Pinus halepensis* and/or *P. pinea* under xeric to mesic conditions. However, although the inner bark of both pine species is highly susceptible, it is less likely that severe mortality could occur because these species only exhibited long, thin lesions that were unlikely to girdle trees (in the absence of multiple infections) and because the climate might be less conducive to disease establishment.

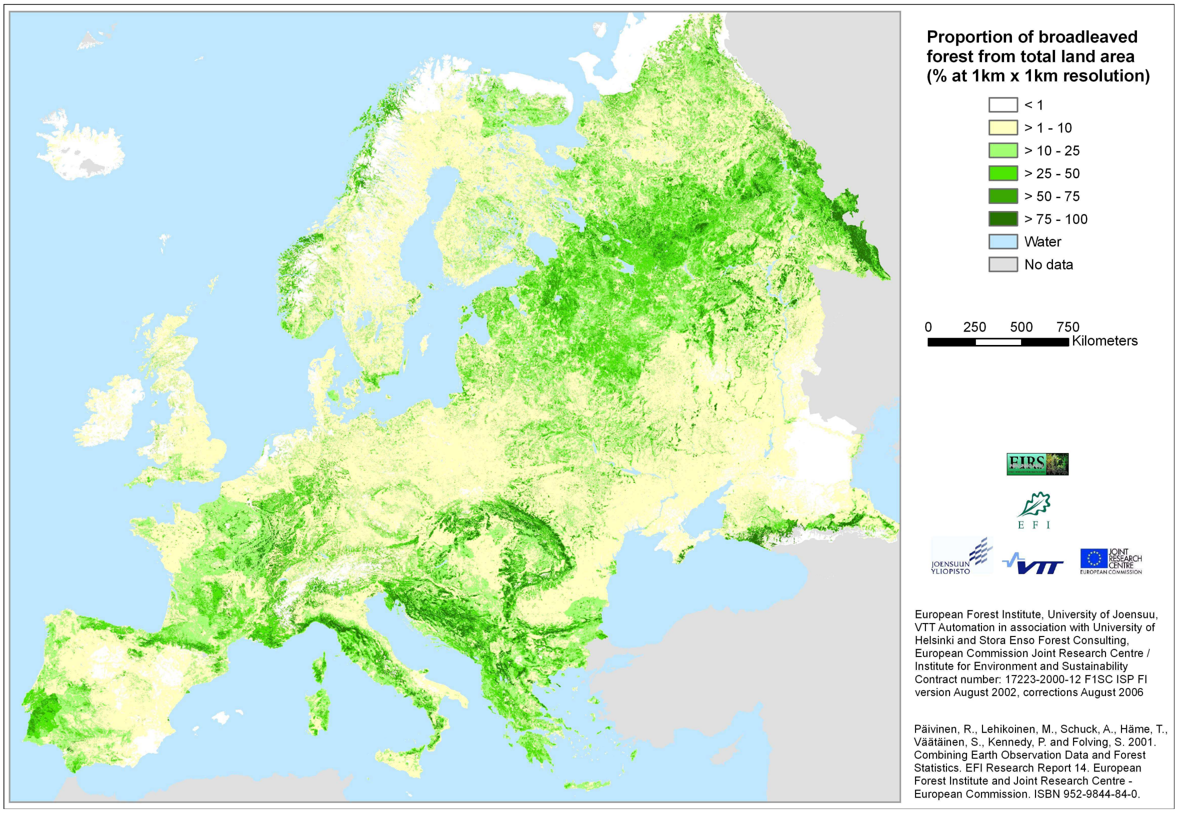
Three pine species forming extensive forests and plantations in Spain and Portugal, *P. pinaster*, *P. nigra* and *P. sylvestris*, were resistant or only slightly susceptible to *P. ramorum* in log inoculation experiments (Moralejo *et al.;* 2008a). Similar results were obtained by Brasier *et al.* (2002) for *P. nigra* and *P. sylvestris* in the UK. Therefore, it is unlikely that *P. ramorum* will threaten these forest types and plantations. Of major concern is the possibility of *Eucalyptus* plantations becoming infected, as they are usually in areas where very favourable conditions for *P. ramorum* establishment are found, e.g. in the northwest and north of Spain, as well as in Portugal. However, caution should be taken when extrapolating species susceptibility to the whole genus. Inoculation tests were made only with *E. dalrympleana*, which is not as widely planted as *E. globulus* or *E. camaldulensis*.

Oak-laurel forests thrive along the fog belt of the Pacific coast of the USA, characterised by a Mediterranean climate with narrow seasonal and moderate daily temperature fluctuations and a long period of drought in summer. This type of climate has affinities with those where the Macaronesian laurel forest (MLF) has survived in the Canary Islands, Madeira, Azores and Cape Verde, with no other counterpart found in the Northern Hemisphere. The MLF is composed of members of the Tertiary relict flora that once extended throughout the Northern Hemisphere. Thirteen of the 15 species of the Macaronesian laurel forest were to some degree susceptible to *P. ramorum*, of which seven species had infection efficiencies near 100% (i.e. all leaf replicates successfully infected). Additionally, in other experiments, the leaves of *Erica arborea*, an important component of MLF, were consistently susceptible to *P. ramorum* when dipped in a zoospore solution. Furthermore, other plant species commonly associated with the laurel forest, such as *Prunus lusitanica*, *Castanea sativa*, *Pittosporum undulatum*, *Erica scoparia* and *Rhamnus glandulosa* have been reported as hosts (Denman *et al.* 2005; Hüberli *et al.* 2006) or belong to genera including many susceptible species. The leaves of most of the species tested, even those being asymptomatic, sustained relatively low levels of sporangial formation, which has been suggested to be related to trade-offs between transmission and virulence (Moralejo *et al.*, 2006, 2006a).

In south-eastern Europe, some mixed evergreen forests of oak and chestnut (which may have rhododendron understorey), and forests of oriental beech (*Fagus orientalis*) with understoreys of

Prunus laurocerrasus, *Rhododendron ponticum* and *Vaccinium arctostapylos* may also be at risk in areas south and east of the black sea and in SE Bulgaria (Cronk and Fuller, 1995).

Figure 2. Calibrated broadleaved forest map as a percentage of land area for Europe, produced by combining geographically referenced Earth observation data and forest statistics. Source: Päivinen *et al.* (2001 and Schuck *et al.* (2002).



Acknowledgement and disclaimer: This information is based on outputs from the project "Forest tree groupings database of the EU-15 and pan-European area derived from NOAA-AVHRR data", which was awarded by the European Commission, Joint Research Centre (Institute for Environment and Sustainability), to a consortium consisting of EFI, VTT Information Technology and the University of Joensuu under the contract number: 17223-2000-12 F1SCISPFI. The information contained herein has been obtained from or is based upon sources believed by the authors to be reliable but is not guaranteed as to accuracy or completeness. The information is supplied without obligation and on the understanding that any person who acts upon it or otherwise changes his/her position in reliance thereon does so entirely at his/her own risk. The European Commission nor the project consortium are responsible for its use in this publication and the content is at the sole responsibility of the end-user.

Heathland

Heathlands are a feature of north-west European landscapes (Figure 3). They are characterised by dwarf shrubs of the botanical family Ericaceae. Lowland heath occurs at altitudes below 300m. http://www.english-nature.org.uk/heathlands/default.htm

Some heathland species are susceptible to infection by *P. ramorum.*

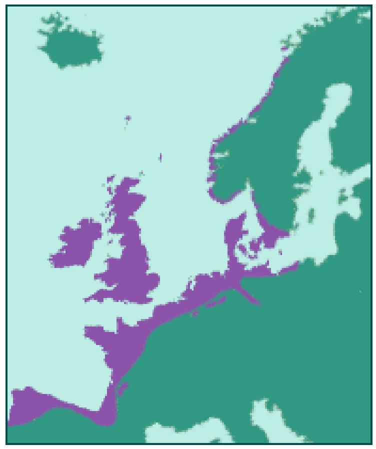


Figure 3. The area of European heathland around 1900.
http://www.english-nature.org.uk/heathlands/default.htm

Vaccinium myrtillus (bilberry) has been shown to be highly susceptible in tests using unwounded foliage and zoospore inoculation methods, and is also capable of supporting high levels of sporulation on both leaves and green stems (Inman *et al.*, 2005) similar to those observed on Californian bay laurel (*U. californica*). Bilberry therefore has the potential to sustain and perpetuate the pathogen in heathland habitats, causing significant impact (Inman *et al.*, 2005; de Gruyter *et al.*, 2002; Kaminski and Wagner, 2008). *P. ramorum* has now been found on *V. vitis-idaea* (cowberry) in the UK on nursery plants (D. Slawson, Defra PHSI, UK, *personal communication*, October 2008). Other heathland plants might also support sporulation and disease cycling, e.g. *Calluna* species (Inman *et al.*, 2005; Kaminski and Wagner, 2008; Werres *et al.*, 2007), and be affected by *P. ramorum.*

Maquis:

Maquis is defined as a scrubland vegetation of the Mediterranean region, composed primarily of leathery, broad-leaved evergreen shrubs or small trees. Many of the shrubs are aromatic, such as mints, laurels, and myrtles. Where soils are rocky a poorer version of the maquis named garriga occurs. This kind of vegetation is englobed in the EU Habitat Directive as Sclerophyllous scrub (matorral) Species at risk from infection by *P. ramorum* in this habitat include: *Pistacia lentiscus*, *Rhamus alaternus*, *Viburnum tinus*, *Arbutus unedo*, *Ceratonia siliqua*, *Quercus ilex*, *Lonicera implexa*, *Smilax aspera*, *Cistus salvifolius*, *Cistus albidus*, etc. Fruits as well as foliage of many species of the maquis vegetation are susceptible to *P. ramorum* infection (Moralejo *et a*l. 2006; Moralejo *et al.*, 2008)

Vettraino *et al.* (2007) reported that Mediterranean macchia (maquis) species were less susceptible than cold- and warm-temperate plant species, but that they supported a relatively higher rate of sporulation of *P. ramorum*. The production of sporangia occurred even on asymptomatic leaves, something also observed by others (Moralejo *et al*., 2007; Denman *et al.*, 2008).

Maquis vegetation usually develops where total annual rainfall is below 600 mm in zones exposed to high levels of solar radiation and high temperatures in summer. These climatic conditions might be relevant in containing the potential of establishment and spread of *P. ramorum* in this type of vegetation.

Nurseries and managed parks and gardens

There is very large range of known hosts (Appendix II) and experimentally susceptible hosts (Appendix III) that are found in nurseries and in managed gardens of public or historic importance (Sansford and Woodhall, 2007; RAPRA database: http://rapra.csl.gov.uk/) and parks and public greens. Serious impacts are already being experienced in historic and public gardens in the UK due to dieback, defoliation and in some cases death of ornamental broad leaved shrubs and trees (Wright, 2008).

Foliage of various conifer species can also be affected. In the Pacific Northwest of the USA, Douglas fir (*Pseudotsuga menziesii*), coastal redwood (*Sequoia sempervirens*) and grand fir (*Abies grandis*), in particular, have been shown to develop needle necrosis and shoot dieback (Davidson *et al.*, 2002a; Maloney *et al.*, 2002; Chastagner *et al.*, 2005; Chastagner *et al.*, 2008) in either natural forests or in nursery plantations. Other foliar conifer hosts in the USA are *Abies concolor, Abies magnifica, Taxus brevifolia* (also a canker host) and *Torreya californica* (see Appendix II). In the UK, *Sequoia sempervirens* has been found with serious dieback and defoliation caused by *P. ramorum* in a public garden in south Wales (D. Slawson, Defra PHSI, UK, *personal communication*). In Canada, *Taxus* sp. as been found to be a foliar nursery host. In Europe, *Taxus* sp. has been found as a foliar host on a nursery in France, *Taxus baccata* on a UK nursery (foliar and dieback host) and *Taxus* x *media* on a nursery in the Netherlands (canker host). Nurseries supplying commercial conifers are potentially at-risk since *P. ramorum* can cause dieback and potentially death of seedlings and young plants, especially Douglas fir (*P. menziesii*) and noble fir (*Abies procera*), and to a lesser degree hemlock (*Tsuga heterophylla*) (Denman *et al.*, 2005). However, only small shoots and branches are typically affected. Disease spread and development may be limited in the absence of other foliar hosts due to the more limited potential for such hosts to produce sporangial inoculum and lower susceptibility to infection compared with broadleaf hosts (Garbelotto 2004, Garbelotto and Rizzo 2005; Chastagner *et al.*, 2005; Maloney *et al.*, 2007; Denman *et al.*, 2005; Hansen *et al.*, 2005; Callan *et al.*, 2008).

1.17. How widespread are the host plants or suitable habitats in the PRA area? (specify)

Very limited, limited, moderately widely, widely, **very widely**

Very widely

Level of uncertainty: Low

The distribution of susceptible foliar hosts in the nursery environment is very wide, as are hosts in the semi-natural environment and in natural habitats. In northern Europe, *Rhododendron ponticum* is a key sporulating host in the semi-natural and natural environment but there are other species of *Rhododendron* (Werres, 2003) which may play a role. However, the susceptibility and sporulation potential of these other *Rhododendron* species is not known and they tend to have limited or niche-climate distributions (e.g. *R. ferrugineum* in central Europe, above the tree line; *R. lapponicum* in northern Europe (Scandinavia) in woodlands; *R. luteum*, locally naturalised in parts of western and northern Europe; *R. hirsutum* in alpine regions;

R. tomentosum in moorland regions); as such, it is unlikely that these other *Rhododendron* species would be epidemiologically significant at a Europe-wide scale. According to Cross (1975) *R. ponticum* occurs naturally in small areas of south-west Spain and central and southern Portugal *(R. ponticum* subsp. *baeticum*) and in Bulgaria, Turkey, the Caucasus and Lebanon (*R. ponticum* subsp. *ponticum*). In southern Spain and in Portugal, *R. ponticum* subsp. *baeticum* typically occurs in riparian forests on acid soils (pH 4.0–6.4); seasonal water stress of a Mediterranean climate appears to be the main factor restricting its distribution beyond these areas due to the lack of seedling establishment (Mejías *et al*, 2007). In the Euxinian regions around the black sea, *R. ponticum* subsp. *ponticum* is usually associated with *Fagus* forests (Stevens, 1978; Mejías *et al*, 2007). *R. ponticum* has been introduced into north-west Europe where it is naturalised in at least Belgium, France, Ireland, Netherlands, northern Germany and the UK. It is an aggressive invader in the British Isles and areas in temperate Atlantic Western Europe (Mejías *et al*, 2002). It is intolerant of drought, prefers deep podsolised sands and well drained humus soils with a pH in the range of 3.3–6.4, though growth on soils >pH 5.0 is poor. In the UK, naturalised *R. ponticum* is considered to be primarily of Iberian origin (Milne *et al*., 2000); there is evidence for hybridisation/introgression with *R. catawbiense* (a species originating in the Appalachian Mountains of the eastern USA) in about 10% of *R. ponticum* accessions, especially from colder parts of the UK where it could be conferring increased cold tolerance (Milne *et al*., 2000). Although *R. ponticum* is unlikely to significantly extend its European distribution, such introgressions could contribute to a more northerly spread.

Q. ilex (holm oak) is another key sporulating host that could especially support sporulation in Mediterranean countries in place of rhododendron. Mejías *et al*., (2007) report that *R. ponticum* subsp. *baeticum* is distributed in southern Spain in riparian forests and that in the western Mediterranean it is restricted to southern Spain and south-western Portugal. The distribution of *Q. ilex* in the EU is primarily in evergreen woodlands in the western Mediterranean where it is found in at least Spain, France, Italy, Portugal, Slovenia, Greece and Albania. In the UK it is planted in parks, large gardens, churchyards and cemeteries, and has become well-established in copses and woodlands, especially near coasts. It prefers light, warm soils. It can colonise natural habitats aggressively and replace native vegetation. Denman *et al*. (2006) reports that sporulation on *Q. ilex* leaves is similar in quantity to that produced on rhododendron leaves *in vitro*.

Various laurophyllous and sclerophyllous understorey shrubs could also play a role as sporulating foliar hosts in Mediterranean countries. Of these, *Rhamnus alaternus* (an evergreen shrub usually associated with oak woodlands) could contribute large amounts of sporangial inoculum, but only locally due to its relative low density; *Pistacea lentiscus* (an evergreen shrub associated with maquis vegetation and holm oak woodlands) could support similar levels of sporulation as holm oak; *Viburnum tinus* (widely distributed in the northwest of the Mediterranean basin) could contribute only moderately due to its more moderate sporulation potential; *Arbutus unedo* (also widely distributed in the Mediterranean) may be less important due to its low sporulation potential (Moralejo *et al.*, 2006b; Moralejo *et al.*, 2007). However, in laboratory inoculations the average number of sporangia formed by *P. ramorum* on *A. unedo* lesions is similar to that formed on *R. ponticum.* In another study (Vettraino *et al*., 2007), *A. unedo* had one of the highest sporulation potentials.

For Italy, risk maps have been produced based on climatic and host factors (susceptibility and sporulation potential). The plant species tested included 70 species from 24 families, representing three phytoclimatic zones (Castanetum, Fagacetum, Lauretum); this represented 81% of the Italian woodland species (Vettraino *et al*., 2007). In sporulation-potential tests, sporangia were produced on all 51 species tested, with over half producing >500 sporangia/cm^{-2}; some of the highest sporulators included *A. unedo* and *V. tinus*, with *Q. ilex* and *Rhododendron* producing moderate numbers of sporangia. The ability to produce sporangia was inversely proportional to the disease index, i.e. plant species in the Lauretum phyoclimatic zone had a lower disease index but produced the most sporangia, while those in the Fagetum phytoclimatic zones had the highest disease index but produced the lowest number of sporangia. These risk maps predict that 40% of Italian woodland would be suitable for *P. ramorum* spread; three areas in Sardinia (representing 33,000 ha) had the highest risk level.

P. ramorum can cause bleeding bark cankers on a range of tree species (see Appendix II for natural hosts and Appendix III for experimental hosts). These are likely to be widespread in forests, woodlands, parks and gardens in the PRA area.

Heathlands occur in several parts of the world under similar soil and climatic characteristics, but they were first described in northwest Europe. Heathlands occur from the north coast of Spain northwards through Brittany and Normandy in France, continuing into Belgium, the Netherlands, the north German plain up to Jutland in Denmark, the British Isles and the southern provinces of Norway and Sweden (Figure 3). See http://www.english-nature.org.uk/heathlands/default.htm

Heathland is a habitat of European importance and seven types of heathland are included on Annex 1 of the EC Habitats Directive (Anon., 1992), four of which occur in England.
http://www.naturalengland.org.uk/sone/docs/HabitatHeathlandRD.pdf

It is estimated that Britain and Ireland together support roughly 20% of the world's lowland heath resource. The UK supports 2–3 million hectares of upland heath which represents approximately 75% of the total (global) resource. (J. Sherry, Countryside Commission for Wales, *personal communication*, 2008).

Bilberry (*Vaccinium myrtillus*– reported as a natural host) and heather (*Calluna vulgaris* – reported as a natural host) are susceptible to infection by *P. ramorum* and also have the potential to support a high amount of sporulation (Inman *et al.*, 2005; de Gruyter *et al.*, 2002; Kaminski and Wagner, 2008; Moralejo *et al.*, 2007). These species are common in heathland in north-west Europe, especially in the UK. In France, bilberry is abundant in northern France, especially in mountainous regions >400 m and north-western France (Normandy, Britain); *Calluna vulgaris* is frequent except in south-eastern France.

Maquis habitats occur in the EU around the northern area of the Mediterranean basin from southern of Portugal to Greece including all the Mediterranean islands belonging to the EU territory. Maquis is a shrubland biome, typically consisting of densely growing evergreen shrubs. It is similar to the English heath in many aspects, but with taller shrubs, typically 2-4 m high as opposed to 0.2-1 m for heath. A similar habitat type in North America is known as chaparral, though the shrubs involved are different. Although maquis is by definition natural, its appearance in many places is due to destruction of forest cover, mainly by frequent burning that prevents young trees from maturing. It tends otherwise to grow in arid, rocky areas where only drought-resistant plants are likely to prosper. Many species forming part of the maquis vegetation are also components of the understorey of holm oak forests. The leaves of *Arbutus unedo*, *Viburnum tinus*, *Pistacia lentiscus*, *Rhamnus alaternus*, *Ceratonia siliqua*, *Lonicera implexa*, etc., are moderately to highly susceptible to *P. ramorum* (Moralejo *et al.* 2006b); many maquis shrubs have also been shown to have significant sporulation potential (Vettraino *et al.*, 2007). Fruits of nine species of the maquis vegetation were susceptible to *P. ramorum* and sustained moderate to high numbers of sporangia (Moralejo *et al*., 2006; Moralejo *et al.*, 2007).

Ornamental plants occur on nurseries, in managed gardens and in landscape plantings throughout the PRA area. Susceptible natural hosts and experimental hosts are listed in Appendix II and III respectively.

1.18. If an alternate host or another species is needed to complete the life cycle or for a critical stage of the life cycle such as transmission (e.g. vectors), growth (e.g. root symbionts), reproduction (e.g. pollinators) or spread (e.g. seed dispersers), how likely is the pest to come in contact with such species?

Note: *Is the species present, widespread and abundant could it be introduced or could another species be found?*

N/A, very unlikely, unlikely, moderately likely, likely, very likely

N/A

No vector or alternate host is required in the strictest sense. However, in the case of trees, species are only at significant risk if they are either foliar as well as bark hosts (i.e. they can potentially produce inoculum on their own foliage for subsequent bark infections) or, if they are bark hosts without susceptible foliage, e.g. *Fagus sylvatica*), they are in close proximity to a foliar host that can support sufficient sporulation of the pathogen. To date all infected trees (UK and the Netherlands) have been found in close association with infected *R. ponticum.* Heathland plants are mostly foliar/dieback hosts that are likely to be able to sustain the pathogen and its full disease cycle in the absence of other hosts (Inman *et* al., 2005; Moralejo *et al.,* 2007; Kaminski and Wagner, 2008).

Evergreen shrubs (e.g. various species of *Arbutus, Camellia, Kalmia, Pieris, Rhamnus, Rhododendron, Viburnum*, etc) and some ornamental trees in parks/gardens that are foliar hosts are also not so dependant on the presence of other foliar hosts to sustain the disease cycle. Deciduous foliar hosts may also sustain the pathogen if they can be readily reinfected from diseased debris, or the pathogen survives on the outer bud scales, in buds, and in leaf scars (e.g. *Magnolia*; Denman, 2007; Denman *et al.*, 2007); otherwise they require the presence of other infected foliar hosts that can more readily sustain the pathogen for re-infection.

<u>Suitability of the environment</u>

Specify the area where host plants (for pests directly affecting plants) or suitable habitats (for non parasitic plants) are present (cf. QQ 1.16-1.18). This is the area for which the environment is to be assessed in this section. If this area is much smaller than the PRA area, this fact will be used in defining the endangered area.

1.19. How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?

Note: the climatic conditions in the PRA area to be considered may include those in protected cultivation. When comparing climates in a pest's current distribution with those in the PRA area, it is important to ensure that, as far as possible, the variables selected are relevant to the pest's ability to exploit conditions when these are favourable for growth and reproduction and to survive unfavourable periods, such as those of extreme cold, heat, wetness or drought.

not similar, slightly similar, **moderately similar**, largely similar, completely similar,

<u>Moderately similar</u>

Level of uncertainty: <u>Low</u>

The area of origin of *P. ramorum* is unknown but it is speculated to be Asia, especially Taiwan and the eastern Himalayas, or the Yunnan province of China (Brasier *et al*., 2004; Goheen *et al*., 2005, 2006; Vannini *et al*., 2007). The climate in parts of northern Yunnan correlates well with those predicted to be favourable for *P. ramorum* and native forest ecosystems have many plant genera (oaks, tanoaks, rhododendron) that could be *P. ramorum* hosts (Goheen *et al.*, 2006). However, field trips to Yunnan, as well as to Western Nepal (Vannini *et al.*, 2007), where temperate and sub-tropical forests were sampled, have not yet revealed *P. ramorum* to be present there. Given the uncertainty over the precise origins of *P. ramorum* (both North American and European lineages), further climatic comparisons with parts of Asia are not made here.

The known distribution outside Europe is limited to North America, where *P. ramorum* is considered an exotic species introduced from its unknown area/s of origin (Mascheretti *et al.*, 2008; Brasier *et al.*, 2004), specifically woodlands in the Pacific Northwest coast of the USA (California and southwest Oregon). These areas have a Mediterranean climate and are therefore **largely similar** in climate to those European countries adjoining the Mediterranean. Other parts of Europe have less similar climates ranging from **not similar** to **slightly similar**. Climate matching between the woodland outbreak near Brookings in SW Oregon (Figure 5) and with affected parts of California provide a direct comparison between the various parts of Europe. In climate matches with Oregon, which has a more similar climate to northern Europe than does California, the areas of north-west Spain, northern Portugal, south-west England, and parts of Italy and western Albania have the most similar climates (70–90% matched) to SW Oregon; larger parts of the UK, Ireland, France, Belgium, the Netherlands, western Germany, Italy, the Adriatic coast of the Balkan peninsula as well as north-west Turkey and east Bulgaria on the black sea coast, also have relatively good climate matches (60–70% matches). Climate matches with two locations in California, highlighted roughly similar areas to those identified through climate matching with the Oregon area, though similarities with more Mediterranean areas were, not surprisingly, much higher (Figure 6).

Care must be taken in interpreting such climate matches. Oregon and California favour development of the pathogen partly due to the presence of specific hosts within the diverse plant communities that are present in coastal redwood woodlands and in evergreen oak woodlands; these include significant foliar hosts (principally California bay laurel – *U. californica*, and tan oak – *L. densiflorus*) that drive the epidemics of tree mortality. However, the climate itself in the Pacific Northwest of the USA may not necessarily be optimal. Even though parts of the year are mild and wet (mild and rainy winters), the relatively hot dry summers do not favour the pathogen and it primarily survives during this period as infections/chlamydospores in evergreen leaves, especially of California bay laurel (*U. californica*). Some European climates may potentially be more favourable where sporulation and dispersal of the pathogen can occur throughout the whole year (e.g. in NW Europe) or through greater parts of the year. Similarly, many parts of the Mediterranean basin have a rainy season that is typically several months longer than that in California (Moralejo and Descals, 2003; Figure 4); epidemiological studies in California have shown that extended rains in late spring are correlated with 20-fold increases in spore production (Rizzo and Garbelotto, 2003; Rizzo *et al.*, 2005; Davidson *et al.*, 2005). Laboratory studies (Turner *et al.*, 2008; Werres *et al.*, 2001) indicate that the pathogen is favoured by cool-temperate conditions. However, it is also adapted to survive prolonged periods of hot, dry weather, e.g. California (Davidson *et al.*, 2005; Rizzo *et al.*, 2002; Fitchner *et al.*, 2005, 2006, 2007, 2008); it is therefore likely that the pathogen would survive hot dry summers in the Mediterranean area also, in leaves of evergreen hosts or within the soil.

Some climate matching has also been done between the areas of northern Europe that currently have significant outbreaks of *P. ramorum* in the environment, especially those areas where trees are affected. Two such areas are Cornwall, UK (Figure 7) and Nijmegen, the Netherlands (Figure

8). Again, care must be taken with the interpretation though such maps can highlight other areas that could be at high risk based on climate.

Figure 4. Comparison between rainfall in one area of Portugal with one area of California, showing the longer period of rainfall at the Portugese location.

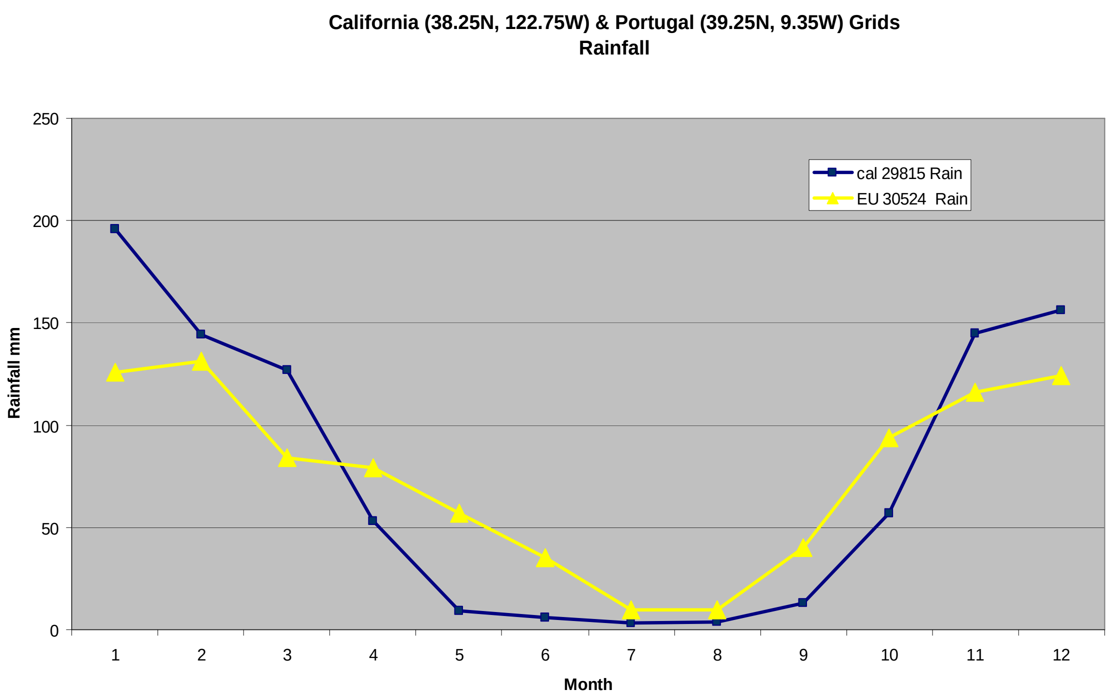


Figure 5. CLIMEX Match Index comparison of the 10' latitude/longitude resolution grid cell in Oregon where *P. ramorum* is damaging with climatic conditions in the rest of Europe.

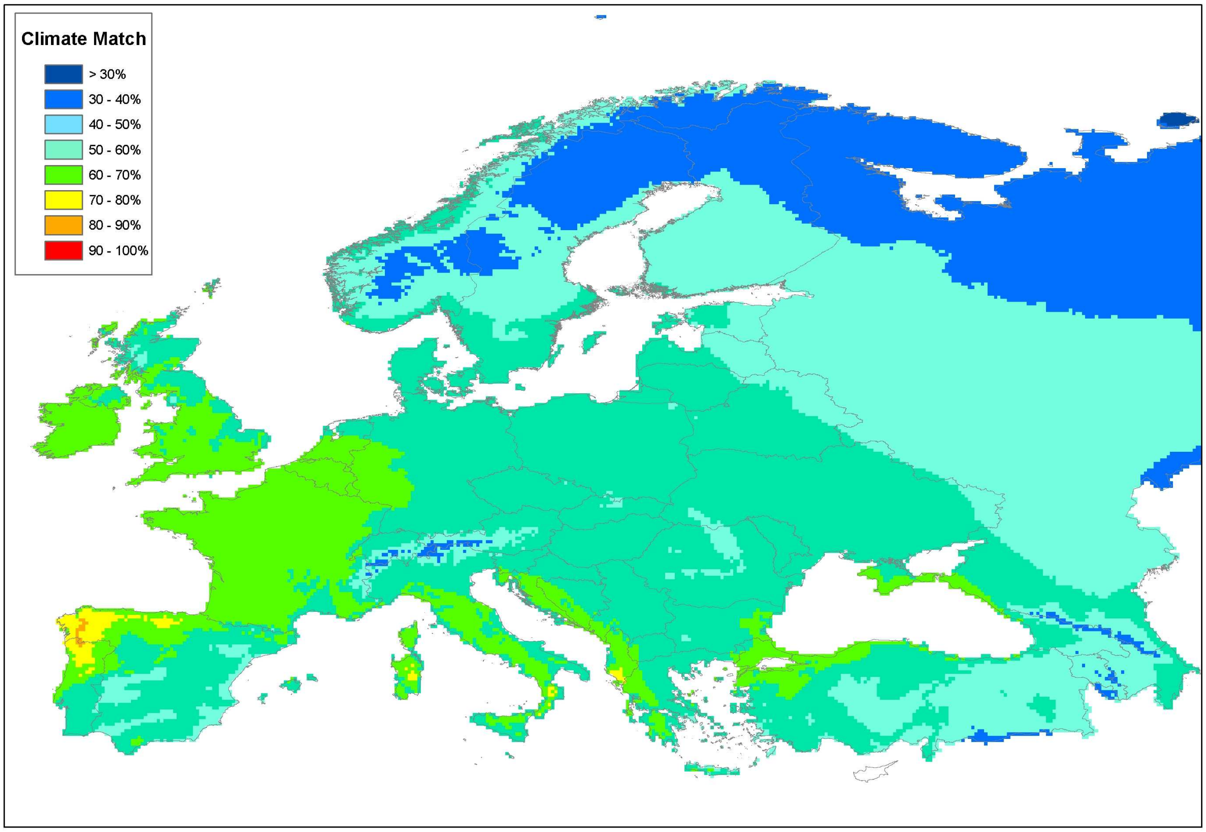


Figure 6. CLIMEX Match Index comparison of the 0.5' latitude/longitude resolution grid cell in a location in California where *P. ramorum* is damaging (an area just north of the San Francisco bay area, south of Santa Rosa) with climatic conditions in the rest of Europe.

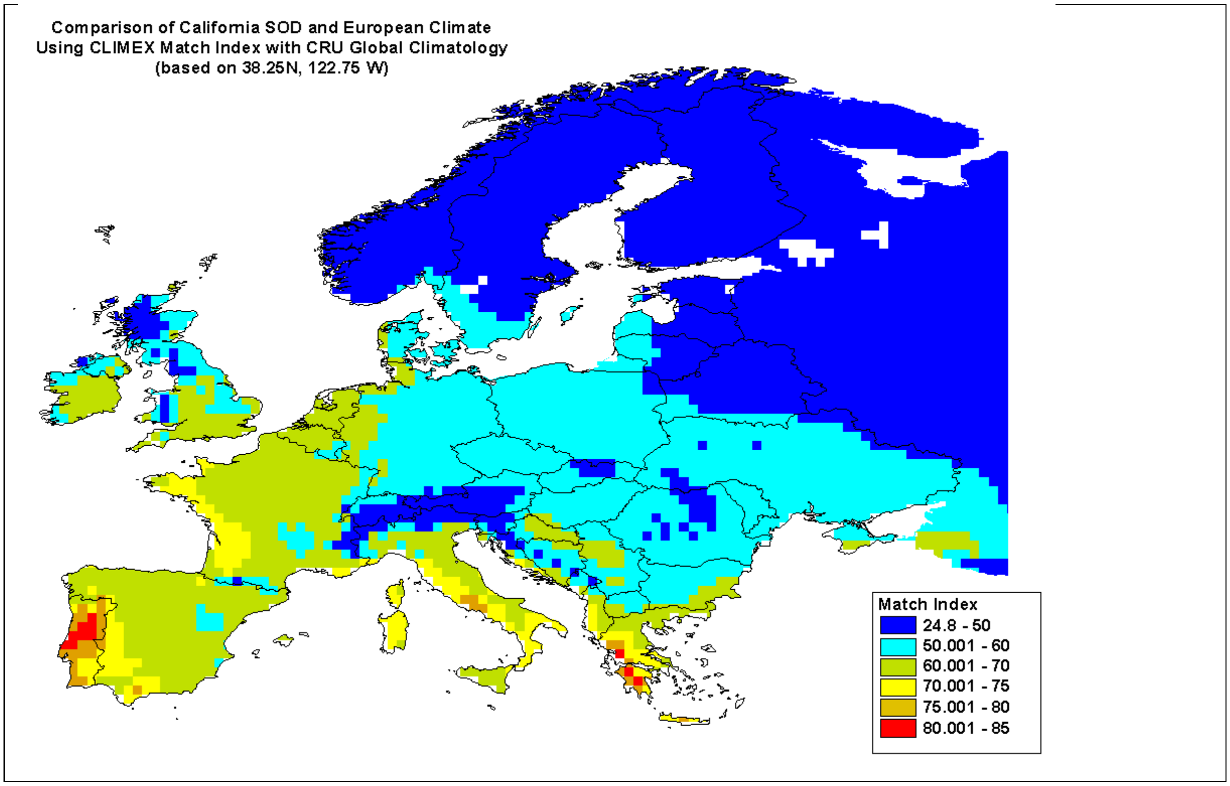


Figure 7. CLIMEX Match Index comparison of the 10' latitude/longitude resolution grid cell in Cornwall where *P. ramorum* is damaging, especially on rhododendron and beech, with climatic conditions in the rest of Europe.

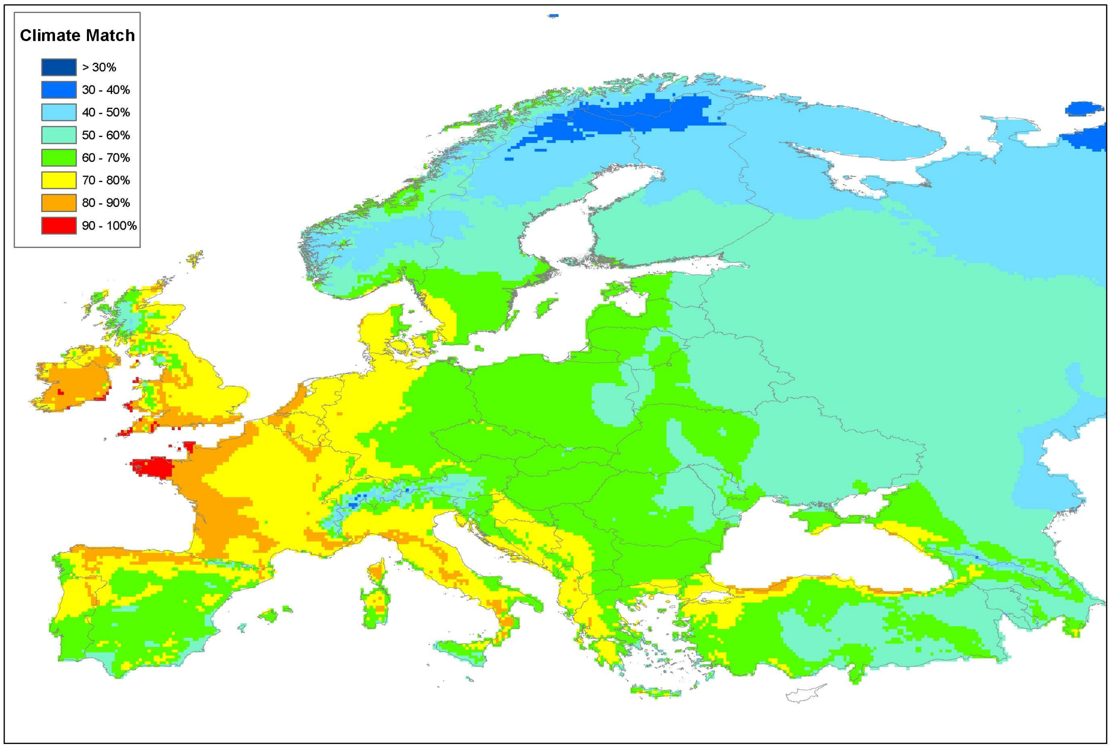
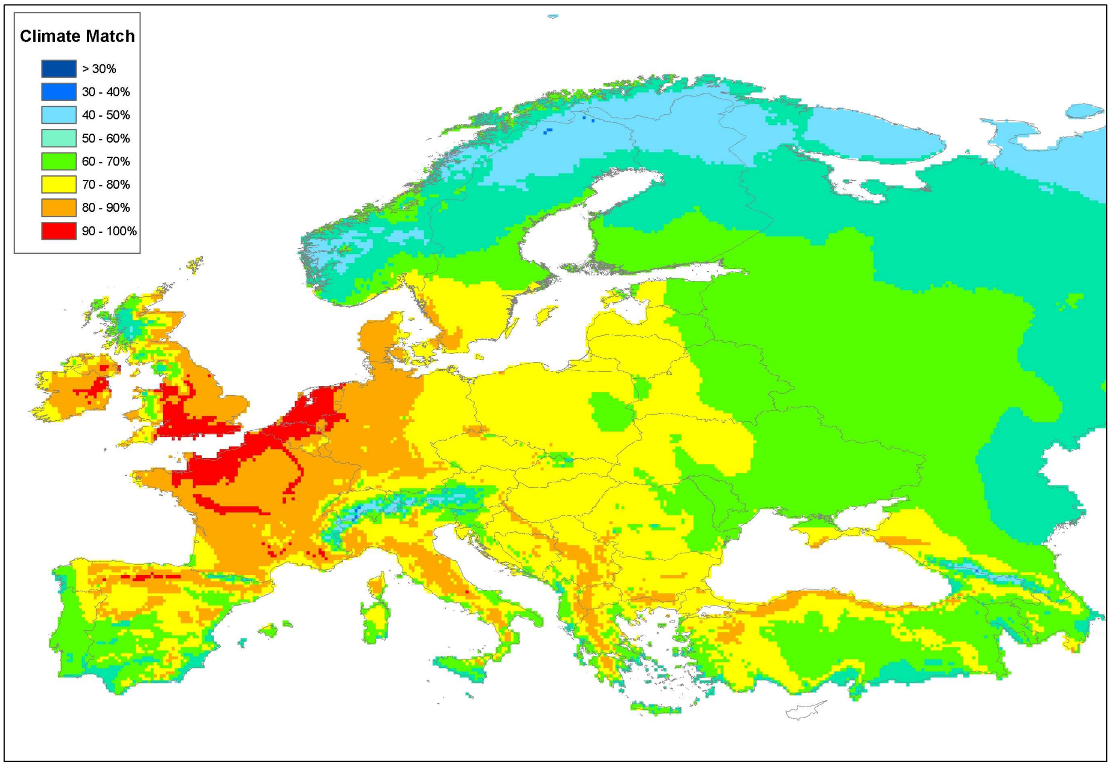


Figure 8. CLIMEX Match Index comparison of the 10' latitude/longitude resolution grid cell in Eastern Netherlands near Nijmegen where *P. ramorum* is damaging on rhododendron with climatic conditions in the rest of Europe.



In addition to the climate-matching work undertaken within the RAPRA Project, a ranking system developed specifically to predict potential *P. ramorum* distribution in California using climatic parameters that favour *P. ramorum* (Meentemeyer *et al*. 2004) was also applied to Europe. Scores, ranks and weights were assigned to precipitation, maximum temperature, relative humidity and minimum temperature during December to May (Table 15). Precipitation and maximum temperature were given an importance weighting of 2; relative humidity and minimum temperature were given an importance weighting of 1; host species index (not used in European applications of the model) was given an importance weighting of 6.

The host species index in the model for California was based on their potential to produce inoculum and their epidemiological significance. The maps for Europe are constrained by the lack of high resolution host data (individual host distribution and also host associations) for the whole of Europe.

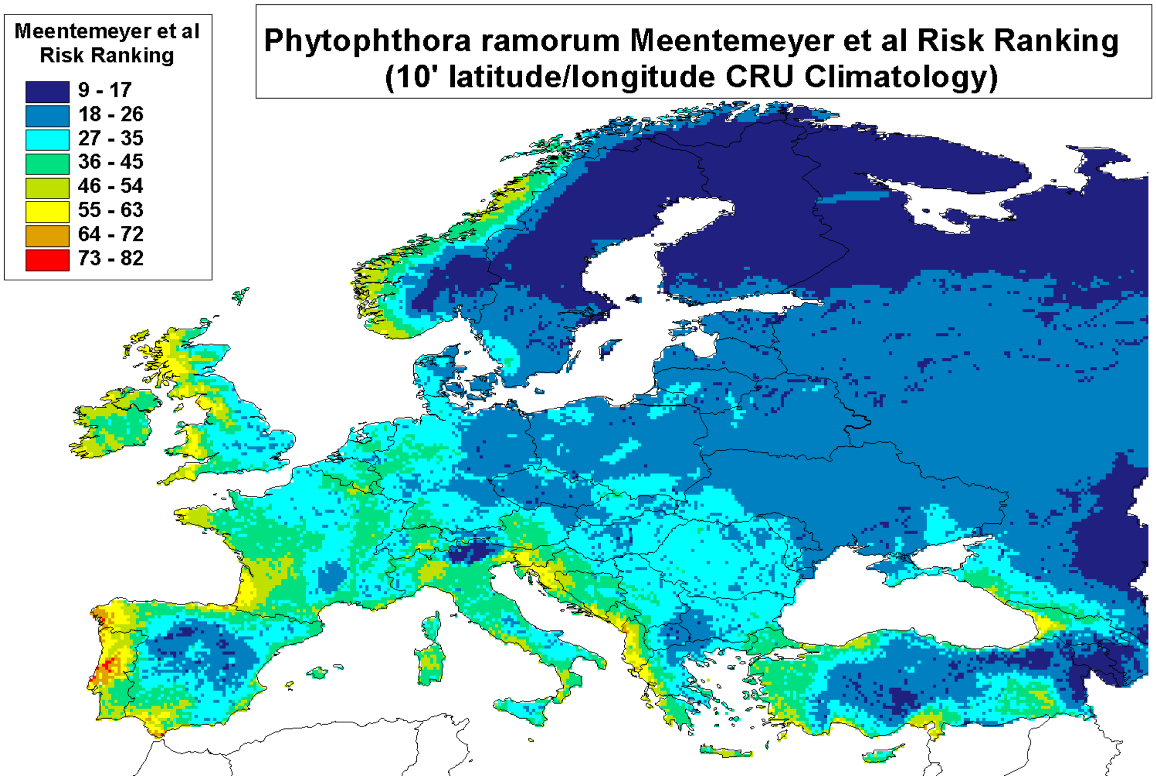
The risk maps for California produced by Meentemeyer *et al*. (2004) can also accommodate various elements of human activity (e.g. proximity to nurseries).

Table 15. Range of values for predictor variables and assigned ranks in the Meentemeyer *et al.* (2004) *Phytophthora ramorum* spread risk model, ranked 0–5 from least to most suitable for spread of the pathogen.

Rank	Precipitation (mm)	Average maximum T (°C)	RH (%)	Average minimum T (°C)
5	>125	18–22	>80%	-
4	100–125	17–18; 22–23	75–80	-
3	75–100	16–17; 23–24	70–75	-
2	50–75	15–16; 24–25	65–70	-
1	25–50	14–15; 25–26	60–65	>0
0	<25	<14; >26	<60	<0

The abiotic-based rules (Table 15) developed by Meentemeyer *et al.* (2004) were applied to the 10’ latitude/longitude resolution global climatologies constructed by New *et al.* (1999, 2000) and mapped in a GIS. This mapping showed that northern Portugal, north-western Spain, the southern tip of Spain, the Adriatic coast of the Balkan peninsula (e.g. western parts of Greece, Albania, Montenegro, Bosnia and Herzegovina, Croatia, Slovenia), south-western France, north-west France (Brittany), northern coastal Spain, southern Turkey and western UK and south-west Ireland have the highest risk ranking.

Figure 9. *Phytophthora ramorum* risk ranking model based on Meentemeyer *et al.* (2004) for Europe using the New *et al.* (2000) 10’ latitude/longitude resolution global climatology for December–May 1961–1990.



Additional approaches that have been developed by others and used in the RAPRA Project are:

- A CLIMEX compare-locations module (Venette and Cohen, 2006) that calculates an index of climatic suitability for a species, known as the ecoclimatic index, based on climatic responses obtained in the laboratory and by extrapolation based on the climate in areas where the species is present. The same CLIMEX parameters developed by Venette and Cohen (2006) for mapping climatic suitability for *P. ramorum* in the USA (Table 16; Figure 10c) were used to produce maps for Europe (Figure 10a and 10b). Figures 10a and 10b are identical except that Figure 10b follows the same index and colouring scheme as Venette and Cohen (2006) in their predictions for the USA (Figure 10c), whilst Figure 10a uses additional colours and categories to emphasize the highest levels of risk.

- A technique using the genetic algorithm GARP (Genetic Algorithm for Rule-set Production; Kluza *et al.*, 2007) (Figure 11).

Since all the maps were created using different techniques and different parameters, it is not easy to combine them into one simple summary map of risk that represents the endangered area for *P. ramorum* hosts in Europe based on climate, though this has been attempted for the USA (Kelly *et al.* 2005). It is also not possible to say that one technique or map is “better” than another since validation is not possible using the limited case data in Europe where the pathogen is under regulatory control. However, models using current pathogen distribution with climate matching are likely to predict a more limited distribution than those that do not (Kelly, 2005; Kelly *et al.*, 2006). Nevertheless, the considerable similarities between the various maps are striking, despite the different approaches taken.

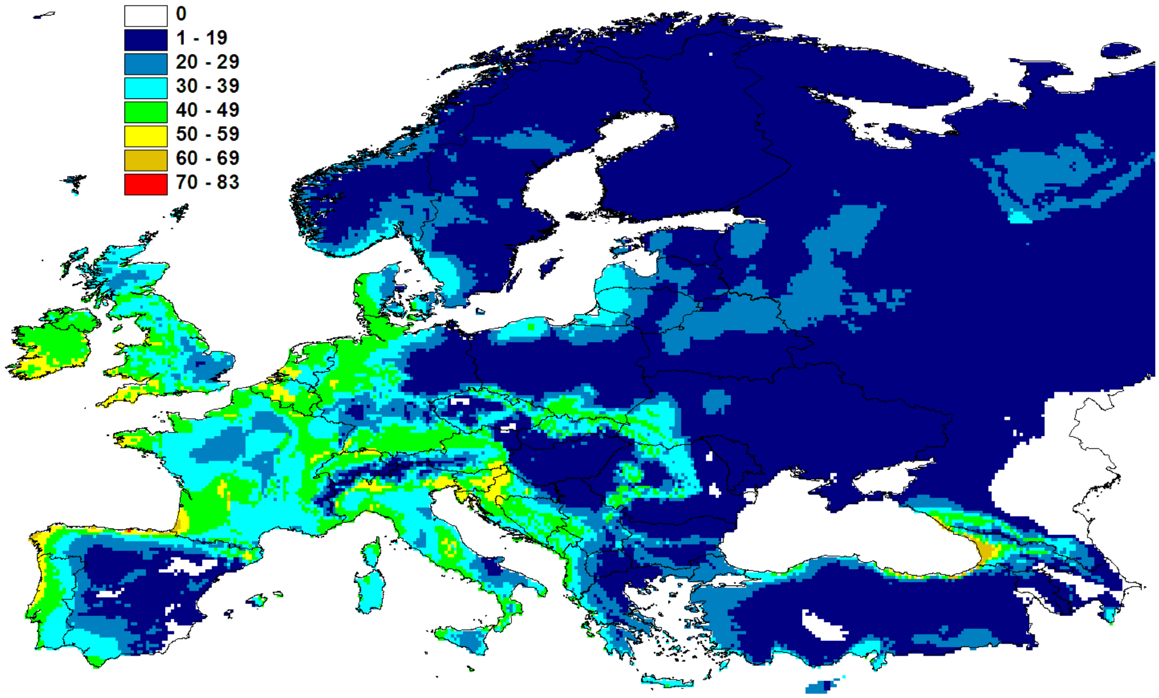
It is important to stress that although the maps show that the western coastal areas of Europe and various coastal areas of the Mediterranean have climates that are most similar to those where *P. ramorum* is damaging, they also show that areas to the east, while not so similar, may also be suitable for *P. ramorum*. This is particularly the case with the climate risk map produced using Venette and Cohen’s (2006) classification (Figure 10): here, all of Europe, except the areas that are very dry, e.g. central Spain, or very cold in winter, e.g. Eastern and Northern Europe, are either favourable or very favourable. It should be noted that although Venette and Cohen (2006) used temperature parameters derived from *P. ramorum* data sets, they used soil moisture parameters developed for *Phytophthora cinnamomi*, which is a soil-borne rather than an aerial *Phytophthora*.

The apparently clear distinctions between climatic favourability and unfavourability provided by these maps must also be treated with caution. The climatic data summarise information from thirty years (1961-90) and interpolate data from weather stations over a wide area. It is therefore likely that the microclimatic factors in the western coastal fringes of Europe that appear to be particularly suitable for *P. ramorum*, e.g. woodland in a steep valley near the sea or a large water body that provides continuous high relative humidity, occur in some locations over a much wider area. These climate-based maps also do not account for more local microclimatic factors. For example, in the UK, the pathogen has been found in several more central or eastern areas, considered of lower risk based on climate, causing significant disease on established rhododendron: these sites have had favourable microclimates; in one case in East Yorkshire there has also been a beech tree with bleeding bark cankers.

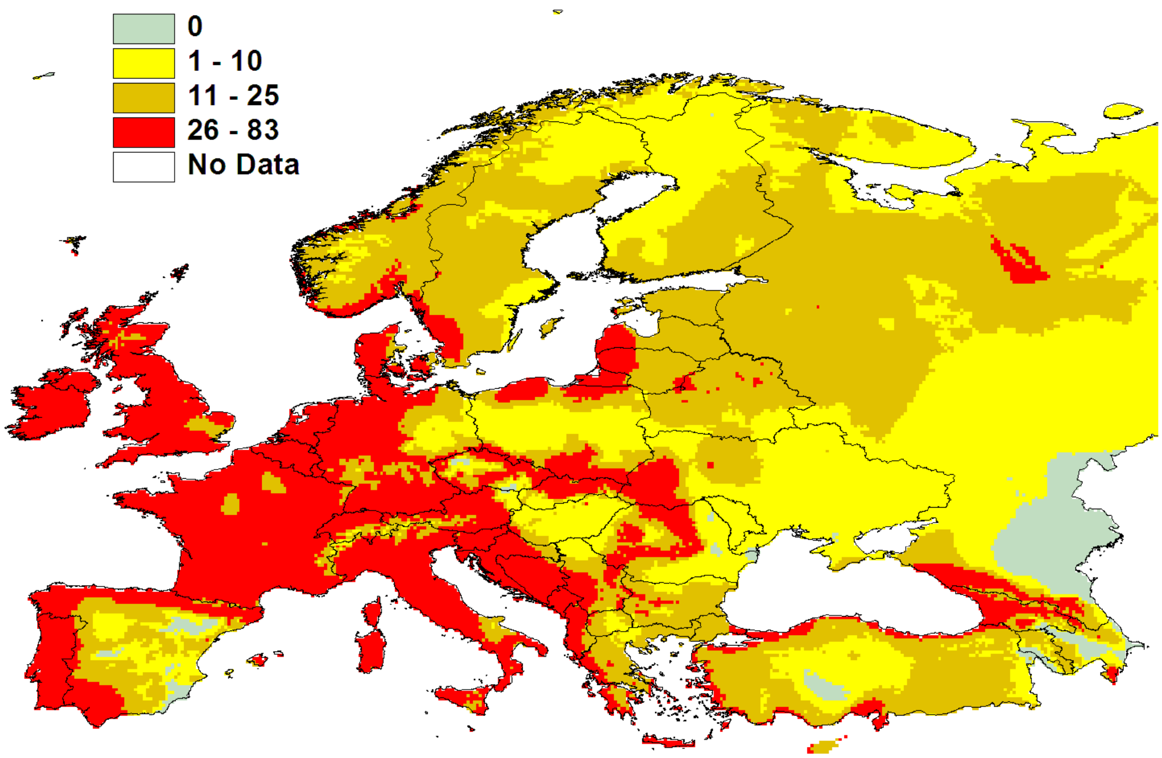
Nevertheless, it is still important to highlight those areas where climatic conditions are most similar to those where *P. ramorum* has been found to be damaging: it is here that a larger proportion of the area is expected to have a suitable microclimate and, given the presence of suitable hosts and sufficient inoculum, to most likely suffer damage to trees and other flora.

Figure 10. CLIMEX suitability based on the ecoclimatic index using parameters developed by Venette & Cohen (2006) for: (a) Europe using 1961-1990 climate interpolated to a 10 min latitude/longitude grid and using colours and categories that highlight the highest levels of risk; (b) Europe, but with colours and categories matching those used in their original risk map for the USA; (c) USA, as published in Venette & Cohen (2006).

(a)



(b)


0
1 - 10
11 - 25
26 - 83
No Data

(c)

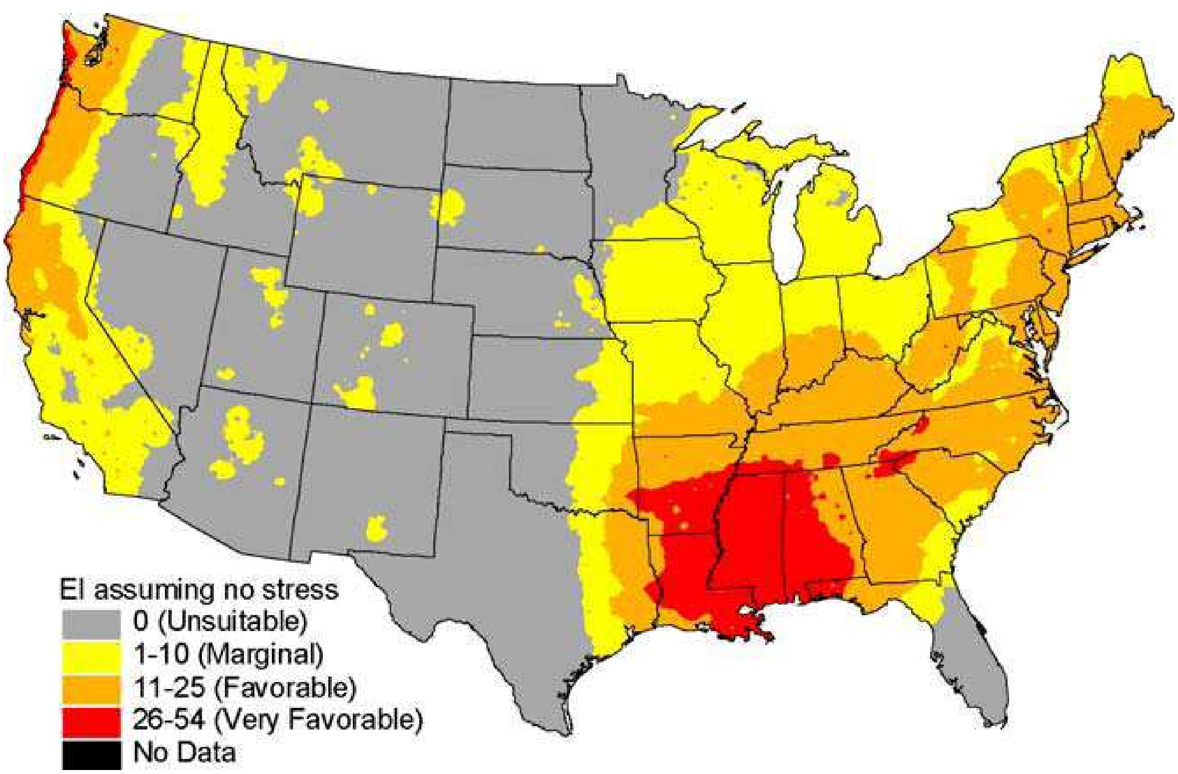

EI assuming no stress
0 (Unsuitable)
1-10 (Marginal)
11-25 (Favorable)
26-54 (Very Favorable)
No Data

Table 16. CLIMEX parameter values used by Venette & Cohen (2006) to map potential *Phytophthora ramorum* distribution in the USA and by the EU RAPRA Project to map potential *P. ramorum* distribution in Europe.

Parameter	**Definition**	**Value**
	Temperature	
DV0	Lower limit for growth	2
DV1	Lower optimum for growth	17
DV2	Upper optimum for growth	25
DV3	Upper limit for growth	30
	Moisture	
SM0	Lower limit for growth	0.4
SM1	Lower optimum for growth	0.7
SM2	Upper optimum for growth	1.3
SM3	Upper limit for growth	3.0
	Cold stress	
DTCS	Cold stress degree day threshold	15
DHCS	Cold stress degree day rate	-0.0001
	Heat stress	
TTHS	Stress threshold	30
THHS	Stress accumulation rate	0.005
	Dry stress	
SMDS	Stress threshold	0.2
HDS	Stress accumulation rate	-0.005
	Wet Stress	
SMWS	Stress threshold	2.5
HWS	Stress accumulation rate	0.002

Figure 11. Potential distribution of *Phytophthora ramorum* in Europe based on GARP (Genetic Algorithm for Rule-set Production; Kluza *et al*., 2007).

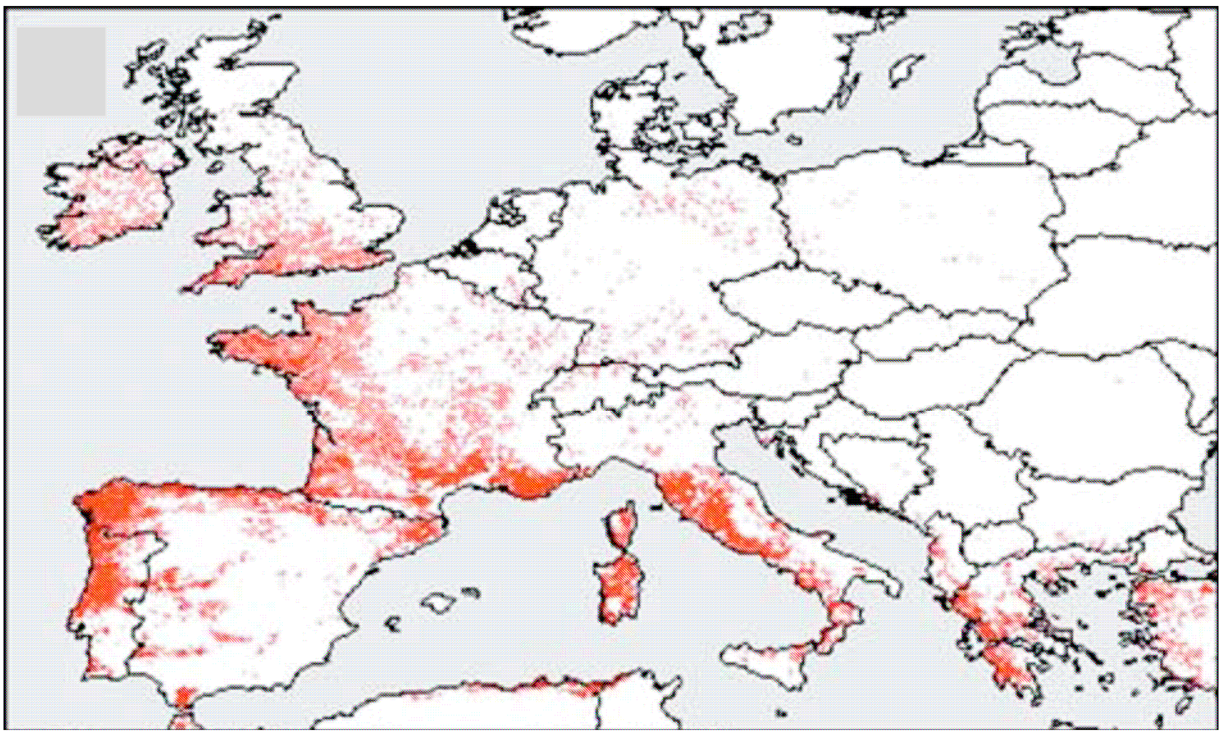
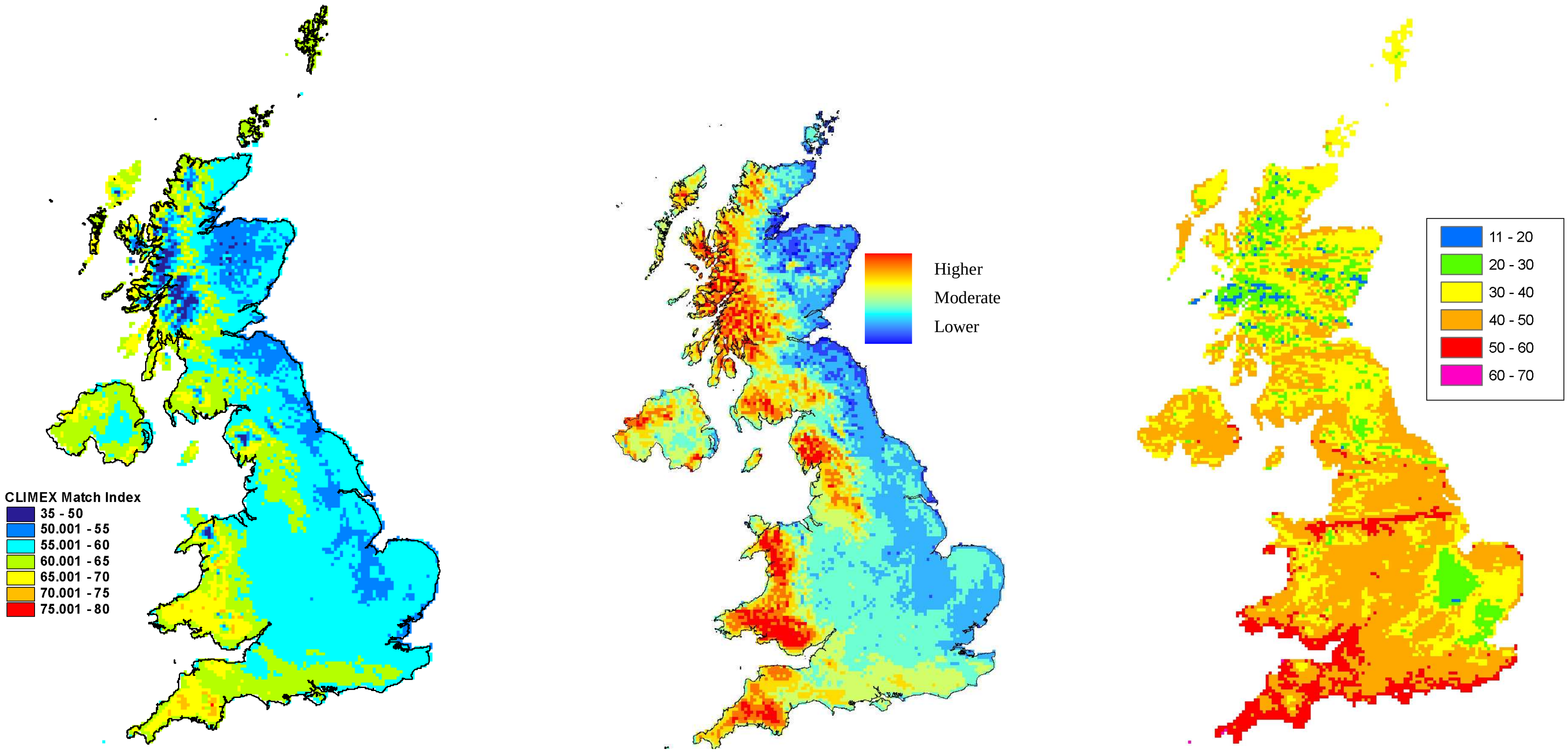


Figure 12. Comparisons of different climate-based risk mapping approaches, as applied to the UK.



CLIMEX Match Index
comparison with SW Oregon

Risk Ranking method
Meentemeyer et al 2004

CLIMEX Ecoclimatic Index
Venette & Cohen (2006)

Metzger *et al.* (2005) produced a European climatic classification (see Figure 13). Based on this classification and risk mapping, we can say that areas with *Atlantic Central* and *Lusitanian* climates provide the most suitable conditions for *P. ramorum*, with *Mediterranean* and *Atlantic North* climates also being potentially favourable. The *Atlantic Central* area has a moderate climate where the average winter temperature does not go far below 0°C and the average summer temperatures are relatively low. The *Lusitanian* climate is found from western France to Lisbon, Portugal; here summer temperatures are rather high and some dry months occur, while winters are mild and humid.

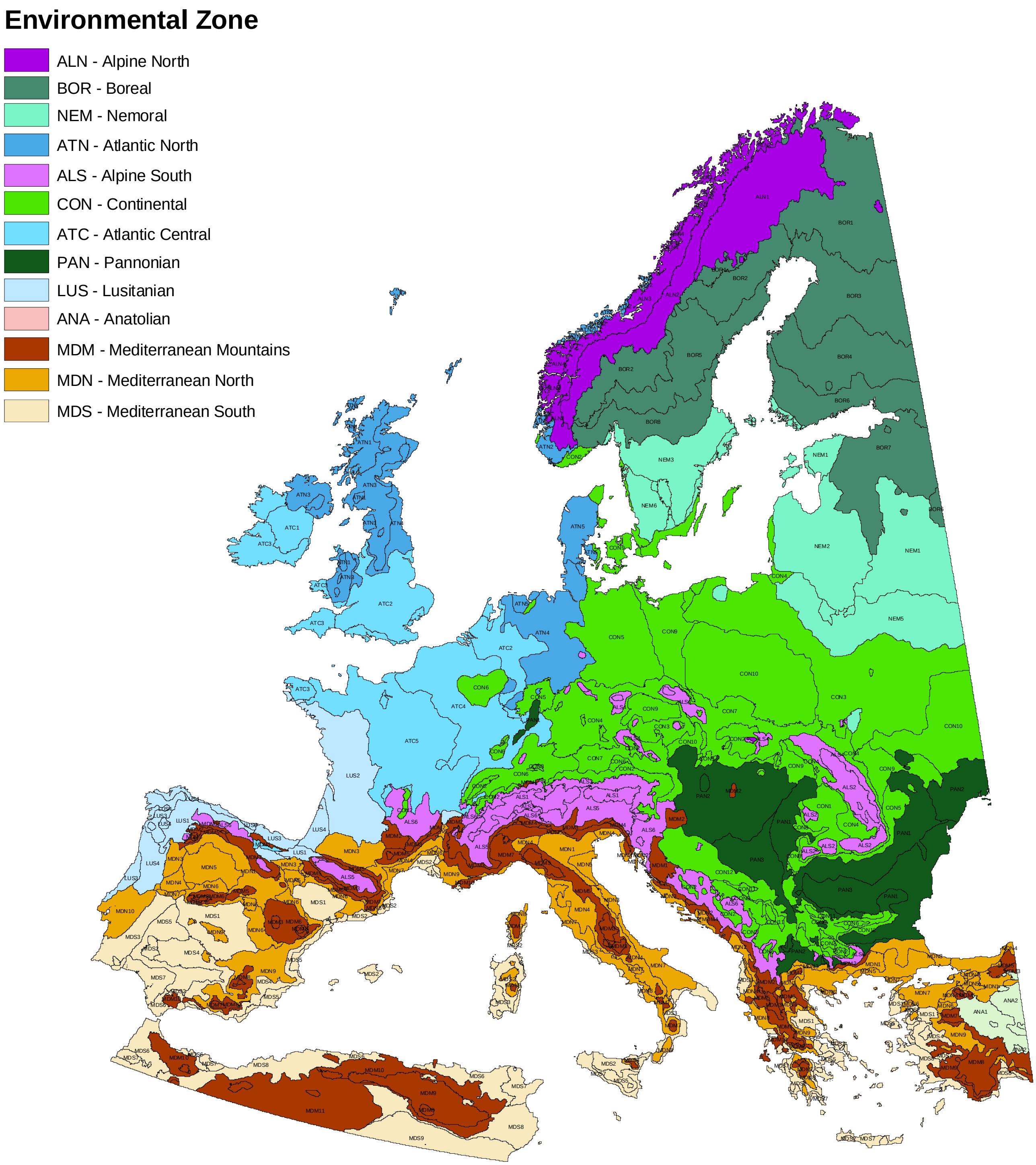
Experimental work supports the fact that *P. ramorum* is a pathogen adapted to a cool-temperate climate or to climates where part of the year is cool-temperate. In this respect, these studies sufficiently support the parameterisations used in the various climate-based risk maps (Meentemeyer *et al.*, 2004; Venette and Cohen, 2006).

<u>Growth and survival:</u>
Mycelial growth occurs at 2–30°C (Werres *et al.*, 2001; Rizzo *et al.*, 2002; Swain, 2006; Englander *et al.*, 2006) and is optimal at about 15–25°C with a peak at 20°C. *P. ramorum* does not grow at 35°C, though it does have a relatively significant degree of heat tolerance. It can survive in California bay leaves incubated at 55°C for 1 week (Harnik *et al.* 2004) as chlamydospores. Turner *et al*. (2008) showed that mycelium of *P. ramorum* in culture was very resilient to dry-heat treatments, with isolates surviving a 15 minute, but not a 30 minute, treatment at 60°C; extending the treatment time to 60 minutes reduced the lethal temperature to 50°C. When heat treatments (37.5, 40, 42.5 or 45°C) were applied over different periods to detached leaves 2, 12, 24 and 96 hours after inoculation with zoospores, *P. ramorum* was not recovered by isolation from any of the temperatures tested at duration times of 60, 80, 100 and 240 min respectively (Jennings, 2008).

Sporangia and chlamydospores are also relatively resilient (Turner *et al.*, 2005), but are susceptible to periods of sub-zero or high temperature: sporangia and chlamydospores were able to both survive and germinate on agar after exposure to -2°C for 24 hours; chlamydospores in culture were not capable of germinating after exposure to 55°C for one hour or 40°C for 24 hours or –25 °C for just 4 hours, and no sporangia survived a 2-hour exposure to 40°C or -25°C. Although chlamydospores died after short periods at high (40°C) or low (-25°C) temperatures, they survived treatment at 0°C and 30°C for at least 2 months in a separate experiment (Turner *et al.*, 2008) which assessed both viability (using vital stains) and germination. Sporangia were found to survive for up to 6 hours but not 24 hours at room temperature in moisture-free conditions (Turner *et al.*, 2005).

<u>Sporulation:</u>
Production of infectious inoculum (sporangia and zoospores) requires both humidity and moderate temperatures (Turner and Jennings, 2008); dispersal is favoured by rainfall since the pathogen is primarily splash-dispersed locally, though longer-distance dispersal over several kilometres is considered to be possible as rarer events via turbulent (dry) air (Hansen, 2008) or during rain storms (Rizzo *et al*., 2005; Mascheretti *et al.*, 2008).

Figure 13. The Environmental Stratification of Europe (Metzger *et al*., 2005). Climate-based risk maps for *P. ramorum* predict that *Atlantic Central* and *Lusitanian* climates are most suitable, though *Mediterranean* climates and some *Atlantic North* zones are also potentially favourable for the pathogen.



Turner *et al.* (2008) reported that sporulation of both European and North American isolates was suppressed at levels up to and including 62% relative humidity (RH), and was optimal at 93% or above. In experiments combining temperature and humidity (Turner *et al.*, 2008), sporulation was greatest at temperatures of 20°C or 25°C with humidities of 100% or 93%, though significant levels of sporulation also occurred at 85% and 62% RH; only minimal sporulation occurred at 10°C and at 30°C. Sporangial production under each humidity regime increased with increasing temperature up to the optimum temperature and then decreased. Optimal sporulation occurred at 100% humidity. Overall, changes in temperature were more influential on sporulation compared to humidity. Englander *et al.* (2006) reported that sporangial production on agar plus immersed in soil extract solutions occurred from 10-30°C but was optimal at 16-22°C; chlamydospore production on V8 agar was optimal at 14-26°C and was generally favoured by higher temperatures than were optimal for sporangial production.

<u>Germination and infection:</u>
Zoospore germination and infection is favoured by the presence of free water and/or high humidity (Turner and Jennings, 2008; Kessel *et al.*, 2007). Maximum levels of zoospore germination occur at 100% humidity or water potentials of 1. A broad range of temperatures support zoospore germination with the optima ranging from 10–30°C depending on the water potential of the experiment. Maximum zoospore germ tube lengths were obtained at 20°C at a water activity of 0.98–1.0 MPa; germ tube lengths were generally slightly longer at 10°C than at 25°C. Levels of zoospore germination were typically above 70% at humidity levels of 85% and above. Germ tube development was more sensitive to humidity levels with limited germ tube elongation occurring at humidity levels below 85%. Experiments on the effects of combined temperature and humidity treatments on zoospore germination and germ tube development showed that humidity levels of 100% were critical for zoospore germination and germ tube elongation and that optimum temperatures were between 20 and 30°C.

Sporangial germination (either indirectly via zoospore release or directly via hyphal/germ tube growth) also increased with increasing water potential (at higher temperatures, sporangia tend to germinate directly by producing hyphae, whilst at cooler temperatures below 20°C germination is indirect via the production and release of zoospores). Optimal germination and germ tube development occurred under conditions of high water potential (>0.99) at temperatures between 20 and 25°C. Reduced humidity levels did not significantly reduce sporangial germination such that similar rates of germination were obtained within the tested range of 38–100% RH; changes in temperature had the most effect on sporangial germination.

Frequency of infection of California bay laurel (*U. californica*) leaves under laboratory conditions was 92% of leaves infected at 18°C, 50% at 12°C and 37% at 30°C (Garbelotto *et al*., 2003); leaves were infected within 12 hours at 18°C in the presence of free water (D. Huberli, Oregon, 2002, *personal communication*). Garbelotto *et al*. (2003) reported that a minimum of 6 to 12 consecutive hours of free water is a prerequisite for the infection of *U. californica* leaves. Infection of leaves is via stomata or wounds (Florance, 2002; Inman *et al*., 2005) or other leaf structures such as oil glands (Geltz *et al.,* 2005). Shoots can be infected via lenticels (Florance, 2002) and tree bark via medullary rays (Florance, 2005).

In conclusion for natural or semi-natural habitats or environments, climates that are generally mild and wet for most, or a significant part, of the year will favour disease development for *P. ramorum* by supporting sporulation, dispersal, germination, infection and survival. The interaction between temperature and rainfall is considered to be critical in California, where spore production increased 20-fold in years with warm rains (late/extended rains in the spring when temperatures are around 19°C) compared to years when rains did not extend into this warmer period (Rizzo and Garbelotto, 2003; Rizzo *et al.*, 2005; Davidson *et al.*, 2005). The breadth of the temperature range and optima for growth, sporulation and survival would favour establishment in a wide range of climates.

For managed nursery environments, the environmental conditions in protected cultivation are likely to be broadly similar in the PRA area compared to nurseries in areas where the pathogen occurs, since environmental conditions (temperature, humidity, irrigation) are often controlled and optimised for plant growth. For nurseries outside of the EU where plants are not grown under protection, environmental conditions will be more influenced by climate. However, the range of climatic conditions is very likely to be similar to the range of climates across the PRA area where host plants are grown in nurseries.

1.20. How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the current area of distribution?

Note: *the major abiotic factor to be considered is soil type; others are, for example, environmental pollution, topography/orography. For organisms having an aquatic stage pH, salinity, current and temperature are important factors to consider.*

not similar, slightly similar, moderately similar**, largely similar**, completely similar

Largely similar

Level of uncertainty: Low

The area/s of origin are currently unknown, though parts of Asia are proposed, based primarily on climate and native host genera (Brasier *et al*., 2004; Goheen *et al*., 2005, 2006; Vannini *et al.*, 2007). Since the centre/s of origin for *P. ramorum* are not known, it is not possible to make an assessment of the abiotic factors present there. It is only possible to make comparisons with the parts of North America (Pacific Northwest coast) where it has been introduced in addition to Europe.

The soil environments where the pathogen occurs in the environment in California and Oregon are woodland soils of various types (Fitchner *et al.*, 2006). In California, the woodlands are largely *coastal redwood – tanoak* forests and *mixed evergreen* woodlands (e.g. *coast live oak – California bay laurel* woodlands); in Oregon, the affected woodland area is predominantly a *Douglas fir – tanoak* forest type, though some *coast redwood – tanoak* forest is also affected (Goheen *et al.* 2008). The pH of soils in California woodlands are typically pH 5.5–6.0 (D. Rizzo, UC Davis, USA, *personal communication*), but vary with soil and woodland type (Fitchner *et al.*, 2006). Redwood forests have organic soils typically of about pH 5.9; California bay laurel (*U. californica*) and tanoak (*L. densiflorus*) are more associated with mineral soils and typical have pH values of 6.0 and 5.7 respectively. Soil pH is unlikely to have a significant impact on the pathogen since experiments have shown that *P. ramorum* can survive in a wide range of pH, albeit under relatively short exposure times. Turner *et al.* (2005) showed that sporangia and chlamydospores were both able to survive equally well in the range of pH 3 to pH 9, but did not survive at pH 2 (experiments only tested short exposures of up to 6 hours). Others have also shown that the pathogen survives in a range of different growing media components and in a garden clay-loam soil (Linderman and Davis, 2006), so soil type is unlikely to significantly impact on survival.

However, soil can have an indirect effect on the pathogen by influencing the presence of host species. In Northern Europe, for example, rhododendron (principally *R. ponticum*, family Ericaceae) is the primary foliar/sporulating host for *P. ramorum* in woodlands and prefers moist acid soils, typically in the range of pH 3.3–6.4, though growing only poorly above pH 5.0

(Cross, 1975). Mejías *et al*., (2007) showed that the soil in areas where *R. ponticum* subsp. *baeticum* occurs in southern Spain has a ph range of 4.0 to 6.4. Many northern European heathland species that are potentially at risk from *P. ramorum* (e.g. *Arctostaphlos uva-ursi, Calluna* spp., *Erica* spp. and *Vaccinium* spp.) are similarly ericaceous and found on acid soils.

There are some similarities in topographical factors where *P. ramorum* occurs in North America (California/Oregon) and in areas of Europe where the pathogen occurs in the environment most frequently on established plants. In California, *P. ramorum* disease development may be positively influenced in coastal hills subjected to sea mists. Condeso and Meentemeyer (2008) also found a positive association between disease severity and elevation in Californian forests. They attributed this to topographically driven optimal temperature and moisture conditions for *P. ramorum*. However, they suggest that it is also possible that greater wind velocities at high elevations increase the rate of leaf-to-leaf and or tree-to-tree spread. They determined that optimal microclimatic conditions for *P. ramorum* growth and reproduction was influenced in California more by topography that by landscape pattern (Condeso and Meentemeyer, 2007). In Oregon, disease spread in the quarantine areas of woodlands near Brookings appears to have some links with topography (coastal location with elevation/hills/valleys) and associated microclimates; this is supported by observations (Hansen, 2008; Kanaskie *et al.*, 2008) on the general direction of spread and locations of new infections in relation both to topography and the host (new infections often being at the tops of tanoak trees).

There are topographical factors associated with outbreaks in the UK with a number of outbreaks being located in coastal valleys, near to watercourses, and associated with footpaths (Cushman and Meentemeyer, 2005; Elcock *et al.*¸ 2008). Western coastal fringes of Europe may be particularly suitable for *P. ramorum*, e.g. woodlands in valleys near the sea or other large water bodies that provides relatively continuous high relative humidity. However, it is likely that these microclimatic factors will occur in other locations over a much wider area.

P. ramorum does not have a defined aquatic phase that forms a distinct part of its life cycle. However, oomycetes generally thrive under moist conditions and in water, and *P. ramorum* is commonly detected in water courses in the USA and in Europe in areas where the pathogen is found on plants in the environment (Turner, 2007; Turner *et al.*, 2005; Tsjosvold *et al.*, 2002; COMTF, 2008) and up to several kilometres distant, though the significance of inoculum in watercourses as a pathway for spread is still unclear.

1.21. If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?

N/A, never, very rarely, rarely, occasionally, **often**, very often

<u>Often</u>

Level of uncertainty: <u>Low</u>

P. ramorum has been recorded on nursery plants in the USA and Canada (Frankel, 2008) on a very wide range of host genera, species and cultivars. In North America, the pathogen was first recorded in nurseries in California in 2001, then subsequently in Oregon and Washington State USA and British Columbia (Canada) in 2003. In 2006, the number of positive nursery findings in the USA for California, Washington State and Oregon was 110, 55 and 38 respectively. In 2004 (Frankel, 2008), two large California nurseries and one in Oregon shipped millions of potentially infected plants to over 1,200 nurseries in 39 US states: the pathogen was found in 22 of these states (177 nursery-related detections) by the end of that year (COMTF, 2008) and eradication action continued to be taken. Subsequently, the pathogen was found in nurseries in California, Oregon and Washington State, as well as other states, as follows (COMTF, 2008):

- In 2006, USDA APHIS reported 62 sites in 11 states as having had nursery-related *P. ramorum* detections. Positive findings by state were: AL(1), CA(28), CT(1), FL(2), GA(1), IN(1), ME(1), MS(1), OR(13), PA(1), and WA(12).

- A total of 21 positive nursery finds were made in 2007. The states with positive detections were CA(7), OR(2), WA(7), FL(1), GA(3), and MS(1).

In Canada, *P. ramorum* has been intercepted on nursery plants in areas of the Lower Mainland, Vancouver Island and Sunshine Coast of British Columbia (Wong, 2008). *P. ramorum* was first detected in Canada in 2003 on rhododendron container plants from Oregon at a nursery in British Columbia. In 2004, positive plants were recovered from 9 retail garden centres and 3 wholesale nurseries, all of which were in the south coastal area of British Columbia (http://www.inspection.gc.ca/english/plaveg/pestrava/phyram/sodmsce.shtml) as a result of trace forward inspections on plants shipped from California or as part of the national survey. Recall of plants and additional survey activities in 2004 detected infected plants at 17 residential properties that had planted nursery plants in south coastal British Columbia. In each of these cases, eradication action of positive plants and a surrounding buffer area of plants were eradicated. In 2006, *P. ramorum* was detected at three retail garden centres that had been positive in 2004 (but negative in 2005) and eradication efforts continued at one wholesale nursery where *P. ramorum* was detected in late 2005. In 2007, *P. ramorum* was found on 10 nurseries in British Columbia; all are subject to eradication (S. Sela, CFIA, Canada, *personal communication*, 2008). In April 2007, the Government of Canada established compensation regulations for nursery producers and others that are required to destroy plants or undertake treatments when *P. ramorum* is detected (http://canadagazette.gc.ca/partI/2007/20070407/html/regle1-e.html). *P. ramorum* remains a quarantine pest for Canada.

In non-EU countries in Europe, *P. ramorum* has also been found in nurseries in Norway and Switzerland. In Norway, *P. ramorum* was found on nurseries during national surveys in 2004, 2005 (27 nursery sites) and 2006; the proportion of positive samples was noticeably high, ranging from 25–60% of samples tested, compared to typical values of 1–5% for most EU countries (Slawson *et al.*, 2008; de Gruyter and Steeghs, 2006; Schenck, 2006). Switzerland also recorded findings in nurseries in 2004–6 (3 nursery sites in 2005).

The pathogen has not been recorded on nursery plants outside of Europe and North America, though Europe and North America are not the suggested areas of origin for the pathogen since the genetic evidence is that *P. ramorum* has been separately introduced in to Europe and North America (Ivors *et al.*, 2006; Mascheretti *et al.*, 2008; Sansford and Woodhall, 2007; Goss and Grünwald, 2008; Goss *et al.*, 2009). The origin is speculated to be Asia, especially Taiwan and the eastern Himalayas, and the Yunnan province of China (Brasier *et al.*, 2004; Goheen *et al.*, 2005, 2006; Vannini *et al.*, 2007) There is therefore a risk that *P. ramorum* may also be present on nurseries in its area/s of origin.

1.22. How likely is it that establishment will occur despite competition from existing species in the PRA area?

Note: For pest plants, how likely is the pest plant to build up monospecific stands? Is the species a freshwater macrophyte? Is the species allelopathic? Is the species able to fix nitrogen?

very unlikely, unlikely, moderately likely, likely, **very likely.**

Very likely

Level of uncertainty: Low

It is highly unlikely that *P. ramorum* will be out-competed by other pathogens on its host plants. Although it has a relatively non-competitive saprophytic stage, long-lived chlamydospores enable it to survive in infected plant debris and soil in the presence of other microbes (Turner, 2007; Turner *et al.*, 2005, 2006). It also appears to survive in the bark of cut stumps of woody shrubs/trees and re-growth is often systemically infected (Turner *et al.*¸2006; Hansen and Sutton, 2005; Hansen *et al.*, 2005; Aveskamp *et al.*, 2005). Brown and Brasier (2007, 2008), also report survival in the xylem after at least 27 months after the overlying bark has been removed. The pathogen also appears able to survive in watercourses (Turner *et al.*, 2006; Turner 2007); there is the possibility that saprophytic colonisation of plant debris in watercourses may result in pathogen multiplication also, though there is no evidence for this as yet. In addition, it can apparently survive in roots of some plants such as *Rhododendron* (Fitchner *et al.*, 2008, 2008a; Parke *et al.*, 2006; Riedel *et al.*, 2008; Kessel *et al.*, 2007).

1.23. How likely is it that establishment will occur despite natural enemies already present in the PRA area?

Note: *natural enemies include herbivores, predators and parasites. For plant pests, the assessor should consider if the species is unpalatable to grazing animals or toxic.*

very unlikely, unlikely, moderately likely, likely, **very likely.**

Very likely

Level of uncertainty: Low

There are currently no known natural enemies of *P. ramorum* in the areas where it has been introduced in Europe and North America. Since the original area/s of origin are as yet unknown, the presence there of natural enemies cannot be determined.

It is possible that there may be competitive dominance from other *Phytophthora* species or micro-organisms already present in Europe, though there is no evidence that *P. ramorum* is being outcompeted by other *Phytophthora* species in areas where the pathogen occurs in the environment on both foliar hosts (primarily rhododendron) and tree hosts with bleeding bark cankers. In log tests, *P. ramorum* had the same colonising ability as *P. cambivora* on beech and red oak, though *P. cambivora* was more aggressive on sweet chestnut and *Q. robur*. In the environment *P. ramorum* is considered to have a competitive edge over *P. cambivora* due to the role of infected rhododendron as the source of inoculum for *P. ramorum*, compared to soil-borne inoculum for *P. cambivora*. There is no indication that other *Phytophthora* species out compete *P. ramorum* in naturally infected trees, even though several species can occur on the same tree (Brown *et al.*, 2006).

There is some circumstantial evidence though, that *P. ramorum* might be partially out-competed but not eliminated by another exotic species, *P. kernoviae*, on *R. ponticum* in some Cornish woodlands, UK (J. Webber, Forest Research, UK, *personal communication*).

Cultural practices and control measures

1.24. To what extent is the managed environment in the PRA area favourable for establishment?

> *Note*: *factors that should be considered include cultivation practices such as the time of year that the crop is grown, soil preparation, method of planting, irrigation, whether grown under protected conditions, surrounding crops, time of harvest, method of harvest, soil water balance, fire regimes, disturbance, etc.*

Not at all favourable, slightly favourable, moderately favourable**, highly favourable**, very highly favourable

Highly favourable

Level of uncertainty: Low

The managed nursery environment is highly favourable for establishment of the pathogen. *P. ramorum* has a very wide host range and can therefore establish and spread on a wide range of ornamental plants in nurseries across all climatic zones of Europe. Within a nursery, plants are typically closely spaced and certain cultivation practices (e.g. irrigation, pruning, etc.), combined with the general nursery environment, are likely to favour development of the pathogen. Trade networks may also favour wider establishment. Modelling work has suggested that the UK nursery trade network in hardy ornamental nursery stock most likely fits a scale-free network dominated by super-connected nodes (Jeger, 2008). Scale-free networks have a lower epidemic threshold than other kinds of complex networks; in the absence of controls this favours rapid spread and establishment throughout the network, increasing the risk of wider spread in the environment also (Jeger, 2008; Pautasso *et al.*, 2008.

Historic or heritage gardens and public greens are considered to be managed environments. Here, conditions are considered favourable for establishment since the range of plant species grown is typically diverse and is likely to include many susceptible species. Establishment may be favoured by the higher risk of introduction through planting infected host plants sourced from the nursery trade and, potentially, through introduction and spread via the public (Webber and Rose, 2008).

Once introduced to the managed environment (nurseries, gardens, as well as managed or semi-managed woodlands), establishment is favoured by the soil-borne phase of the pathogen since it can potentially survive for long periods in the soil and leaf litter, presumably as chlamydospores (Turner *et al*., 2005; Aveskamp *et al.*, 2005): this is at least 3 years in parts of the UK; and at least 1.5 years in soil in the Netherlands, and 2 years in infested chipped woody material (M. Steeghs, Plant Protection Service, Netherlands, *personal communication*).

1.25. How likely is it that existing pest management practice will fail to prevent establishment of the pest?

very unlikely, unlikely, moderately likely, likely, **very likely**

Very likely

Level of uncertainty: Low

Existing pest management approaches in nurseries are very unlikely to prevent establishment in both nurseries and in the landscape.

In both Europe and North America, the pathogen has become established in nurseries in the presence of existing management practices that include the widespread use of fungicides applied against oomycetes. Indeed, resistance to some pesticides such as metalaxyl-M is already reported for *P. ramorum* (Wagner *et al.*, 2006, 2008; Turner *et al.*, 2008; Turner *et al.*, 2008c). There are no current practices based on cultivar resistance for hardy ornamental nursery stock that would prevent or reduce the likelihood of introduction; the host range is very wide.

There are no pest management practices in gardens, public greens or managed and semi-managed woodland that would prevent establishment of *P. ramorum*. However, the policy of removing rhododendron from woodlands in north west Europe (principally UK and Ireland), because of its invasive behaviour, would have the additional advantage of removing the most important foliar host of *P. ramorum* in these locations and thereby reduce the probability of establishment in areas where clearance is successful and maintained.

1.26. Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the PRA area?

Note: Some pests can be eradicated at any time (survival is very unlikely), others at an early stage (moderately likely) and others never (very likely). Similarly, incursions of some pests may be difficult to find and/or delimit (very likely). Note that intentionally imported plants may need to be eradicated from the intended habitat as well as from the unintended habitat. Some plants should be eradicated before fructification.

very unlikely, unlikely, **moderately likely**, likely, very likely.

Moderately likely

Level of uncertainty: Medium

There are various biological characteristics that would contribute to the pathogen's ability to potentially survive eradication programmes in both nursery situations and in the landscape. These are primarily its ability: to produce thick-walled chlamydospores that can survive long periods in soil or debris; to recolonise new growth from cut stumps of established shrubs/trees and to colonise and persist in roots of some host species; to persist in the aquatic environment, though the epidemiological significance of this is uncertain at the landscape level; to disperse larger distances than is possible by splash dispersal (typically up to 10–15m) alone, including via turbulent air (1km or up to 3–5km) or via contaminated soil/debris attached to feet, thereby reducing the effectiveness of buffer zones or *cordon sanitaires*; to infect a very wide range of host species; to develop resistance to some commonly-used fungicides.

Chlamydospores in soil, growing media or plant debris:

The pathogen's ability to produce long-lived and thick-walled chlamydospores that enable it to survive at least several years under suitable climatic conditions is probably the most important characteristic that would enable *P. ramorum* to survive eradication programmes. Under temperate conditions, as in the UK and Netherlands, the pathogen has been shown to survive in the soil for several years after removal of rhododendron (Turner *et al.*, 2005, 2008b; Turner, 2007; Aveskamp *et al.*, 2005). Survival of chlamydospores is likely to be reduced in climates with prolonged periods of very cold weather where temperatures fall significantly below freezing

(Turner *et al.*, 2008b). Similarly, chlamydospores survive less well during prolonged exposure to high temperatures and/or dry conditions (see *Section 1.19*). However, studies in California have shown that although survival in litter and soil declines significantly over the very hot and dry summer period (Davidson *et al.*, 2005; Fitchner *et al.*, 2006, 2007), the pathogen is still able to over-summer in soil in Mediterranean-type climates in buried debris or in bulk soil (Fitchner *et al.*, 2005, 2006), as well as in infections on leaves of evergreen hosts especially California bay laurel.

In the nursery environment, survival after eradication measures is considered to primarily be due to survival of the pathogen in the underlying soil or debris, presumably as chlamydospores, though there is the possibility that it could also be surviving as root infections (see below) or sporangia and/or chlamydospores in growing media of potted plants (Linderman and Davis, 2006). In the UK, emergency measures have resulted in a decline in the number of positive inspections on nurseries, decreasing from 2.7% in 2003, to 1.9% in 2004, to 1.1% in 2005 and 0.8% in 2006 (Slawson *et al.*, 2008). At the European level, the number of new outbreaks in nurseries has declined from 255 in 2004, to 203 in 2005, to 108 in 2006 (Slawson *et al.*, 2008). Based on the experience of the UK and the Netherlands, and questionnaire responses from other Member States, the destruction of associated debris and growing media was added to the EU emergency measures in May 2007, as well as phytosanitary measures (e.g. disinfection/decontamination) applied to the growing surface within a 2 m radius of infected plants.

<u>Survival in or with living plant material:</u>

After the removal of infected rhododendrons and other shrubs from landscape outbreaks in Europe, the pathogen is able to re-infect regrowth from cut stumps (Turner *et al.*, 2006; Aveskamp *et al.*, 2005; de Gruyter and Steeghs, 2006). This can occur through two main avenues: (a) via the stump directly, most likely as a result of the stump/bark becoming infected via inoculum splashed from the soil surface on to the cut surfaces of the stump (or, potentially, systemically via root infections – but his has not been observed to date), in which case infections spread up from the base of the shoot; or (b) indirectly via inoculum splashed vertically from contaminated soil or debris, in which case infections typically occur on individual leaves or progress downwards from the shoot tips (Turner *et al*., 2006; Turner, 2007). This highlights the importance of preventing rhododendron regrowth, either by fully removing stumps, or by treating stumps with herbicides. In Oregon, where eradication efforts have also focused on removal of infected (tanoak) plants, the pathogen behaves similarly with respect to being able to infect and persist in re-growth (Kanaskie *et al.*, 2008; Goheen *et al.*, 2007). Eradication and containment efforts based on tanoak removal and treatment of stumps with herbicides to prevent regrowth have been largely successful, though the pathogen can still be detected in soil and watercourses at outbreak sites (Hansen, 2008; Goheen *et al.*, 2007; Kanaskie *et al.*, 2008); this compares to the rapid development of the epidemic in Humbolt country, California where eradication measures were not rapidly implemented (Hansen, 2008).

In the case of rhododendron, re-growth in the form of seedlings should similarly be managed to prevent new infections. Seedlings are most likely to become re-infected via inoculum that is splashed up from the soil; however, there is also evidence that *P. ramorum* can colonise roots of rhododendron (Fitcher *et al.*, 2008, 2008a; Lewis *et al.*, 2004; Parke and Lewis, 2007; Riedel *et al.*, 2008) and also tanoak seedlings (Parke *et al.*, 2006) and there is therefore the potential for survival in roots and potentially for systemic colonisation, though the latter has not yet been fully proven. This ability to survive in roots, mostly as asymptomatic infections may also enable the pathogen to survive eradication programmes since it may enable the pathogen to persist below ground for longer periods of time. *P. ramorum* has also been shown to survive cryptically on the aerial parts of some hosts. On deciduous magnolias that are only leaf-blight hosts, *P. ramorum* can survive over the winter in the UK by means of bud or leaf scar infections that give rise to infected leaves the following spring (Denman, 2008). In California, the pathogen survives over the hot, dry summer period as infections on evergreen California bay laurel (*U. californica*), whereas it is only rarely detected in soil during this summer period (Davidson *et al.*, 2005; Rizzo *et al.*, 2005; Fitchner *et al.*, 2006).

In nurseries, there is the potential for *P. ramorum* to persist undetected as infections/colonisations of roots of host plants (Lewis *et al.*, 2004; Lewis and Parke, 2005; Parke *et al.*, 2002a; Parke and Lewis, 2007; Shishkoff, 2007, 2008; Kessel *et al.*, 2007). It can also potentially survive in contaminated growing media (Linderman and Davis, 2006) of both host and non-host material, via both sporangia and chlamydospores. This ability for the pathogen to persist as propagules in growing media or undetected in host roots, is a characteristic that could enable the pathogen to survive the eradication measures on nurseries and increase the possibility of disease re-occurring or of spreading undetected.

Host range:

The very wide host range could have a negative impact on the success of eradication programmes or measures. In the case of nursery stock, current EU emergency measures for outbreaks on nurseries are applied only to known susceptible hosts (in relation to distances from symptomatic plants). Currently, this involves: destruction of susceptible plants within 2m of infected plants; holding known susceptible hosts within 10m of infected plants (Anon., 2002, 2004, 2008). However, the host list is continually expanding and the full range of host genera and species is not known. Susceptible plant species that are not currently known hosts could therefore be infected and not be encompassed in current measures, both in terms of actions at nursery outbreaks (if infections not detected) and in terms of regulations governing movement in trade, e.g. EU plant passporting requirements presently only apply to the three most significant hosts (rhododendron, excluding *R. simsii*, viburnum and camellia), therefore eradication efforts could be compounded by re-introductions of *P. ramorum* by non-passported hosts (e.g. *Pieris*, *Kalmia*, *Magnolia*, etc). The current wide host range, and its potential to increase, is therefore a factor that is challenging for regulators and which could reduce the effectiveness of measures.

Dispersal potential, mechanisms and pathways:

P. ramorum sporangia are typically splash-dispersed over short distances by rain. In the case of small nursery plants, this is considered to be mostly within 1m of the infected plant, though spores could potentially be dispersed longer distances (considered to be up to 10m) via wind-blown rain (Gregory 1973; Fitt *et al.*, 1989; Davidson *et al.*, 2005; Tjosvold *et al.*, 2005; Chastagner *et al.*, 2008). EU emergency measures in relation to nursery outbreaks are based on these typical splash-dispersal distances. However, *P. ramorum* can also be spread in nurseries via wind-blown infected debris which could reduce the impact of measures that are based solely on splash-dispersal distances. Uninfected host debris can also act as a bait; it can be colonised from inoculum in the soil or in water and the pathogen can then multiply further and spread from this colonised debris. In this respect, the EU emergency measures were strengthened in May 2007 through the added requirement to destroy associated debris and growing media. There is also the potential for spores (sporangia and zoospores) to be spread via surface water or in contaminated irrigation water (Werres *et al.*, 2007a; Seipp *et al.*, 2008; Ufer *et al.*, 2008; Jennings *et al.*, 2008) since the pathogen readily survives, multiplies and disperses in water. Spread can also occur via the movement of contaminated soil/debris on footwear (Cushman *et al.* 2005, 2008; Tjosvold *et al.*, 2002a; Webber and Rose, 2008).

In the landscape, the pathogen can be dispersed naturally over greater distances than by splash-dispersal alone, thereby potentially confounding eradication measures. The most significant means for natural longer-distance dispersal are through aerial dispersal via turbulent air (Hansen, 2008; Peterson *et al.*, 2007) and via movement of contaminated soil/debris attached to footwear (Cushman *et al.* 2005, 2008; Tjosvold *et al.*, 2002a; Webber and Rose, 2008). In the case of aerial dispersal, turbulent air in Oregon has been proposed as the means by which *P. ramorum* is dispersed several kilometres within infected woodlands in Oregon, USA (Hansen, 2008). Initial buffer zones in 2001 of 15-30m around infected trees were ineffective and have more recently been increased to 100m (Goheen *et al*., 2007; Kanaskie *et al.*, 2008): about half of new infections occur within 100m of previously infected trees, but there is a long tail which can extend for up to 3 km (Hansen, 2008; Rizzo *et al.,* 2005). In 2006, new outbreaks 1.5 to 2.5 km outside the Oregon quarantine zone were best explained by dispersal in turbulent air since these infections typically originated in the crowns of tanoak (*L. densiflorus*) trees (Hansen, 2008; Kanaskie *et al.*, 2008). There is evidence for this relatively rare longer-distance dispersal in California also. Mascheretti *et al.* (2008) showed potential dispersal gradients with one peak at 10–15m (splash-dispersal), declining to about 300m but then increasing to a second peak at 1 km (turbulent air during storms). In the UK, *P. ramorum* has been detected in spore traps about 50m from the nearest inoculum source and associated with storm events (Turner, 2007). *P. ramorum* is also found in watercourses (Beales, 2007; Tjosvold *et al.* 2002; Davidson *et al.*, 2005; Turner *et al.*, 2006), though the epidemiological significance of inoculum in water courses is not yet certain; *P. ramorum* can be detected a few kilometres downstream of areas of host infection.

<u>Pesticide resistance or tolerance</u>:

Current EU emergency measures (Anon., 2002, 2004, 2008) do not permit the use of anti-*Phytophthora* fungicides at nursery outbreak sites. However, if measures were amended to allow the use of fungicides it is likely that *P. ramorum* would survive treatment of infected or potentially infected plants. This is because the use of fungicides is very rarely 100% effective and many are considered fungistatic rather than fully fungitoxic to *Phytophthora* spp.. There are also increasing risks of resistance developing; indeed isolates of *P. ramorum* with resistance or reduced sensitivity to metalaxyl-M are already reported in Europe (Wagner *et* al, 2006, 2008; Turner *et al.*, 2008; Turner *et al.*, 2008c). Pruning combined with subsequent fungicide applications on large, valuable, established rhododendrons in historic gardens has also been shown to be relatively ineffective (Turner, 2007).

Disinfectants applied to inert surfaces are almost certain to be effective when applied in the absence of organic matter and at the correct duration and temperature (Jennings *et al.*, 2008). However, they are rarely effective when applied in the presence of organic matter (Jennings *et al.*, 2008; Turner, 2007). Water can be relatively easily decontaminated with disinfectants: Jennings *et al.* (2008) reported that water was successfully decontaminated of *P. ramorum* following a 5 min exposure to either Jet 5 or a 10% bleach solution; chlorine dioxide was also effective, though lower concentrations required longer exposure times (500 and 50 ppm solutions of chlorine dioxide required less than 5 and 60 minutes respectively to decontaminate water containing *P. ramorum* sporangia).

There are only limited reports on the effectiveness of soil sterilisation methods, but those tested include solarisation and the use of dazomet. Yakabe and MacDonald (2008) reported that, in initial experiments, *P. ramorum* was still detectable after dazomet (Basamid®, 158.77 kg/0.4 ha) was applied to an infested nursery site and sealed with a water cap, as opposed to a polyethylene tarpaulin. However, in tests at three infected nurseries, Basamid® (158.76 kg/0.4 ha) was effective when incorporated throughout the soil profile and sealed with a polyethylene tarpaulin for 14 days. Decontamination was not achieved in other nurseries that could not apply fumigants and which applied hypochlorite, quaternary ammonia, or phosphates to the soil instead. The efficacy of soil solarisation or steam treatments, as alternatives to the use of fumigants, is not fully known. However, *P. ramorum* is highly heat tolerant and can survive 1 week at 55°C in Californian bay laurel leaves (Harnik *et al.*, 2004).

Other characteristics of the pest affecting the probability of establishment

1.27. How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment?

> *Note: consider characteristics which would enable the pest to reproduce effectively in a new environment, such as parthenogenesis/self-crossing, short life cycle, number of generations per year, resting stage, high intrinsic rate of increase, self fertility, vegetative propagation, production of viable seeds, prolific seed production, formation of a persistent seed bank or offspring bank. For a pest transmitted by a vector the reproductive strategy of the vector should also be taken into account.*

very unlikely, unlikely, moderately likely, **likely**, very likely

Likely

Level of uncertainty: Low

P. ramorum has a flexible and adaptive reproductive strategy that would favour establishment, producing various asexual spores with different functions under different conditions. Sporangia and zoospores have a primary dispersal and infection function. Sporangia germinate indirectly under moist conditions by releasing motile zoospores at cool temperatures (typically ≤20°C) (Davidson *et al*., 2005). At higher temperatures, sporangia tend to germinate directly by the production of hyphae, which can then produce further sporangia. Further adaptive behaviour includes the ability of encysted zoospores to produce further motile zoospores, so called repetitive diplanetism (Moralejo *et al.*, 2006b). Zoospore cysts may therefore provide an additional survival function.

Chlamydospores principally have a survival function, but can also be involved in dispersal, e.g. via movement of contaminated soil/debris. The production of chlamydospores favours establishment as it allows the pathogen to survive a range of adverse conditions and in the absence of a host plant or susceptible plant part.

P. ramorum can also potentially reproduce sexually and produce long-lived oospores. It is an outcrossing (heterothallic) species and therefore requires the presence of two opposite mating types for sexual reproduction. A heterothallic sexual-reproduction strategy is arguably less favourable for the establishment of exotic pathogens than a homothallic (self-fertile) strategy since both mating types may not be present during limited introductions, or one mating type may be more prevalent that the other. This has been the case with *P. ramorum*, where isolates of the North American lineages introduced to California have only the A2 mating type within the population (Ivors *et al.*, 2006), and isolates of the European lineage (EU1) introduced to Europe almost exclusively have the A1 mating type, though three A2 isolates of the EU1 lineage have been reported in Belgium (Werres and de Merlier, 2003). However, there is some uncertainty over whether the mating system is fully functional in *P. ramorum* (Brasier *et al.*, 2007; Brasier and Kirk, 2004; Brasier *et al.*, 2004; Boutet and Chandelier, 2007). New evidence suggests that the lineages introduced separately to Europe and to the USA have been diverged for several hundred thousand years although their ancestors were part of a sexually reproducing outcrossing population (Goss and Grünwald, 2008). It is suggested that the three known lineages (NA1, NA2, EU1) may have been introduced from three separate geographic areas (Goss and

Grünwald, 2008). If the mating system were functional, then the production of oospores could favour establishment since, like chlamydospores, they are likely to facilitate longer-term survival.

In terms of its life cycle duration and generation times, establishment is favoured by its fairly generalist nature: it is a necrotrophic pathogen that is able to infect and sporulate on foliage of a wide range of hosts. It also has relatively short latent periods (time from infection to production of infectious spores). Under optimal conditions, lesions have been found to develop on rhododendron leaves within 3 days of inoculation (Turner *et al.*, 2005) and after 14 days even at 0°C. Sporangia can then be produced relatively quickly (as quickly as 3 days of inoculation) under suitable temperature and moisture conditions, or even prior to symptom development (Denman *et al.*, 2008; Moralejo *et al.*, 2006; Vettraino *et al.*, 2007) on both foliage and fruits. Sporangia can be produced across a relatively broad range of relative humidities from 62 to 100%, with 93% to 100% being optimal. The effect of temperature is more significant than changes in humidity. However, sporangial production can still occur within a relatively broad range from 10–30°C (Englander *et al*, 2006; Turner *et al.*, 2008). Under optimal conditions, generation times can be considered relatively rapid, thus favouring establishment and spread. The life cycle duration is extended under adverse conditions via chlamydospores in leaves, debris and soil.

1.28. How likely are relatively small populations to become established?

> *Note: if very small populations are known to survive for long periods in their area of current distribution, such evidence may be used to answer this question. For plants, is the species able to hybridise freely? Is the species polymorphic, with, for example, subspecies? Is the species self-compatible? Does the species reproduce by vegetative fragmentation?*

No judgment, very unlikely, unlikely, moderately likely, **likely**, very likely

Likely

Level of uncertainty: Low

Small populations are likely to become established. In its current distribution in both the USA and Europe, there is evidence that isolated populations of relatively low genetic diversity can thrive and survive, even under eradication measures, e.g. in Oregon (Kanaskie *et al.*, 2008; Prospero *et al.*, 2008). Mascheretti *et al.* (2008) showed that the clonally reproducing population (lineage NA1) in California could generate new genotypes locally and therefore change and adapt. The pathogen's asexual reproductive cycle that involves both sporangia (for dispersal and infection) and chlamydospores (for survival), and lack of any need specific need for sexual reproduction, would enable small populations to become established and survive. Its wide host-range will ensure that it is not restricted by availability of susceptible plant material.

1.29. How adaptable is the pest?

> *Note*: *is the species polymorphic, with, for example, subspecies or pathotypes? Is it known to have a high mutation rate? Does it occur in a wide range of climate and habitats? Such evidence of variability may indicate that the pest has an ability to withstand environmental fluctuations, to adapt to a wider range of habitats or hosts, to develop resistance to plant protection products and to overcome host resistance.*

Adaptability is:
very low, low, **moderate**, high, very high

<u>Moderate</u>

Level of uncertainty: <u>Low</u>

P. ramorum is moderately adaptable. Genetically, the existence of separate and divergent populations in its two areas of introduction (North American versus European) indicates that it can readily evolve. Goss and Grunwald (2008) suggest that the North American and European populations diverged up to 500,000 years ago. At the local level, Mascheretti *et al.* (2008) demonstrated the ability for the clonally reproducing California population to generate new genotypes through mutation even in the absence of sexual reproduction. *P. ramorum*'s ability to adapt would be enhanced by sexual reproduction, although the mating system does not appear to be fully functional (Brasier *et al.*, 2007; Brasier, 2005; Boutet and Chandelier, 2007). Even in the absence of sexual reproduction, genetic recombination might occur through somatic hybridisation (Brasier, 2008; Brasier *et al*., 2006), e.g. via zoospore fusion.

However, although it is thought that the EU1, NA1 and NA2 lineages may have diverged up to 500,000 years ago (Goss and Grünwald, 2008; Goss *et al.*, 2008), there are very few significant differences in host specificity and they are considered conspecific. EU1 and NA1 lineages demonstrate almost identical host ranges in laboratory tests (Brasier, 2005; Inman *et al.*, 2005; Moralejo *et al.*, 2008; Kessel *et al.*, 2008). Their very wide host range in their areas of introduction indicate an inherent ability to adapt and accommodate new hosts and habitats. Climatically, *P. ramorum* has been found to establish and survive in a wide range of climates, ranging from Mediterranean climates in California and Oregon with a prolonged hot and dry period, to climates in Northern Europe that are cooler and wetter. Potentially adaptive phenotypic differences between the EU1 and NA1 lineages have been shown in growth x environment tests (Brasier, 2005). EU1 isolates are uniform in growth rate and appearance and on average faster growing, whereas NA1 isolates show extensive growth rate and phenotypic variation (Werres and Kaminski, 2005; Huberli *et al.*, 2006; Brasier, 2005 ; Brasier *et al.*, 2006). NA1 isolates have a slightly higher upper temperature limit for growth than EU1 isolates. EU1 isolates are on average more aggressive (Brasier *et al.*, 2006). The differences are likely to reflect underlying genetic differences in genes governing fitness attributes of the EU1 and NA1 lineages. However, it is uncertain whether these differences are due to selection pressures before or after introduction (Brasier *et al.*, 2006). Further adaptive ability has been shown by the development of fungicide resistance to metalaxyl-M in European isolates exposed to its use in nurseries (Wagner *et al.*, 2006, 2008; Turner *et al.*, 2008; Turner *et al.*, 2008c).

1.30. How often has the pest been introduced into new areas outside its original area of distribution? (specify the instances, if possible)

> *Note*: *if this has happened even once before, it is important proof that the pest has the ability to pass through most of the steps in this section (i.e. association with the pathway at origin, survival in transit, transfer to the host or habitat at arrival and successful establishment). If it has occurred often, it suggests an aptitude for transfer and establishment.*

never, very rarely, rarely, **occasionally**, often, very often

<u>Occasionally</u>

Level of uncertainty: <u>Low</u>

P. ramorum is considered to have been introduced separately to North America (NA1 and NA2 lineages) and to Europe (EU1 lineage) via very occasional events that are considered to have occurred relatively recently, e.g. potentially in the last 20–30 years based on genetic studies (Ivors *et al.*, 2004, 2006; Mascheretti *et al.*, 2008); the area or areas of origin are unknown. Once introduced to North America and to Europe, more regular introductions and spread from the initial points of entry have occurred. E.g. From California, introductions have been made to many other US states and to Canada. The EU1 lineage has also spread to many other European countries after its original introduction, and recently also to nurseries in the Pacific Northwest of the USA, though the source is unknown (but assumed to be Europe).

In the case of North America, there are believed to have been two initial escapes into woodlands around the San Francisco bay area of California from initial introductions with nursery stock (Mascheretti *et al.*, 2008). From those early introductions, the pathogen has clearly spread, and established, elsewhere in California, as well as one woodland area in southern Oregon (Frankel, 2008). The two lineages (NA1 and NA2) are thought most likely to have been introduced simultaneously (Martin, 2008). In Europe, the pathogen was first detected in Germany and the Netherlands in the early 1990's (Werres *et al.*, 2001) and has since spread to other European countries. In both Europe and the USA, the very limited degree of genetic variation in the populations suggests recent and limited introductions (Ivors *et al.*, 2006; Brasier, 2008, 2008a).

1.31. If establishment of the pest is very unlikely, how likely are transient populations to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment)?

Note: *Non-applicable applies when establishment has already been observed in the PRA area. Transience is defined as the presence of a pest that is not expected to lead to establishment [ISPM No. 8, 1998]*

N/A, very unlikely, unlikely, moderately likely, likely, very likely

<u>N/A</u>

Level of uncertainty: <u>Low</u>

<u>Conclusion on the probability of establishment</u>

There is a significant probability that *P. ramorum* could establish in wider areas of the EU than its current distribution. This is based upon its known and potential host range, climatic factors, current cultural practices and the biology of the pathogen itself.

P. ramorum has a very wide host range. This includes many important shrubs and trees of ornamental and environmental importance; the host range is likely to continue to expand. There are many suitable habitats including a variety of different types: woodland (managed, semi-natural or natural habitats), heathland, maquis (macchia) shrubland, managed gardens/parks/public greens, especially those that have a heritage or historic value. Many of the potentially at-risk habitats are covered by the EC Habitats Directives. In northern Europe, trees in the family Fagaceae which have susceptible bark (especially species of *Quercus* and *Fagus*) are considered most at risk, although trees in other families are also potentially at risk. However, tree species with susceptible bark are only likely to be at high risk if they occur in close association with foliar hosts capable of supporting significant sporulation (e.g. rhododendron, especially *R. ponticum*), or if they themselves are also foliar hosts. In southern Europe, evergreen oak woodlands are among the most widespread forest ecosystems in the Mediterranean basin (especially Mediterranean holm oak woodlands). These, and laurel forests (laurisilva), are considered most at risk in this area since establishment could be possible on a range of foliar hosts, especially tree and understorey species such as *Quercus ilex*, *Rhamnus alaternus*, *Viburnum tinus,* and *Arbutus unedo,* all of which have the potential to support moderate to high levels of sporulation. Mediterranean semi-deciduous forests might also be locally at risk where suitable understorey species and climatic conditions are favourable. Example of these are areas of southern and northeast Spain with forests composed of *Q. canariensis* and *Q. suber* and *R. ponticum* and/or *V. tinus* as understorey species. Most of these Mediterranean forests are very unlikely to have been exposed to the pathogen so far. Heathland species, especially those in the genus *Vaccinium*, are also at risk as they have been shown to be particularly susceptible and can support significant sporulation.

P. ramorum is likely to establish outside of nurseries in a variety of climatic zones, based on climate risk mapping. *Atlantic Central* and *Lusitanian* climatic zones are most suitable for establishment based on a range of climatic risk models. However, *Mediterranean* and *Atlantic North* climates are also potentially favourable, especially in coastal locations. Although mild and wet climates are most likely to favour disease development and establishment, the pathogen's ability to form long-lived chalmydospores enables it to survive Mediterranean climates with hot and dry summers, as demonstrated in California, and potentially also colder climates with cold winters.

Finally, pre-existing cultural and control practices are unlikely to prevent establishment and, indeed, have already failed to do so in some parts of the PRA area, both on nurseries and in managed gardens or public greens and managed woodland. The wide host range, ability to produce long-lived chlamydospores and to survive in soil and water favours establishment.

Probability of spread

Spread potential is an important element in determining how quickly impact is expressed and how readily a pest can be contained. In the case of intentionally imported plants, the assessment of spread concerns spread from the intended habitat or the intended use to an unintended habitat, where the pest may establish. Further spread may then occur to other unintended habitats. The nature and extent of the intended habitat and the nature and amount of the intended use in that habitat will also influence the probability of spread. Some pests may not have injurious effects on plants immediately after they establish, and in particular may only spread after a certain time. In assessing the probability of spread, this should be considered, based on evidence of such behaviour.

1.32. How likely is the pest to spread rapidly in the PRA area by natural means?

Note: consider the suitability of the natural and/or managed environment, potential vectors of the pest in the PRA area, and the presence of natural barriers. Spread depends on the capacity of a pest to be dispersed (e.g. wind dispersal) as well as on the quantity of pest that can be dispersed (e.g. volume of seeds).

Natural spread can result from movement of the pest by flight (of an insect), wind or water dispersal, transport by vectors such as insects, birds or other animals (internally through the gut or externally on the fur), natural migration, rhizomial growth. Spread is defined as the expansion of the geographical distribution of a pest within an area [FAO, 2007] very unlikely, unlikely, **moderately likely**, likely, very likely

Moderately likely

Level of uncertainty: Low

P. ramorum is only moderately likely to spread rapidly by natural means. The rate of spread will depend on a variety of factors, including: pathogen factors, most importantly those relating to spore production, spore dispersal and pathogen survival (i.e. infection pressure); host factors, especially the availability of hosts that support the pathogens full life cycle (i.e. foliar hosts) and the degree of connectivity or fragmentation of susceptible habitats/hosts; climatic factors, especially those conditions that influence the degree of infection pressure.

Natural dispersal occurs primarily by rain splash at a local level, with typical dispersal distances being in the order of up to 10–15(–25)m depending on topography and habitat architecture (plant community structure, plant height, etc) (Davidson *et al.*, 2005; Rizzo *et al.*, 2005; Chastagner *et al*., 2008; Mascheretti *et al.*, 2008). More rarely, aerial dispersal in turbulent air could result in longer-distance spread up to several kilometres (typically 1 km, but up to 3–5 km), as suggested by Oregon (Hansen, 2008; Kanaskie *et al.*, 2008) and Californian studies (Mascheretti *et al.*, 2008; Rizzo *et al*., 2005). The frequency of such longer-distance dispersal events via turbulent air will most likely depend on the frequency of the storm events responsible, the area of infected plants and amount of inoculum at the source, and the presence/abundance/density of hosts at the distances where inoculum is deposited. This highlights the importance of both climatic and host factors in determining the potential for the pathogen to spread rapidly. In California, fragmentation of susceptible woodlands (Condeso and Meentemeyer, 2007), combined with limited long-distance dispersal events, has contributed to a relatively low rate of spread. As such only about 20% of areas considered to be at risk from *P. ramorum* have so far become infected (Meentemeyer *et al.*, 2008a; Condeso and Meentemeyer, 2007, 2008). In Europe, rapid natural spread beyond the local scale has not yet been observed. Most infections outside of nurseries have been attributed to the human-mediated movement of infected plants, though there is some statistical evidence for natural spread from nurseries to nearby (within 1 km) semi-natural environments (Jeger, 2008).

More rapid and longer-distance natural spread could also occur via the movement of contaminated soil on the feet of animals, via wind-blown debris, or via inoculum in water courses, though the significance of the latter two dispersal pathways is not yet established.

1.33. How likely is the pest to spread rapidly in the PRA area by human assistance?

> *Note: consider the potential for movement with commodities or conveyances*, *the fact that the species is intentionally dispersed by people, the ability of the pest to be unintentionally dispersed along major transport routes. As for 1.32, consider the capacity to be spread as well as the quantity that can be spread. For intentionally introduced plants consider spread to the unintended habitat.*

very unlikely, unlikely, moderately likely, likely**, very likely**

Very likely

Level of uncertainty: Low

The pathogen is very likely to spread rapidly by human-mediated means, most significantly through the commercial movement of infected plants for planting. This is amply demonstrated by the increase in the numbers of nurseries in the USA (despite regulatory actions) that have become infected, or have received infected plants, since the first US nursery finding in 2001. Of particular note, was the movement of millions of potentially infected plants from just a few large north-west coast nurseries in 2004 to 39 US states (Frankel, 2008; McKelvey *et al.*, 2008); subsequently infected plants were confirmed in at least 20 of the receiving states. In Europe, *P. ramorum* has also spread to the majority of EU countries since first being described in 2001, though it is detected at a relatively low frequency (typically <1–5% of nurseries infected). Almost every year since the first findings, new European countries have found *P. ramorum*; there has also been an increase in the numbers of countries reporting *P. ramorum* outside of nurseries. Modelling of the ornamental trade network in the UK has suggested that a scale-free network may best describe the network structure. Scale-free networks are characterised by super-connected nodes and have a low epidemic threshold; therefore the pathogen could spread rapidly through the network in the absence of controls (Jeger *et al.*, 2007) and then into the environment. In addition to the movement of infected planting material, *P. ramorum* can also be spread by humans through contaminated soil/debris attached to footwear (Tjosvold *et al.*, 2002a; Cushman and Meentemeyer, 2005; Cushman *et al.*, 2008; Webber and Rose, 2008) and potentially also on tyres of bike and cars. Risks of spread through other human-mediated means, such as the movement of potentially infected wood, bark, cut foliage, seeds or fruits is considered less important for rapid spread, primarily due to the end use of the material. However, there is a risk of reintroduction where this material is recycled through composting as there is no guarantee of eradication via this disposal route.

1.34. Based on biological characteristics, how likely is it that the pest will not be contained within the PRA area?

> *Note*: *consider the biological characteristics of the pest that might allow it to be contained in part of the PRA area. For intentionally introduced plants consider spread to the unintended habitat.*

very unlikely, **unlikely, moderately likely**, likely, very likely

Moderately likely

Level of uncertainty: Low

It is moderately likely that *P. ramorum* could not be contained within the PRA area, based on its biological characters. The main biological factor that favours containment is its relatively limited ability for long-distance natural spread: it is mainly a splash-dispersed pathogen that is much more rarely moved longer distances via turbulent air (e.g. during storm events) or via contaminated soil/debris attached to footwear etc. Successful containment is however threatened by the pathogen's very wide host range, which is a significant challenge for regulation of trade in plant material. The host range is likely to continue to grow and, as such, potential hosts will initially escape current statutory controls. On the other hand, the predominance of some specific ornamental hosts (rhododendron, viburnum and camellia) as 'super-spreaders' within trade networks would favour containment measures being successful if measures were targeted at major nodes (i.e. production nurseries/wholesalers and/or major distribution centres) and these super-spreaders (Jeger, 2008), even if less significant hosts were not so closely regulated (e.g. via plant passporting).

Go to conclusion on the probability of spread

Conclusion on the probability of spread

P. ramorum is very likely to spread quickly throughout the nursery network within the PRA area in the absence of statutory controls on host plants for planting. This is due to its very wide host range and the likely characteristics of the trade network itself. Spread from nurseries in to the environment will be facilitated by the planting of infected plants; potential natural spread from nurseries in to semi-natural or natural habitats is likely to be relatively slower. Similarly, natural spread within the semi-natural or natural environment is likely to be relatively slow due to the pathogen's somewhat poor ability to disperse very long distances naturally, especially in spatially heterogeneous landscape where susceptible habitats/hosts may be fragmented. However, in more homogenous landscapes where there is an abundance of continuous hosts, spread could be significantly more rapid. Although speed of spread is highly relevant to determining the likelihood of containment being successful or not at the spatial scale, it may not be entirely relevant to overall impact at a longer-term temporal scale.

Go to Conclusion on the probability of introduction and spread

Conclusion on the probability of introduction and spread

In the absence of phytosanitary measures the highest risk of entry ('*high*') of *P. ramorum* into the EU is on plants for planting of host plants from the area, or areas, of origin, as well as from the USA (see Table 14). Uncertainty is highest ('*medium*') for plants for planting from the pathogen's origin(s) since: (a) the area/s of origin for *P. ramorum* are unknown; (b) the host range in the area of origin is unknown; (c) it is uncertain whether specific phytosanitary controls will be in place for host material from the area of unknown origin; (d) entry has already occurred at least once in Europe, as well as in the USA. Uncertainty on the risk of entry on plants for planting of host plants from the USA is '*low*'. There is a '*medium*' risk of entry into Europe on plants for planting of host plants from Canada and from non-EU countries in Europe where the pathogen is recorded (Norway/Switzerland) with a '*low*' level of uncertainty for both pathways. Soil as a commodity carries a '*medium*' risk of entry from all potential sources with a '*low*' level of uncertainty. Susceptible isolated bark represents a '*medium*' risk of entry from the USA and from the unknown area or areas of origin with a '*low*' level of uncertainty but a '*very low*' level of risk of entry from Canada and the non-EU European countries ('*low*' uncertainty for both) since *P. ramorum* has not been found in forests in these countries. All other pathways (soil as a contaminant, foliage and cut branches of susceptible hosts, seeds and fruit and susceptible wood from all known or potential origins) have a '*low*' or '*very low*' risk of entry with a '*low*' level of uncertainty. Establishment is favoured by the pathogen's wide host range and its ability to produce long-lived chlamydospores that facilitate survival. Mild and wet climates are most favourable for both establishment and spread: moist, humid conditions and moderate temperatures favour sporulation and infection, whilst rainfall is important for dispersal since sporangia are primarily splash- dispersed. Despite this, Mediterranean climates with a prolonged hot and dry period are still likely to support establishment: chlamydospores would most likely enable over-summering (as in California), whilst the cooler and wetter winter period would provide suitable conditions for disease development and spread. Regardless of the climatic regime, establishment and spread in the semi-natural and natural environment will depend on the presence and spatial distribution of host plants, especially foliar hosts that are responsible for driving spore production. In northern Europe, in the case of woodlands, this is most importantly the presence of rhododendron, especially *R. ponticum*. In other areas where rhododendron is not present in woodlands, other foliar hosts could play a significant role, especially *Q. ilex* (especially in southern Europe) and various laurophyllous and sclerophyllous understorey shrubs in Mediterranean habitats. Lowland heaths are likely to support establishment since the pathogen is likely to be self-sustaining on a range of ericaceous species, based on laboratory studies, and the climates of north-west Europe where these habitats occur favour the pathogen. Natural spread in the semi-natural or natural environment is likely to be relatively slow if it is limited primarily to local splash-dispersal by rain and restricted by fragmented host landscapes (i.e. non-contiguous host distribution), therefore increasing the likelihood of containment measures being successful.

Go to 1.35

Conclusion regarding endangered areas

1.35. Based on the answers to questions 1.16 to 1.34 identify the part of the PRA area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.

Note: The PRA area may be the whole EPPO region or part of it. The endangered area may be the whole of the PRA area, or part or parts of the area (i.e. the whole EPPO region or whole or part of several countries of the EPPO region). It can be defined ecoclimatically, geographically, by crop or by production system (e.g. protected cultivation such as glasshouses) or by types of ecosystems.

Nurseries involved with hardy ornamental plants across the whole PRA area are likely to be favourable for *P. ramorum* to establish. In this context, the whole PRA area is an endangered area with respect to cultivated ornamental shrubs and trees (sapling production) due to the wide host range of the pathogen and the general suitability of the nursery environment for disease development and spread.

Timber plantations, especially mixed-deciduous types may be at risk where they have sporulating hosts in them as an understorey and where they fall in the climatic zones highlighted below.

The areas of the PRA area that most favour establishment in non-nursery environments, including parks, managed gardens and public greens, semi-natural (including woodlands) and natural environments based on ecoclimatic factors and the presence of suitable hosts/habitats are as follows:

(1) Areas with *Atlantic Central* and *Lusitanian* climates:
Within these western European climatic zones, habitats or host environments that favour establishment include: gardens and public greens with a diversity of ornamental host plants; woodlands with susceptible tree species, especially those in the family Fagaceae, where rhododendron (especially *R. ponticum*) is present to act as the foliar host and source of inoculum; and heathland habitats with a diverse range of ericaceous plant species, especially *Vaccinium* and *Calluna* species. The *Atlantic north* climatic zone may also favour the pathogen.

(2) *Mediterranean* climates:
Within these climatic zones (*Mediterranean North, Mediterranean South, Mediterranean Mountains*), evergreen oak woodlands and laurel forests are considered most as risk, as are maquis habitats that contain host, or potential host, species.

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Go to 2 Assessment of potential economic consequences

2. Assessment of potential economic consequences

The main purpose of this section is to determine whether the introduction of the pest will have unacceptable economic consequences. It may be possible to do this very simply, if sufficient evidence is already available or the risk presented by the pest is widely agreed. Start by answering Questions 2.1 - 2.10. If the responses to question 2.2 is "major" or "massive" and the answer to 2.3 is "with much difficulty" or "impossible" or any of the responses to questions 2.4, 2.5, 2.7, 2.9 and 2.10 is "major" or "massive" or "very likely" or "certain", the evaluation of the other questions in this section may not be necessary and you can go to 2.16 unless a detailed study is required or the answers given to these questions have a high level of uncertainty. In cases where the organism has already entered and is established in part of the PRA area, responses to questions 2.1, 2.6 and 2.8, which refer to impacts in its area of current distribution, should be based on an assessment of current impacts in the PRA area in addition to impacts elsewhere. *Expert judgement is used to provide an evaluation of the likely scale of impact. If precise economic evaluations are available for certain pest/crop combinations, it will be useful to provide details.* *The replies should take account of both short-term and long-term effects of all aspects of agricultural, environmental and social impact.* *In any case, providing replies for all hosts (or all habitats) and all situations may be laborious, and it is desirable to focus the assessment as much as possible. The study of a single worst-case may be sufficient. Alternatively, it may be appropriate to consider all hosts/habitats together in answering the questions once. Only in certain circumstances will it be necessary to answer the questions separately for specific hosts/habitats.* *Consider potential hosts/habitats identified in question 6 when answering the following questions:*

Pest effects

2.1. How great a negative effect does the pest have on crop yield and/or quality to <u>cultivated plants</u> or on <u>control costs</u> within its current area of distribution?

Note: factors to consider are types, amount and frequency of damage and crop losses in yield and quality, together with costs of treatment.

Minimal, minor, **moderate**, **major**, massive

Excluding the cost of phytosanitary controls, the current impact on <u>cultivated plants</u> (nursery grown ornamental species) is thought to be **moderate** within the areas in which *P. ramorum* occurs in the EU, USA, and Canada. (See comments on uncertainties below). Including the costs of phytosanitary controls the impact is **major.**

<u>Moderate to major</u>

Level of uncertainty:	**<u>Medium</u>**

The current impact on cultivated plants planted-out in managed gardens is **minor** in many EU Member States but locally damaging and **major** in the south-west and west of the UK. This is dealt with under 2.8 as strictly speaking these are not '*crops*'.

Minor to major

Level of uncertainty:	**Medium**

The current impact on timber production in the EU, USA and Canada is **minimal.**

Minimal

Level of uncertainty:	**Low**

The impact in the area or areas of origin is **unknown**, as this has yet to be identified.

Unknown

Level of uncertainty:	**High**

Unusually for a pest subject to an EPPO-style PRA, *P. ramorum* is already present in the PRA area as well as the USA and Canada and is subject to phytosanitary measures in the areas where it occurs. Consequently it is difficult to calculate or estimate a value for the direct effect that the pathogen has on the yield and/or quality of its cultivated host plants, or on the costs of control, since the former has not been evaluated and current control costs arise from the implementation of the phytosanitary measures. It is also difficult to separate out the costs of phytosanitary controls on nurseries from those for non-nursery environments, as this depends upon whether and how these figures have been recorded by the National Plant Protection Organisations (i.e. whether they are separated-out). For these reasons the responses below account for data that have been published or calculated to date, but do not enable a clearly-defined answer to be given to this or to subsequent questions in this section of the PRA. Current and future costs arising from implementation of phytosanitary measures are included, mainly for Great Britain and the USA. Costs for other EU Member States are only available for a few countries based upon enquiries to Project partners up until the end of 2006 (H. Kehlenbeck, JKI, *personal communication*).

In terms of the direct effect on cultivated nursery plants, the pathogen causes quality losses, which can render nursery stock unsaleable because of the symptoms. These affect the leaves, shoots, and buds of a wide-range of species.

A variety of host symptoms can be viewed on the RAPRA website at :
http://rapra.csl.gov.uk/background/hosts.cfm

Also on the Defra website at :
http://www.defra.gov.uk/planth/pramorum4.htm

And on the California Oak Mortality Task Force website at :
http://www.suddenoakdeath.org/html/plant_symptoms.html

Cultivated plants: European nurseries

In the EU, *P. ramorum* mainly affects containerised plants grown on nurseries but to varying degrees. These have been found in Belgium, Czech Republic (eradicated), Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, the Netherlands, Poland, Portugal, Slovenia, Spain, Sweden and the UK (including the Channel Islands).

The current situation and therefore the impacts on nurseries in three EU Member States (Greece, Italy and Luxembourg) is not known. Greece have never reported official surveys to the EC and Italy only did so in 2004 when no positive findings were made. However, a separate report (EPPO, 2004) described a positive finding on a rhododendron on a nursery in Italy in 2002 which was subject to eradication. Luxembourg has not reported findings on nurseries; between 2004 and 2007 they only reported the results of official surveys to the EC in 2006, when 6 premises were inspected along with 4 '*public greens*' (where three positive findings were made).

The majority of hosts affected in the EU have been *Rhododendron*, *Viburnum* and *Camellia* (the three most commonly affected traded genera in the EU) although clearly the host-range is much wider than this. (130 different natural host species across at least 75 plant genera and 37 plant families affected, see Appendix II).

In the EU, the proportion of affected nurseries of those that have been surveyed is low (typically <5% of nurseries surveyed nationally) (RAPRA, Workpackage 1, Year 3 Report).

Specific figures (requested from Eurostat, AIPH Yearbooks on International Statistics of Flowers and Plants (see http://www.ishs.org/partners/aiph/), and national statistics) are not available for the value or quantity of individual genera on nurseries that have been affected in the EU.

Kehlenbeck (2008) estimated the current and future economic and environmental impact of *P. ramorum* in three systems/scenarios in Europe. For the '*nursery system*' she estimated the impact as being currently moderate and this includes the costs of implementing phytosanitary measures and the resultant effects on trade. She considered that this would not be likely to change much if the existing measures are maintained. The estimate of '*major*' for the response to this question reflects later work done for Great Britain (Defra, 2008) which includes the costs of phytosanitary controls, described below.

As part of the 2008 public consultation for future management of *P. ramorum* and *P. kernoviae* in Great Britain (GB) http://www.defra.gov.uk/corporate/consult/phytophthora-ram-kern/index.htm; an impact assessment was prepared (Defra, 2008) to determine the cost and benefits of future implementation of two different policy options:

Option 1: This requires meeting (current) EU minimum requirements for control of P. ramorum *(and removing all controls against* P. kernoviae*, other than maintaining a ban on the movement of infected plants to other countries).*

The current EU minimum requirements for findings of *P. ramorum* on nursery stock are (broadly-speaking) that infected plants and all susceptible plants within a 2m radius of the infected plants, as well as the associated growing media and plant debris must be destroyed; additionally all susceptible plants within 10m of the infected plants and any remaining plants from the affected lot must not be moved for at least 3 months (Anon., 2007).

Option 2: This option requires increased phytosanitary activity, aimed at reducing the level of inoculum (of both Phytophthora *species) to epidemiologically insignificant levels; by removal of infected sporulating hosts in woodlands and the wider environment; combined with enhanced containment and eradication measures in infected gardens and nursery sites, as well as the identification and control of any new outbreaks.*

Defra (2008) made various assumptions in calculating the costs and benefits of these two options, which were aimed at managing both *P. ramorum* and *P. kernoviae*, details of which are available online. Costs are averages and are considered to be conservative (low) estimates. Total losses have been calculated over a 20-year period (at present values) and are described below. These are projected values and are not EU-wide but they give an indication of current and future impacts for Member States where *P. ramorum* is found on nurseries (as well as in the wider environment; see 2.6). (Loss of exports is dealt with under 2.10).

Overall, if option 1 is adopted, (which will lead to increased disease levels in the nursery trade) the present value (a loss to the industry), to nurseries and garden centres, is estimated at £2.2 million for Great Britain over 20 years. This results from an annual cost of plants lost on nurseries (destroyed, and held, leading to lost markets or reduced prices) of £54,000 per year, increasing with increasing disease to £163,000 from year 4 onwards. An additional cost to these businesses would be the provision of staff to liaise with plant health inspectors and to implement any requirements resulting from an inspection; the net present value of this cost to the industry would be £1.7 million as a result of increasing disease leading to increased costs of a maximum of £204,000 per year after 20 years.

If option 2 is adopted levels of disease on nurseries will reduce but not be eliminated due to the presence of *P. ramorum* in international trade. Increased inspection will initially detect more disease but this would decline rapidly once measures had been implemented. The present value (a loss to the industry), to nurseries and garden centres, is estimated at £0.4 million for Great Britain over 20 years. This results from £100,000 of plants destroyed in year 1 and loss of sales or reduced prices for those plants that are held of £108,000 per year in year 1 reducing to £13,600 from year 11 onwards. The additional cost to these businesses of the provision of staff to liaise with plant health inspectors and to implement any requirements resulting from an inspection would be a present value of £2.2 million resulting from an initial increase in activity costing £284,000 in year 1 reducing to £77,000 from year ten onwards.

Current and future potential losses for other EU Member States are not available.

Cultivated plants: North American nurseries

In the USA, *P. ramorum* has been found on nurseries in California, Oregon and more than 20 other states. In Canada, most recently, the 2007 national survey detected *P. ramorum* at 10 nurseries, all in British Columbia; all have been subject to eradication (S. Sela, CFIA, Canada, *personal communication*, 2008).

Klieujunas (2003) reported that during 1997, about 14.2 million potted florist azaleas (*Rhododendron* spp.) valued at $48.3 million were produced in the United States. This figure does not include nursery azalea and rhododendron production. Many other foliar hosts of *P. ramorum* are also economically significant. Cave *et al*. (2005) reported that in 2003 the US production of nursery stock was valued at approximately $9.2 billion. The USDA (2005) reported that the US ornamental nursery industry was valued at $13 billion with California and Oregon being the first and fifth most important producer of ornamentals. Griesbach (2008) reported that in the USA, Oregon's nursery industry was second to California in terms of sales, with the wholesale value of nursery stock sales in 2006 being $966 million. Specific figures for the value of affected nursery stock in Canada are not available.

Dart and Chastagner (2007) estimated the losses caused by *P. ramorum* to Washington State nurseries (USA) due to plant destruction undertaken as part of the requisite phytosanitary measures for 2004 and 2005. They calculated that 17,266 plants were destroyed at 32 nurseries with an estimated retail value of $423,043. The most commonly destroyed genera were *Rhododendron* (89%), *Calluna* (4%) and *Camellia* (4%). No information was obtainable on the costs of any of the other aspects of the phytosanitary measures, including restrictions on trade resulting from a 90-day holding period for plants that were not destroyed, or on the direct effect on the nurseries themselves. However, one nursery reported that in addition to the value of 109 plants destroyed (1% of total retail value for losses for Washington State) they spent $30,000 on labour, fees for plant disposal and other risk management measures. The conclusion was that the economic impacts on affected nurseries in Washington were greater than the value of the plants that had been destroyed. No other US states record this information so no comparisons can be made (Frankel, 2008).

In March 2004, the findings of *P. ramorum* on two large southern California nurseries which had shipped potentially infected plants to over 1200 nurseries in 29 states cost the USDA $20 million to trace and destroy all suspect stock (Frankel, 2008).

In southwest Oregon, the potential loss to the nursery industry from *P. ramorum* has been estimated to be between $79 million and $304 million per year (these composite figures comprise direct management and regulatory compliance costs plus loss of markets). (Kanaskie *et al*., 2008a, <u>In</u> Anon., 2008; Griesbach, 2008). It is estimated that the cost of inspections and certification of nurseries in Oregon would increase from $800,000 to $6.5 million per year if the pathogen spread to all of the nurseries in the state. If there is further spread of *P. ramorum* in Oregon, potential loss of sales of nursery stock <u>and</u> Christmas trees through changes in customer perception has been calculated at between $34.1 and $204 million. If the disease became endemic in the nursery industry in Oregon then the additional annual cost of a prophylactic fungicide programme targeted at *P. ramorum* has been calculated as $3,960 per acre. There are 94,250 acres of nursery production in Oregon alone. (Griesbach, 2008).

Cave *et al*. (2005) estimated the value of the US cut Christmas tree industry in 2003 as $520 million. One of the major Christmas tree species, *Pseudotsuga menziesii* (Douglas fir), is recorded as a natural dieback host of *P. ramorum* in the USA; Oregon is the US state that produces the greatest number of these trees for the Christmas trade (USDA, 2005) with a wholesale value of $125 million in 2006 and more than 90% of these trees being shipped nationally and internationally (Griesbach, 2008).

Although not strictly <u>direct</u> losses to cultivated nursery plants, Allen *et al*. (2003) evaluated the impact of the introduction of import restrictions in Canada along with surveys and related activities prior to the first findings of *P. ramorum* on nurseries as approximately $1 million (Canadian dollars). This included loss of access to propagation and planting material from California, such as strawberry plants with soil, rhododendrons and indoor palms. The conclusion was that the necessary precautionary approach taken by Canada before the pathogen was detected there resulted in a substantial economic impact; it was anticipated that the regulations might be relaxed as new information came to light which would reduce the impact on trade whilst offering the necessary phytosanitary protection.

Frankel (2008) commented that the impacts of *P. ramorum* on nurseries have been difficult to quantify. Most of the figures she presented for North America did not quantify direct yield and quality losses, apart from the value of the plants that have had to be destroyed as part of the phytosanitary requirements, but did account for losses due to regulatory activities. In addition to the value of the destroyed plants, other losses include: cost of plant destruction, loss of customers for future sales; fumigation, paving or other '*rehabilitation*' costs; costs of implementation of best management practices etc. Some US nurseries have destroyed thousands of plants before being ordered to do so by regulators to minimise '*mitigation costs and escape additional inspections*'. Some growers have also '*abandoned profitable products*'.

<u>Cultivated plants: timber production</u>

Widespread tree death can result in direct economic loss if timber plantations become affected, however, this has not occurred in the UK, EU, US or Canada and so the impact is currently **minimal**.

Timber species in California are not thought to be at risk of mortality from *P. ramorum* (Rizzo *et al*., 2005). However, in terms of direct economic impact, hardwood tree species in coastal California have historically been treated as '*weeds*' but now a hardwood timber products industry is developing there. In 2002, the state's oak woodlands were estimated to contain about 5 billion cubic feet of wood valued at over $275 million. The 5.8 billion cubic feet of oaks in nearby California timberlands were worth over $500 million for forest products alone. It was estimated that if oaks and other tree species in the eastern deciduous forests of the USA became affected by *P. ramorum*, the potential cost to commercial timber production in the United States was likely to be in excess of $30 billion. (Klieujunas, 2003). The annual timber harvest value of the four south-west Oregon counties (Josephine, Coos, Curry – the county where *P. ramorum* is causing disease in forests, and Douglas) was estimated at $1.6 billion per year based upon 2006 data (Kanaskie *et al*., 2008a).

No tree species have become affected in woodlands or forests in Canada.

No timber plantations have become affected in the EU.

2.2. How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area without any control measures?

> *Note: the ecological conditions in the PRA area may be adequate for pest survival but may not be suitable for pest populations to build up to levels at which significant damage is caused to the host plant(s). Rates of pest growth, reproduction, longevity and mortality may all need to be taken into account to determine whether these levels are exceeded. Consider also effects on non-commercial crops, e.g. private gardens, amenity plantings.*

Minimal, **minor**, **moderate**, **major**, massive

<u>**Minor to major**</u>

Level of uncertainty:	<u>**Low**</u>

Currently *P. ramorum* is subject to phytosanitary measures in the areas of the EU, USA and Canada where it occurs, so its full impact, in the absence of statutory control, remains **unknown.** Estimates for the effect the pathogen will have on cultivated plants on nurseries, timber production and managed gardens in the absence of controls are given below along with the level of uncertainty. Without controls, the pathogen is likely to spread in the wider environment putting managed gardens in areas other than where the pathogen is already present at greater risk. Timber production is currently not affected but again there are areas which may be more at risk than others; however, this will depend upon the presence of sporulating hosts within or near to timber plantations. Climate matching, using CLIMEX, between Oregon/California and Europe indicates that areas of north-west Spain, northern Portugal, south-west England, and parts of Italy and western Albania have the most similar climates (to Oregon/California); larger parts of the UK, Ireland, France, Belgium, The Netherlands, western Germany, Italy, the Adriatic coast of the Balkan peninsula, as well as north-west Turkey and east Bulgaria on the black sea coast, also have relatively good climate matches. These areas are most at risk. (See *1.19* and *Conclusion on the probability of establishment*).

Cultivated plants: nurseries

Major

Level of uncertainty:	Low

The impact that *P. ramorum* is likely to have on the yield/quality of cultivated ornamental species on nurseries in the EU without any control measures is likely to be **major**.

P. ramorum is favoured by the nursery environment, can easily establish there, and has a very wide host-range which is likely to increase.

The pathogen is now relatively widely distributed, but at low incidence in EU nurseries. However, the phytosanitary measures that are in place are reducing the number of new outbreaks in the EU and in England and Wales where for the latter, the number of new outbreaks fell from 161 in 2003 to 34 in 2006 (Slawson *et al*., 2008).

Removing existing phytosanitary controls will most likely lead to increased movement within the nursery trade, spread of *P. ramorum* and further establishment on nurseries and beyond. Jeger (2008) analysed positive findings of *P. ramorum* in the hardy ornamental nursery stock industry made by Defra's Plant Health and Seeds Inspectorate between 2003 and 2006 (and woodland survey data for December 2003 to April 2004 undertaken by the Forestry Commission). They concluded that if the UK horticultural trades network has a '*large heterogeneity in its contact structure*' then '*focusing control on super-connected individuals*' (i.e. wholesalers) would most likely enable more efficient disease control. However, the structure of the UK hardy ornamental nursery network is currently unknown. (Jeger *et al*., 2007). Jeger (2008) also considered that plant passporting genera such as *Rhododendron* and *Viburnum* as required under existing phytosanitary legislation is appropriate as it covers the majority of infected species and sites in England and Wales. Current intervention appears to be controlling the trade epidemic but this is likely to be affected by increases in outbreaks in the semi-natural environment. Ensuring efficacy of trace-back and trace-forward of plants from infected premises reduces the risk of a large epidemic.

Modelling work suggests that the correlation coefficient between links in and out of nurseries has a fundamental influence on the epidemic threshold. Scale-free networks only have a lower epidemic threshold than other kinds of complex networks if the risk of spreading *P. ramorum* from a given nursery to others is correlated to the risk of acquiring the pathogen for that given nursery from other ones (Pautasso and Jeger 2008). However, the form that the trade network for ornamental plants takes is currently unknown for UK nurseries.

Jeger (2008) considered that spatial analyses suggest that the actions taken so far in England and Wales, particularly on garden centres and nurseries, have reduced long-distance spread. They concluded that a policy of containment and eradication is justified to reduce the rate of spread but that complete eradication is unlikely

Cultivated plants: timber production – coniferous species

Minor

Level of uncertainty:	Low

P. ramorum will only establish in forests of coniferous species being grown for timber if the species being grown are sporulating hosts or if there are non-tree sporulating hosts within or near to the plantation. Coniferous plantations tend to be densely planted and following canopy closure, the risk of infection is low because opportunities for invasion by understorey sporulator hosts such as *R. ponticum* into these plantations is also low. Experiments to identify potential hosts have shown that some conifer species have susceptible stems or foliage. In the USA, coniferous species which have been found to be affected by *P. ramorum* are firs (*Abies concolor, A. grandis, A. magnifica* as well as Douglas fir, *Pseudotsuga menziesii*), California nutmeg (*Torreya california*) and Coast redwood (*Sequoia sempervirens*). These are all foliar hosts (and all except *A. concolor* are dieback hosts) and therefore are potential sporulators. *Taxus brevifolia* (Pacific yew) is a foliar, dieback and canker host in the USA. In Canada, *Taxus* sp. as been found to be a foliar nursery host. In Europe, *Taxus* sp. has been found on a nursery in France, *Taxus baccata* (yew) on a UK nursery (foliar and dieback host) and *Taxus* x *media* (Anglojap yew) on a nursery in the Netherlands (canker host). *S. sempervirens* was found to be a foliar host in the UK in 2008. The areas of the EU most likely to become affected are those highlighted at the beginning of this question, based upon climatic conditions. Long-term, this impact is likely to be **minor** in the absence of controls.

Cultivated plants: timber production – deciduous species and mixed (conifer and deciduous) species

P. ramorum will only establish in timber stands of mixed or deciduous species if the trees are themselves sporulating hosts, or if there are non-tree sporulating hosts within or near to the plantation. Because timber producing forests and woodlands comprised of deciduous or mixed species are more open-growing compared with plantations of conifers, and often maintained for many decades before harvest, there is potential for sporulating hosts such as *R. ponticum* to invade the understorey, and (if infected) to provide inoculum which may then infect trees with susceptible stems (as well as those with susceptible foliage and shoots). Should this occur, the main species at risk of tree death include beech (*F. sylvatica*) and oak (*Quercus* spp.) as trees of these species have developed stem cankers in the UK and the Netherlands. Some coniferous species are also at risk. The areas most likely to become affected are those highlighted at the beginning of this question, based upon climatic conditions. Long-term, this impact is likely to be **moderate** in the absence of controls.

Moderate

Level of uncertainty:	Low

Cultivated plants: managed gardens

Moderate

Level of uncertainty:	Low

Although not crop plants, the impact that *P. ramorum* is likely to have on the quality of cultivated plants in managed gardens in the EU without control measures is likely to be **massive** but on a local-scale. This is because the pathogen has already established in the south and west of the UK and in parts of the Netherlands and is causing obvious damage there whilst being subject to eradication and containment measures. Lifting the controls will favour further establishment and spread of the pathogen in areas where susceptible hosts occur in the endangered areas (see text at the beginning of this question). Overall of the EU, the impact is likely to be **moderate.**

2.3. How easily can the pest be controlled in the PRA area without phytosanitary measures?

Note: Consider the existing control measures and their efficacy against the pest. Difficulty of control can result from such factors as lack of effective plant protection products against this pest, resistance to plant protection products, difficulty to change cultural practices, occurrence of the pest in natural habitats, private gardens or amenity land, simultaneous presence of more than one stage in the life cycle, absence of resistant cultivars.

Very easily, easily, **with some difficulty**, with much difficulty, impossible

Control on nurseries

With some difficulty

Level of uncertainty:	**Low**

Diseases caused by *Phytophthora* species are usually managed principally through the use of chemical treatments (Garbelotto *et al.*, 2008). *P. ramorum* has become established in nurseries in the EU in the presence of existing management practices for nursery stock that include the widespread use of fungicides applied against *Phytophthora* species and other oomycetes. Resistance to some active ingredients such as metalaxyl-M is already reported for *P. ramorum* (Wagner *et al.*, 2006, 2008; Turner *et al.*, 2008; Turner *et al.*, 2008c). Judicious use of chemicals to avoid a build-up of resistant isolates would be necessary. The host range of *P. ramorum* is very wide which increases the difficulty of control. There is no cultivar resistance to *P. ramorum*. Good hygiene practice including the removal and careful disposal of infected plant material, avoidance of overhead watering, and the use of uncontaminated irrigation water (either through sand filtration of recycled water on site (Ufer *et al*., 2008b) or the use of mains water supplies), will all contribute to control of *P. ramorum*. Propagation material should be pathogen-free; for valuable specimens this could be achieved through micropropagation.

Controls in managed forests and woodlands, managed gardens, and, other non-nursery environments

With some difficulty

Level of uncertainty:	**Low**

The main management practice in non-nursery environments would be to remove infected and susceptible hosts that are able to sporulate (i.e. all hosts except trees that only develop bark cankers) and to dispose of them, probably by burning on-site. Observations in Oregon showed that one year after cutting and burning an area of forest to try to eradicate *P. ramorum*, more than 90% of tanoak (*L. densiflorus*) shoots growing from stumps of trees that had been infected were themselves infected (Lee, 2006). For this reason control of shoots arising from stumps must also be undertaken. Removing rhododendron, especially *R. ponticum*, from woodlands in northern

Europe (principally UK, Ireland, the Netherlands and possibly France), would remove the most important foliar host of *P. ramorum* in these locations and therefore reduce the probability of further establishment. Following clearance, whether or not burning of plant waste occurs on site, repeated application of herbicide to control sprouts emerging from stumps of host plants that are left in the ground (if the stumps are too difficult to remove), as well as control of seedlings of sporulating hosts that emerge post-clearance, must be undertaken.

Protection of valuable specimen trees from infection by *P. ramorum* may be possible by repeat injections of phosphonic acid and copper hydroxide sprays since these chemicals do have some efficacy (Garbelotto *et al*., 2008); however, their use would require approval under the appropriate pesticide regulations. Phosphonic acid is used by homeowners in California along with removal of sporulating Californian bay laurel (*U. californica*) to protect high-value trees (Frankel, 2008).

2.4. How great an <u>increase</u> in production costs (including control costs) is likely to be caused by the pest in the PRA area?

Note: both normal farm practice costs and costs of control should be included, in particular:

- ease of detection of the pest: species that are difficult to detect will require a greater surveillance and monitoring effort which will indirectly result in higher production costs.
- treatment: treatment options may vary (plant protection products, physical removal,…). Treatment costs may be divided into operating (e.g. chemical, fuel, equipment) and labour (i. e. hours per ha).

Minimal, minor, moderate, **major**, massive

The actual <u>increase</u> in *production* costs (excluding phytosanitary controls) is unknown because *P. ramorum* is already present in the PRA area but subject to official control.

If phytosanitary controls are maintained at the current level or increased/reduced, costs will continue to include:

- Surveillance and testing costs (National Plant Protection Organisation - NPPO)
- Administration and compliance costs including publicity (NPPO)
- Value of plants destroyed (grower, managed gardens)
- Costs of destroying plants (grower, managed gardens)
- Purchase of replacement plants to fulfill sales contracts (grower)
- Income loss from cropping restrictions (grower, managed gardens)
- Income loss from loss of sales due to effect on quarantined areas on reputation (grower)
- Income loss from impacts on tourism (managed gardens, businesses related to reductions in visitor numbers)
- Costs of alternative planting schemes (managed gardens)
- Equipment cleaning costs (grower, managed gardens)
- Facility cleaning costs (grower, managed gardens)
- Research and development costs including those needed to develop good management practices (EC, national government and levy bodies)

These costs are **major** (supported by data provided to H. Kehlenbeck, JKI, by the RAPRA partners).

Level of uncertainty:	Low

Should phytosanitary controls be lifted globally the increase in production costs will principally fall on nurseries producing hardy ornamental nursery stock, and managed gardens.

These costs will include:

- Diagnoses and consultancy advice (grower, managed gardens)
- Loss of symptomatic plants (grower, managed gardens)
- Purchase of replacement plants to fulfill sales contracts (grower)
- Change in species grown or planted (grower, managed gardens)
- Additional control costs including fungicide costs and cultural control (grower, managed gardens)
- Implementation of production of healthy certified stock by the use of certification schemes
- Research and development costs (national government and levy bodies)

These costs are **major**

Level of uncertainty:	Low

The impact on production costs for commercial forestry caused by the presence of *P. ramorum* in the PRA area is currently **minimal** (zero) but could change (increase) over a very long period of time should the pathogen become established in timber plantations. This is most likely to occur in timber stands of mixed or deciduous species in climatically-favourable areas if the trees are themselves sporulating hosts, or if there are non-tree sporulating hosts within or near to the plantation.

Level of uncertainty:	Low

Defra (2008) estimated various of these costs for Great Britain over 20 years as part of the analysis of the effects of implementing two options for future management of *P. ramorum* and *P. kernoviae* (see 2.1). (Option 1, EU minimum; option 2 – increased activity).

Costs of diagnostic tests:
Under option 1 diagnostic costs for the official plant health services are estimated at £161,000 in year 1 rising by 5% each year with an overall present value of £3.8 million over 20 years. Under option 2 these costs were estimated as £779,000 per year for the first 5 years after which costs would halve as levels of disease reduce to a level equivalent to the EU minimum surveillance level of £161,000 from year 10 onwards. Over 20 years the present value of diagnostic costs for Great Britain is estimated as £5.7 million.

Costs of government inspections:
Under option 1 inspection levels in Great Britain would reduce to the EU minimum (currently they exceed this). This is estimated as £615,000 per year in year 1 increasing by 5% each year with increasing disease. The present value of these costs over 20 years would be £14 million. Under option 2 government costs would be £2.27 million per year for the first 5 years reducing over the next 5 years with reduction in disease levels to the initial EU minimum cost of £615,000 per year; overall present value of £17.7 million over 20 years.

Cost of administrative burden to industry:
The need for businesses (i.e. nurseries) to maintain records over and above what is normally required (e.g. to demonstrate that susceptible material imported into the EU from the USA has a phytosanitary certificate) is minimal under both options (< £100 per year).

2.5. How great a reduction in consumer demand is the pest likely to cause in the PRA area?

Minimal, minor, **moderate**, major, massive

Plants for planting

Moderate

Level of uncertainty:	**High**

With respect to plants sold commercially, *P. ramorum* affects the quality of a wide-range of genera, principally hardy ornamental nursery stock. Because of this, growers may choose to produce non-susceptible species thus directly influencing consumer demand. Consumers will have to choose whether to purchase available non-host species domestically, or to order plants from overseas such as by mail order. Landscape architects tend to specify particular species when planning landscape plantings and as such if these are susceptible species they may purchase plants from overseas. Whether there will be a reduction in consumer demand for susceptible species is not certain. An estimate of **moderate** is given.

The effects on consumer demand for visiting managed gardens that form part of the tourism industry is discussed under 2.8.

2.6. How important is environmental damage caused by the pest within its current area of distribution?

Note: effects of introduced pests may include: reduction of keystone species; reduction of species that are major components of ecosystems, and of endangered species; significant reduction, displacement or elimination of other species; indirect effects on plant communities (species richness, biodiversity); significant effects on designated environmentally sensitive areas; significant change in ecological processes and the structure, stability of an ecosystem (including further effects on plant species).

Pests which principally have effects on crop yield or quality may also have environmental side-effects. If the main effects are already large and unacceptable, detailed consideration of such side-effects may not be necessary. On the other hand, other pests principally have environmental effects and the replies to this and the following question are then the most important of this part of the analysis.

Minimal, minor, moderate, **major**, massive

Major (overall)

Level of uncertainty:	**Low**

Current distribution

P. ramorum is already in the PRA area (the EU) and is currently distributed in the non-nursery environment (managed parks and gardens and/or in wild (woodland) in the EU in Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Slovenia and Spain, the UK, as well as the non-EU countries of Norway and Switzerland. The only countries where infected trees have been found are the UK and the Netherlands where the first findings were made in October 2003 (reviewed in Sansford and Woodhall, 2007).

Additionally, *P. ramorum* is widely distributed in forests in coastal California (Rizzo *et al*., 2002; Meentemeyer *et al*., 2008 *in press*) as well as in forests near the town of Brookings, Curry County, Oregon, USA (Kanaskie *et al*., 2008).

Its area of origin is unknown but speculated by Brasier *et al*. (2004) to possibly be Yunnan (China), Taiwan or the eastern Himalayas.

Environmental impacts in forests and woodlands and potential impacts for heathlands

Europe

Specific details about the impact of outdoor findings have been difficult to obtain for all of the European countries. RAPRA Workpackage 1 attempted this through the use of proforma questionnaires as well as summarising the annual EU Member State Surveys and the published literature. This is presented in Table 17.

The countries where *P. ramorum* has been found outside of parks ('*public greens*') and managed gardens are the UK, France, Germany, Ireland, and the Netherlands. The UK seems to be most badly affected. Additional information to that provided in Table 17 has been provided by Germany (S. Werres, JKI ; A Frers, Landwirtschaftskammer Schleswig-Holstein; Germany, *personal communication*, 2008).

In northern Germany there is a single area of forest (*ca*. 30 ha) where *P. ramorum* has been detected outside nurseries. The forest is populated by trees of *Acer* sp., *Betula* sp., *F.sylvatica*, *Fraxinus* sp., *Pinus* sp. and *Q. robur* trees. Just after the Second World War, nurserymen stored valuable *Rhododendron* sp., *Pieris floribunda* and *Pieris japonica*, and *Leucothoe walteri* plants in an area of about 1 ha within this forest. These plants are more than 50 years old now and have not been used for propagation for about 20-25 years. During surveys for *P. ramorum* monitoring in 2003, the pathogen was detected on *Rhododendron*. In 2004, *P. floribunda* bushes tested positive. During the last five years the disease has spread slightly on these hosts However, no trees have become infected, including those in close proximity to these infected plants.

In addition to these details *P. ramorum* was found in Poland in the rivers Rawka (2006 and 2007) and the Ner (2007) (Orlikowski *et al*., 2007).

Table 17. Summary of outdoor findings in Europe reported in RAPRA reports and EU MS Surveys. (Workpackage 1 reports 2004–2006* and EU MS Surveys summary tables 2004–2007**)

Country	**Year 2 – 2005***	**Year 3 – Summary 2004–2006*** **EU MS Surveys 2004–2006****	**2007 MS Surveys****
Belgium	See year 3 report	Outdoor outbreaks from 2004 were eradicated in 2005. 2004 – 2 public green	1 public green
Denmark	See year 3 report	1 outdoor outbreak in 2005 persisted through 2006. 2005 – 1 public green; 2006 – 1 public green	2 public green
UK	Mostly SW England (Cornwall).	Mostly SW England (Cornwall) plus south Wales, and western coastal areas of England. Smaller pockets in the south and south-eastern areas. In 2006 additional outbreak sites were reported in the north-east coastal areas and around London. Mostly *Rhododendrons*. Trees – mostly foliage of holm oaks (*Quercus ilex*) and bark of beech (*Fagus sylvatica*) with large bleeding cankers. Other woodland tree species affected e.g. *Castanea*, *Fraxinus* and *Q. robur* and some exotics (*Magnolia*, *Nothofagus*). Not found outdoors in Northern Ireland or Scotland 2004-2006 but found 2002 (presumably both). 2004 – 55 public green; 2005 – 70 public green, 9 forestry; 2006 – 52 public green, 1 forestry	36 public green, 2 forestry

Country	Year 2 – 2005*	Year 3 – Summary 2004–2006*	2007 MS Surveys**
France	No findings	No findings	2 forestry (*Rhododendron* in woodland, Brittany and Normandy – NW France; C. Husson, INRA, France, *pers. comm*.)
Germany	No details in report. Old *Rhododendron* & *Pieris* planted in woodland; *Rhododendron* in '*public green space*' eradicated (S. Werres, JKI, Germany, *pers. comm.*)	Outdoor findings 2004 - 2006. None eradicated. 2004 – 2 forestry; 2005 – 1 public green, 2 forestry. 2006 – 2 forestry, 1 public green (S. Werres, JKI, Germany, *pers. comm.*)	8 public green, 2 forestry
Ireland	3 forest locations on *Rhododendron* and 1 public garden (*Viburnum*).	Outdoor findings 2004-2006. *Rhododendron* and *Viburnum*. Positive findings outdoors increased slightly over time; all located in the southwestern tip of the country. 2004 – 1 public green, 1 forestry; 2005 – 1 public green, 2 forestry; 2006 – 2 public green, 3 forestry	2 public green, 3 forestry
Luxembourg	No report	Positive find – 2006 2006 – 3 public green	No report
The Netherlands	No details.	Outdoor findings 2004 - 2006. *Rhododendron*, *Quercus rubra* and *Fagus sylvatica.* Outdoor outbreaks decreased from 22 in 2004 to 3 in 2006. [Doesn't match survey data]. Since 2005, outbreaks on rhododendron in the outdoor environment not reported; data reflected trees only. Number of infected sites = only newly infected sites each year. 2004 – 7 public green, 6 forestry; 2005 – 7 outdoor; 2006 – 4 public green, 4 forestry	9 public green, 7 forestry
Norway	Four gardens along the W and SW-coast	2004 (2), 2005 (5), 2006 (5). Each eradicated, so new outbreaks each year. Mostly west coast and around Oslo (may include nursery findings)	Not EU
Slovenia	*Viburnum* x *bodnantense* Dawn	2004-2006 findings. *Rhododendron* and *Viburnum* 2004 – 1 public green ; 2005 – 1 public green	Zero
Spain	No findings	No outdoor finds 2004-2006	1 public green
Switzerland	Recently planted *Viburnum bodnatense* in park (north central)	Outdoor findings on *Viburnums* (recently planted in the outdoors) in 2004, 2005; not 2006.	Not EU

Kehlenbeck (2008) estimated the current and future economic and environmental impact of *P. ramorum* in three systems/scenarios in Europe. In the '*northern European tree system*' (trees with stem cankers in association with infected rhododendron in the Netherlands and the UK) the impact is **moderate** and is related to the environmental impact being limited to a few areas only. This is not likely to change unless there is a dramatic change in the presence of infected foliar hosts that sporulate sufficiently to provide inoculum to infect tree stem hosts. In the '*southern European tree system*', a hypothetical system based upon the presence of the infected foliar host *Q. ilex* (holm oak), currently the impacts are **minimal** (zero) as *P. ramorum* has not been detected there in the natural environment. However, should the pathogen be introduced, the impact would shift to **major** because the environment is considered to be highly favourable to the establishment of *P. ramorum*.

Woodlands and forests provide a variety of benefits including open-access free recreation, landscape amenity, biodiversity and carbon sequestration. Forests also affect water supply and quality, pollution absorption, health effects and the preservation of archaeological artefacts. Studies to assign values to these benefits and timber values for Great Britain were reviewed by Sansford and Woodhall (2007). It was estimated that the social and environmental benefits of British forests were *ca*. £1022 million per year (2003 figures) (Willis *et al*, 2003). This figure was based on estimated values of the recreational and biodiversity benefits, landscape value and carbon sequestration.

In examining the likely impact of both *P. ramorum* <u>and</u> *P. kernoviae* in Great Britain as a result of implementing two policy options (see 2.1) (option 1, EU minimum ; option 2, increased activity) the loss of social and environmental benefits of woodland was estimated (Defra, 2008). Without controls in the wider environment (EU minimum maintained under option 1) a 31% annual increase of the area of woodland infected (presumed to be both pathogen species) was estimated. This is because woodlands with invasive *R. ponticum* will <u>not</u> be cleared (i.e. no control in the wider environment) thus perpetuating both pathogens in the environment. A total of 40,000 ha of woodland (maximum) was thought to be at significant risk. However, in the absence of controls in the non-nursery environment (option 1), not only will highly susceptible woodlands become infected but also ornamental plantings in parks and gardens in the west of Great Britain with sporadic findings elsewhere. Additional costs will arise from closure of woodlands and parks prior to felling, with associated felling costs. Ecosystem service benefits will be reduced. The Forestry Commission for Great Britain estimate that under this scenario, severely damaged beech (*F. sylvatica*) woodland would lose between 50% and 70% of annual biodiversity and recreational benefits. Because the <u>initial</u> damage will be lower than this and because visitors have the option to seek recreation in other woodlands the estimate of impacts over 20 years is less, at 25% losses in social and environmental benefits. Landscape and carbon sequestration benefits from woodlands would reduce by 10% per year. Over 20 years the total reduction in benefits is valued at £9.4 million but the level of uncertainty for this figure is **high**. Under option 2 (increased activity) there will be targetted removal of susceptible hosts including *R. ponticum* and as such the level of infection and tree death will reduce. Clearance of *R. ponticum* in woodlands would require a 5-year programme. This is assumed to be 310 ha of *P. kernoviae* infected plants mainly in Cornwall and 112 ha of *P. ramorum* infected plants mainly in England and Wales plus clearance of any newly-identified sites thereafter. Clearance costs would be £750,000 per year (£8,000 per hectare) for the first 5 years diminishing thereafter costing £3.4 million (present value) over 20 years. For *P. ramorum* alone this is estimated at £1.8 million (Defra, 2008a). With social and environmental benefits of British woodland being £1,022 billion per year (Willis *et al*, 2003) and no further trees assumed to become infected as a result of increased activity to reduce inoculum, <u>current</u> loss of benefits is maintained at £16,000 per year with a present value of lost trees of £400,000 over 20 years. The biodiversity <u>benefits</u> of clearance of invasive *R. ponticum* over 20 years therefore has a present value of £3 million.

P. ramorum has the potential to affect heathland environments. Experiments determining the susceptibility of heathland hosts (Inman *et al*., 2005) found that bilberry (*Vaccinium myrtillus*) and heather (*Calluna vulgaris*) were most susceptible and also had the potential to support a high amount of sporulation. Other studies (Kaminski and Wagner, 2008) with detached leaves and twigs classified *Vaccinium corymbosum* and *V. macrocarpon* as not susceptible, whereas most of the cultivars of *Calluna vulgaris* that were tested, as well as *Erica carnea* 'Schneekuppe', *Erica gracilis, Vaccinium myrtillus* and *V. oxycoccu*s were in the highly susceptible category.

Despite official surveillance, *P. ramorum* is yet to be found in a heathland environment in the UK; should this occur the pathogen has the potential to affect key plant species with consequences for the ecology of this important habitat. Great Britain has 89,000 ha of lowland heath and 923,000 ha of upland heath. Defra (2008) estimated that the annual ecosystem value of heathland is between £500 and £6,000 per hectare. If all heathland became infected (with either *P. ramorum* or *P. kernoviae* or both) at its lowest, the loss in value would potentially be £506 million over 20 years. Assuming (as for woodlands) that if future policy for both pathogens in Great Britain is to do the EU minimum (no controls outside of nurseries - option 1 – see 2.1) then a loss of 10% or £50 per hectare per year of ecosystem services would occur. A spread rate of 31% per year as for woodland (31% more infected than the previous year) is assumed. The present value of losses to ecosystem services for heathlands in Great Britain would be £20,000 over 20 years. The uncertainty surrounding these assumptions is however **large**. Under option 2 (increased activity) the risk to heathlands from both species of *Phytophthora* is reduced, such that there is no further infection (which is currently caused only by *P. kernoviae*).

Heathland environments in other areas of north-west Europe are potentially at risk along with maquis in the Mediterranean; the likely impact that *P. ramorum* may cause there has not been evaluated.

<u>North America</u>

In the USA, the major impact of *P. ramorum* to date has been on the coastal woodland environment of California.

Symptoms of *P. ramorum* were first reported on trees in California in the mid-1990s. Since then, it is estimated that over a million oak trees have been killed, including. *L. densiflorus* (tanoak), *Q. agrifolia* (coast live oak) and *Q. kelloggii* (Californian black oak) (Shoemaker *et al*., 2008). Other species of woodland plants have suffered non-lethal foliar and shoot infections. Woodland in Curry County, Oregon, has also become affected.

Rizzo *et al*. (2005) reviewed the pathogen and described the occurrence of *P. ramorum* in the coastal forests that have been affected in California and Oregon as '*patchy*'. At the time of writing (2005), at the largest scale, the incidence of the pathogen was described as discontinuous in coastal forests from the Big Sur (Monterey County) into central California and on to Curry County, Oregon; a distance of 750km. Most forest sites affected were within 30km of the Pacific Coast or San Francisco Bay, along a distance of *ca*. 450km. Areas within the affected areas that were free of disease often contained susceptible hosts and the authors speculated that the absence of disease there is historical (i.e. not yet introduced) rather than related to the environment, or the biology of *P. ramorum*. Because the pathogen is not subject to eradication in California it still has the potential to affect trees and shrubs in unaffected areas, provided a sporulating host such as California bay laurel (*U. californica*) or tanoak (*L. densiflorus*) is present. Rizzo *et al*. (2005) state that because many of the tree species (presumably in the USA) are not commercially important, the economic effects of biotic agents including *P. ramorum* have not been characterised. However, research plots have been established in various forest locations and impacts have been assessed experimentally. Mortality of tanoak (*L. densiflorus*) and coast live oak (*Q. agrifolia*) has been found to be increased by the presence of *P. ramorum* compared to either baseline mortality or other factors, including other diseases. The loss of oaks (*Quercus* spp.) and tanoak (*L. densiflorus*) in California has changed the forest stand structures. It is likely that those plant or tree species that are less susceptible or not susceptible will thrive and increase their population thus changing the local ecology. No data have yet been gathered on the long-term impacts as it is still relatively early in the course of the epidemic.

Meentemeyer *et al*., 2008b (*in press*) reported that the majority of the potential host habitat in the Big Sur has yet to suffer tree mortality. Only 20% of potential host trees in the stands that are currently affected have become infected. By comparison with other forest pathogens where extensive tree mortality and subsequent ecological impacts have taken many decades, it is thought that the 16 years after the first tree deaths (mid-1990s) were observed in this area, it is still too early in the epidemic to determine its full potential. Meentemeyer *et al*., 2008a showed that between 1942 and 2000, in a 275-km^2 region in northern California, oak woodlands significantly increased in area by 25%, while grassland and chaparral decreased by 34% and 51%. This resulted in larger forests with higher densities of primary host trees for *P. ramorum* (*U. californica*, *Q. agrifolia* and *Q. kelloggii*) and cooler understory temperatures. This enlargement and closure of gaps in the forest canopy, most likely due largely to years of fire suppression (to safeguard the human population), facilitated establishment of *P. ramorum* by increasing the area occupied by inoculum-production foliar hosts and enhancing forest microclimate conditions. They consider that without intervention there will be an increase in foliar-host vegetation and consequently further increase in spread and establishment of the pathogen with knock-on effects on the environment. Lee (2006) commented that *P. ramorum* is most common in/near urban areas where active fire suppression occurs.

Klieujunas (2003) suggested that in North America, heavy loss of oaks, or, of related susceptible genera, due to *P. ramorum* infection could result in significant ecological effects, including changes in forest composition, loss of wildlife food and habitat, increased soil erosion and a significant increase in fuel loads for forest fires in heavily populated urban-forest interfaces. *Quercus* spp. are considered the most important and widespread of the hardwood trees in the '*North Temperate Zone*', with about 300 species. Oaks are widespread across North America and Eurasia, (extending south in tropical mountains to Cuba, Colombia, northern Africa, and Indonesia). In California, oak woodlands yield important benefits, including water and watershed protection, grazing, wildlife food and habitat, recreation, and wood products.

Kliejunas (2003) stated that many of the foliar hosts of *P. ramorum* have ecological significance. *Rhododendron* spp. occur worldwide, and some species in the United States are (were) listed under the Endangered Species Act (US). *Vaccinium ovatum* (evergreen huckleberry), native to British Columbia, Washington, Oregon and California, is a common understory component of California and Oregon forests. *Vaccinium* spp. are widely distributed throughout Europe, Asia, and North America; more than 40 species occur in North America.

There have been several studies showing how *P. ramorum* mediated tree death can affect forest wildlife. These have been mainly done in California. These studies have shown that *P. ramorum* can lead to changes in vegetation structure. Oaks may become less dominant and California bay laurel (*U. californica*) becomes more prevalent. This can lead to an open canopy and ultimately, increased light levels could result in dense shrub cover (Winslow and Tietje, 2005). This may affect bird communities with the loss of prey habitat and nesting sites. This theory is concordant with Apigian and Allen-Diaz (2005) who observed a loss of bird nest sites, prey reduction and loss of foraging substrates in *P. ramorum* affected plots. Projections on the effects of *P. ramorum* on bird populations associated with *Q. agrifolia* in California have indicated that the bird population could be 25–68% smaller and 13–49% more variable relative to estimates prior to infection with *P. ramorum* (Monahan and Koenig, 2006).

Effects on other animals are evident. It has been shown that an infected tree can attract greater numbers of beetles (McPherson *et al*., 2005). This may also affect the feeding patterns of birds. Some small mammal species may benefit from loss of trees due to *P. ramorum*. In California, wood rats were projected to benefit from the increased shrub cover, California mice would benefit from an increase in coarse wood debris and brush mice would benefit from lower tree densities. Two salamander species modelled were likely to be relatively unaffected. (Tempel and Tietje, 2005).

In addition to the suggested potential environmental impacts due to disruption to the ecology of the area described above, Appiah *et al*. (2004) included a loss of recreational areas in woodland severely infested with *P. ramorum*, with the presence of dead trees increasing the risk of accelerated water run off, and, as alluded to by Klieujunas (2003), resultant soil erosion and sedimentation and endangering of certain plant species. There is a particular risk from forest fires because of the presence of dead trees (Frankel, 2008) and also the risk to power lines. Two small (less than 1 hectare) fires (one in Napa County and one in Sonoma County) have been caused by dead trees (*P. ramorum*-infected) snapping and hitting powerlines. The Northern California utility company, Pacific Gas and Electric Company, has accelerated clearing along lines to prevent hazards. (Susan Frankel *personal communication*). Local landowners in the infested areas in coastal California have had to pay for the clearance of dead trees to protect homes and property.

Environmental impacts of invasive species in general are difficult to put into a quantitative context because of the non-market value of the resources, and to date there are few cases where economic values have been placed on such invasions (Waage *et al*., 2005). However, it has been postulated that the cost of environmentally invasive species (which *P. ramorum* can be classed as) rises with time. This is because they can be relatively slow spreading compared to crop diseases, and need to reach very high densities before they cause losses (in terms of biodiversity or ecosystem services); also, future wealthier societies are likely to place a greater value on the environment (Waage *et al*., 2005).

2.7. How important is the environmental damage likely to be in the PRA area (see note for question 2.6)?

Minimal, minor, moderate, **major,** massive

<u>Major</u>

Level of uncertainty:	**<u>Low</u>**

P. ramorum is already present in the PRA area and so details of the answer to 2.6 also apply to 2.7.

2.8. How important is social damage caused by the pest within its current area of distribution?

Note: Social effects may arise as a result of impacts to commercial or recreational values, life support/human health, biodiversity, aesthetics or beneficial uses. Social effects could be, for example, changing the habits of a proportion of the population (e.g. limiting the supply of a socially important food) damaging the livelihood of a proportion of the human population, affecting human use (e.g. water quality, recreational uses, tourism, animal grazing, hunting, fishing). Effects on human or animal health, the water table and tourism could also be considered, as appropriate, by other agencies/authorities.

Minimal, **minor**, **moderate**, major, massive

<u>Minor to moderate</u>

Level of uncertainty:	**Medium**

Some of the losses are already accounted for under 2.6.

Managed parks and gardens in Europe

In the EU managed parks (‘*public greens*’) and gardens are or have been affected in: Belgium, Denmark, Germany, Ireland, Luxembourg, the Netherlands, Slovenia, Spain, and the UK, as well as in the non-EU countries of Norway and Switzerland (see Table 17). The majority of findings have been in the UK and the Netherlands.

Established parks and gardens are affected by outbreaks of *P. ramorum* in a range of UK locations but especially in the south-west of England (Wright, 2008).

The presence of *P. ramorum* in the PRA area is slowly impacting on tourism in the south-west of England. This is due to the effect of the pathogen on the appearance of the plants and landscapes of the managed and historic gardens that contribute to the local economy. This effect will worsen in the absence of controls as *P. ramorum* will increase its spread and establishment in areas such as this.

The impact assessment for the effects of implementing two different policy options for future control of *P. ramorum* and *P. kernoviae* in Great Britain (Defra, 2008) (see 2.1) reported that information from the ‘*South West Tourism, Gardens of Cornwall Project*’ suggests that in 2001 the income of 45 gardens in Cornwall, which met the criteria for their study (out of a total of 163 gardens in the county), generated an income of £23.6m (50% from entrance fees and 50% from other income (refreshments, plant and gift sales)) and directly employed nearly 700 people. The gardens attracted over 2.8 million visitors, 75% of which came from outside the southwest (including 8% from overseas).

The impact assessment stated that ‘*there will be impacts on visitor numbers to historic gardens under the baseline (Option 1) and Option 2. The impact has not been costed because it is difficult to assess under which option more visitors are lost and how many of the visitors will just visit other gardens which would represent a redistribution of revenue but no loss of revenue overall (however regional impacts may be substantial see special note regarding Cornwall Annex 8])*’. (Defra, 2008)

The note regarding Cornwall states*: At present the majority of known infection of both* P. ramorum *and* P. kernoviae *in gardens and the wider* [environment] *are within Cornwall. Cornwall has been in receipt of EU Objective 1 aid to ‘promote the development and structural adjustment of regions whose development is lagging behind’. Significant money has been directed into the development of the Cornwall tourist industry particularly in marketing the ‘Gardens of Cornwall’. The ‘Gardens of Cornwall’ project reports a £23.6m annual increase in income to the region as a direct result of the historic gardens.* (More detail given below.) (Defra, 2008a.)

To support the impact assessment (Defra, 2008), the National Trust (NT) (a charity that protects and open to the public over 300 historic houses and gardens amongst other buildings as well as parts of the countryside and coastline of England, Wales and Northern Ireland) completed a questionnaire on the effects of both *P. ramorum* and *P. kernoviae* on historic gardens. This forms Annex 6 of the impact assessment. (Defra, 2008a.)

The NT responses suggested that if disease levels increased in the historic gardens that they manage, then visitor numbers would reduce by 10%, if visible damage occurred to the plant collections and/or the garden character. Removal of plants to control both *P. ramorum* and *P. kernoviae* may change the appearance of gardens to an extent where the public is deterred from visiting. Gardens will need to manage their way through the disease(s) by moving to plantings of non-susceptible plants over a period of time. This would involve the loss of feature specimens of historic significance and in some instances may change the character of gardens substantially. The cost of such a transition, has not been included in the costs for this impact assessment (Defra, 2008) but it is likely to run into some £millions. It is likely that this management process will be undertaken whichever option is chosen. The risk of negative publicity, and, as a consequence any loss in public confidence could have a significantly larger impact on visitor numbers. If a garden with an important plant collection were to lose (e.g.) 60-80% of its collection, this may well have a major impact on visitor numbers over a longer period of time. Numbers would be reduced until temporary solutions could be found and a programme of proactive marketing would be needed. This could take approximately 5 years to allow for any temporary planting to mature and to counteract any loss of reputation and interest. Rebuilding public confidence could take much longer. Visitor numbers to these gardens have not reduced currently, but there has been negative feedback in the form of written comments on the appearance of the gardens. High levels of disease could cause a lack of confidence in how plant collections are being managed and a concern that not enough is being done to inform and protect visitors from carrying the disease(s) away with them. There may also be an adverse affect on the income generated by plant sales and possibly even loss of membership income from any relevant organisations (NT, Royal Horticultural Society) if members strongly believed their organisation was not fulfilling their garden conservation obligations.

In assessing the impact of implementing the two policy options proposed in the public consultation for Great Britain (see 2.1), Defra (2008) assumed that option 1 would increase the level of disease in the wider environment and that all gardens would become infected over a 20-year period. The present value was calculated as £13.7 million over 20 years based upon costs of clearance of infected and susceptible plants increasing from £375,000 per year to more than £1.9 million per year. Under option 2 (increased activity) the impact on these gardens would reduce over time and the number of gardens that become infected will diminish; short-term impacts would arise from removal of all infected or susceptible material within a 5 year period or less. Gardens may have to close whilst this work is undertaken and new plantings are put in place. It is estimated that there would be an average clearance cost of £15,000 per garden with 5 gardens undergoing clearance per year for the first 5 years; after this the costs will diminish to zero in year nine once the gardens are clear of the pathogen. The present value of costs is estimated as £4.4 million over 20 years.

Heritage trees and plants (those with historical or cultural value or that have significant features e.g. old trees, wide trees, tall trees, rare trees, unusual trees) are at risk of infection but the value of their loss is not possible to estimate.

This impact is thus highly damaging locally but would be described as **minor to moderate** for the whole of the PRA area (the EU 27).

Nurseries

Some specialist producers of ornamental nursery stock may have to change the types of species that they produce. This may result is loss of business or loss of employment for specialist staff. Over all of the EU 27 this impact is likely to be **moderate.**

2.9. How important is the social damage likely to be in the PRA area?

Minimal, **minor, moderate,** major, massive

Minor to moderate

Level of uncertainty:	**Medium**

P. ramorum is already present in the PRA area and so the answer to 2.8 also applies to 2.9.

2.10. How likely is the presence of the pest in the PRA area to cause losses in export markets?

Note: consider the extent of any phytosanitary measures likely to be imposed by trading partners.

Impossible, very unlikely, unlikely, **moderately likely**, likely, very likely, certain

Moderately likely

Level of uncertainty:	**Low**

There are a number of countries which have listed *P. ramorum* in their legislation (Appendix IV). This list was last updated in February 2007. The details of the phytosanitary requirements of individual countries have not been investigated.

Export losses will vary by country. The Netherlands, Germany and Belgium (for example) are thought to be major exporters of *Rhododendron* and there have been '*major*' losses of exports for Germany related to *P. ramorum* (S. Werres, JKI, *personal communication*).

Some countries have implemented phytosanitary requirements in the past which have led to a prohibition on imports from Europe. An example of this is New Zealand where measures effectively prohibited imports of *Rosa* species from Europe (and the USA). These measures were reviewed in 2004 such that *Rosa gymnocarpa* was deemed the only species that was a natural host, thus facilitating imports of other *Rosa* spp. provided area freedom could be proven. (Anon., 2004a).

Defra (2008) considered the effects of the future implementation of two policy options in Great Britain including the effects on export markets (see 2.1). Under option 1, (mainly keeping current EU minimum requirements for *P. ramorum* but removing most of the controls for *P. kernoviae*) loss of export markets may happen but this depends upon bilateral agreements and plants may be sold on domestic markets instead. This has been calculated for Great Britain as £800,000 over 20 years based upon : £355,000 of exports (mainly roses) per year, a loss of 50% of the market value for the first five years, followed by a change to non-susceptible plants or new markets. Under option 2 (increased activity aimed at reducing inoculum levels) loss of export markets will not occur.

In March 2004, the findings of *P. ramorum* on two large southern California nurseries which had shipped potentially infected plants to over 1200 nurseries in 29 states led to 15 states imposing quarantines on nursery stock from California within a month; the estimated losses in the first month to the nursery industry in California was $4.3 million. Although commented on earlier under 2.1 the USDA response to trace and destroy all suspect stock cost $20 million. (Frankel, 2008).

Oregon ships 75% of its nursery production to other states or countries (Griesbach, 2008). Frankel (2008) reported that in 2001 Canada '*closed its markets*' to imports of plants from Oregon and California leading to losses in sales to Canada of $15 to 20 million.

As noted in the introduction to section 2, the evaluation of the following questions may not be necessary if the response to question 2.2 is "major" or "massive" and the answer to 2.3 is "with much difficulty" or "impossible" or any of the responses to questions 2.4, 2.5, 2.7, 2.9 and 2.10 is "major" or "massive" or "very likely" or "certain". You may go directly to point 2.16 unless a detailed study of impacts is required or the answers given to these questions have a high level of uncertainty.

In relation to the above note it is possible to go to 2.16 but because of the importance of this PRA, responses have been given to the remaining questions.

2.11. How likely is it that natural enemies, already present in the PRA area, will not reduce populations of the pest below the economic threshold?

Note: For pest plants, natural enemies include herbivores.

Very unlikely, unlikely, moderately likely, likely, **very likely**

<u>Very likely</u>

Level of uncertainty:	**<u>Low</u>**

There are no natural enemies of *P. ramorum* in the PRA area. *P. kernoviae* may out-compete *P. ramorum* in some circumstances

2.12. How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment?

Impossible, very unlikely, **unlikely**, **moderately likely**, likely, very likely, certain

<u>Nurseries</u>

<u>Unlikely</u>

Level of uncertainty:	**<u>Low</u>**

Control of *P. ramorum* on nurseries is **unlikely** to affect existing biological or integrated systems of control as the hosts are mainly hardy ornamental nursery stock which tend to be grown outdoors and for which biocontrol agents are unlikely to be used or rarely used.

<u>Managed forests and woodlands, managed gardens, and, other non-nursery environments</u>

<u>Moderately likely</u>

Level of uncertainty:	**<u>Low</u>**

Control of *P. ramorum* in non-nursery environments mainly relies on removal of sporulating hosts. Depending upon the contribution that individual species make to the environment their removal may either benefit the environment (if it is an invasive species such as *R. ponticum*) or have a negative effect if it contributes significantly to the environment.

In northern Europe, removal of *R. ponticum* is seen as a benefit. In looking at the impact of removing *R. ponticum* in Great Britain as part of the review of policy options for both *P. ramorum* and *P. kernoviae* (Defra, 2008) it was assumed that this would lead to an increase in biodiversity in woodlands and heathlands. The value of the increase in biodiversity was assumed to be equivalent to 70% of the cost of clearance accounting for the fact that the woodland areas where clearance is needed may not be the best sites for improvements in biodiversity. The biodiversity benefit from undertaking this clearance for disease control was estimated as £3 million over 20 years. Removal of *R. ponticum* in heathland is also seen as a benefit enabling the government to achieve targets in biodiversity and heathland condition. This was calculated as a reduction in heathland loss amounting to £20,000 over 20 years.

In southern Europe, epidemics in Mediterranean forests and in maquis (macchia) shrubland have not occurred to date but are most likely to also depend on the presence of susceptible (especially evergreen) foliar hosts, such as *Rhamnus alaternus* and *Pistacia lentiscus*, that can support significant sporulation. (See 1.16 for more detail). Should *P. ramorum* become established in these areas then control would again focus on removal of sporulating hosts. On the northeast of the Iberian Peninsula *R. alaternus* produces fruits at times when other ripe fruits are not available for several bird species e.g. *Sylvia melanocephala, S. undata S. atricapilla, Erithacus rubecula* and *Turdus merula* (Bas *et al.*, 2006). Should this plant have to be removed to control *P. ramorum* then this will have a negative effect on these species. Fruits of *Pistacia lentiscus* are also eaten by birds (Jordano, 1989). Whether this host is critical for the support of bird populations is not known. Other species will play a role in these environments either as food or shelter for animals, or for soil stabilisation etc.

2.13. How important would other costs resulting from introduction be?

Note: costs to the government, such as project management and administration, enforcement, research, extension/education, advice, publicity, certification schemes; costs to the crop protection industry.

Minimal, minor, moderate, **major**, massive

Level of uncertainty:	**Low to high**

P. ramorum has already been introduced to the PRA area and so these costs have been evaluated under previous questions, particularly 2.4.

2.14. How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests?

Impossible, very unlikely, unlikely, **moderately likely**, likely, very likely, certain

Moderately likely

Level of uncertainty:	**Medium**

Brasier (2008a) considers that nurseries in Europe and elsewhere where more than one species of the same pathogen genus are '*potential breeding grounds for evolution of new, interspecific hybrids that are more aggressive, or have host ranges unknown in the parent species'*. He cites examples of interspecific hybridisation between *Phytophthora* species leading to new organisms such as *Phytophthora alni*, an emergent hybrid pathogen of alder (*Alnus* spp.) with three variants (Brasier *et al*., 2004b, Ioos *et al*., 2005, Ioos *et al.*, 2007). This organism is killing native alders across Europe. Two other new hybrid *Phytophthoras* have been detected in glasshouses in the Netherlands (Man in't Veld *et al*., 1998, 2007). It is possible that *P. ramorum* could hybridise with other species of *Phytophthora*, the progeny of which has the potential to be as serious as *P. ramorum.*

2.15. How likely is the pest to cause a significant increase in the economic impact of other pests by acting as a vector or host for these pests?

Impossible, very unlikely, unlikely, moderately likely, likely, very likely, certain

Impossible

Level of uncertainty:	**Low**

P. ramorum is not a vector or host of other pests.

Conclusion of the assessment of economic consequences

2.16. Referring back to the conclusion on endangered area (1.35), identify the parts of the PRA area where the pest can establish and which are economically most at risk.

Endangered areas of the EU where *P. ramorum* has the potential to establish

Nurseries involved with hardy ornamental plants across the whole PRA area are likely to be favourable for *P. ramorum* to establish. In this context, the whole PRA area is an endangered area with respect to cultivated ornamental shrubs and trees (sapling production) due to the wide host range of the pathogen and the general suitability of the nursery environment for disease development and spread.

The areas of the PRA area that most favour establishment in non-nursery environments, based on ecoclimatic factors and the presence of suitable hosts (including sporulating hosts) are as follows:

(1) Areas with *Atlantic Central* and *Lusitanian* climates:
Within these western European climatic zones, habitats or host environments that favour establishment include: parks, managed gardens and public greens with a diversity of ornamental host plants; woodlands with susceptible tree species, especially those in the family Fagaceae, where rhododendron (especially *R. ponticum*) is present to act as the foliar host and source of inoculum; mixed deciduous timber plantations with sporulating hosts in the understorey; heathland habitats with a diverse range of ericaceous plant species, especially *Vaccinium* and *Calluna* species. The *Atlantic north* climatic zone may also favour the pathogen.

(2) *Mediterranean* climates:
Within these climatic zones (*Mediterranean North, Mediterranean South, Mediterranean Mountains*), evergreen oak woodlands and laurel forests are considered most as risk, as are maquis habitats that contain host, or potential host, species. If mixed deciduous timber plantations occur here they may also be at risk if they have sporulating hosts in the understorey.

Economic risk to the endangered areas

P. ramorum is already present in the PRA area but subject to official control. It still has the potential to increase its host range and to become more widespread in the nursery trade and in the non-nursery environments that are identified as being endangered. There is the potential for the pathogen to affect timber production but this has not occurred to date in North America or Europe. The potential economic impacts have not been quantified for the PRA area as there are insufficient data to do so. The impacts will increase if controls are lifted.

If phytosanitary controls are maintained at the current level or increased/reduced, costs will continue to include:

- Surveillance and testing costs (National Plant Protection Organisation - NPPO).
- Administration and compliance costs including publicity (NPPO).
- Value of plants destroyed (grower, managed gardens).
- Costs of destroying plants (grower, managed gardens).
- Purchase of replacement plants to fulfill sales contracts (grower).
- Income loss from cropping restrictions (grower, managed gardens).
- Income loss from loss of sales due to effect on quarantined areas on reputation (grower).
- Income loss from impacts on tourism (managed gardens, businesses related to reductions in visitor numbers).
- Costs of alternative planting schemes (managed gardens).
- Equipment cleaning costs (grower, managed gardens).
- Facility cleaning costs (grower, managed gardens).
- Research and development costs including those needed to develop good management practices (EC, national government and levy bodies.

These costs are **major.**

There may also be costs incurred if timber plantations become affected including those for the NPPO, destruction of infected trees and removal of sporulating hosts.

Should phytosanitary controls be lifted globally the increase in production costs will principally fall on nurseries producing hardy ornamental nursery stock, and managed gardens.

These costs will include:

- Diagnoses and consultancy advice (grower, managed gardens).
- Loss of symptomatic plants (grower, managed gardens).
- Purchase of replacement plants to fulfill sales contracts (grower).
- Change in species grown or planted (grower, managed gardens).
- Additional control costs including fungicide costs and cultural control (grower, managed gardens).
- Implementation of production of healthy certified stock by the use of certification schemes.
- Research and development costs (national government and levy bodies).

These costs are also **major.**

The impact that *P. ramorum* is likely to have on the yield/quality of cultivated ornamental species on nurseries in the EU without any phytosanitary measures is likely to be **major** because of the wide host range of the pathogen.

Although not crop plants, the impact that *P. ramorum* is likely to have on the quality of cultivated plants in managed gardens (especially heritage plants in heritage gardens) in the EU without control measures is likely to be **massive** but on a local-scale. Overall of the EU, the impact is likely to be **moderate**

At risk habitats that are yet to become affected by *P. ramorum* include heathlands in northern Europe, as well as evergreen oak woodlands and laurel forests (laurisilva) and maquis/matorral habitats in southern Europe, but only where they contain susceptible host species. Should these areas become affected there will be knock-on effects on the ecology of the area. If controls are lifted, in the '*northern European tree system*' (e.g. trees with stem cankers in association with infected rhododendron) the environmental impact will increase as the pathogen becomes more widespread in the environment increasing the number of infected foliar hosts that sporulate sufficiently to provide inoculum to infect tree stem hosts with subsequent tree mortality. This impact has the potential to be **major** on a local basis but **moderate** over the whole of the PRA area. In the '*southern European tree system*', should the pathogen be introduced, the impact would shift from minimal (zero) to **major** because the environment is considered to be highly favourable to the establishment of *P. ramorum.*

The pathogen has yet to be found in timber plantations but should it do so, long-term, the impact may be **minor** to **moderate** in the absence of controls.

Go to degree of uncertainty

Degree of uncertainty for the pest risk assessment

Estimation of the probability of introduction of a pest and of its economic consequences involves many uncertainties. In particular, this estimation is an extrapolation from the situation where the pest occurs to the hypothetical situation in the PRA area. It is important to document the areas of uncertainty (including identifying and prioritizing of additional data to be collected and research to be conducted) and the degree of uncertainty in the assessment, and to indicate where expert judgement has been used. This is necessary for transparency and may also be useful for identifying and prioritizing research needs.

It should be noted that the assessment of the probability and consequences of environmental hazards of pests of uncultivated plants often involves greater uncertainty than for pests of cultivated plants. This is due to the lack of information, additional complexity associated with ecosystems, and variability associated with pests, hosts or habitats.

Pathways

Although there are data available in the Eurostat Comext database for six of the eight pathways the level of uncertainty surrounding the data is **high** for Pathway (i) plants for planting (hosts), Pathway (ii) plants for planting (non-hosts) and Pathway (v) foliage/cut branches of susceptible hosts because the only named hosts in the database are rhododendron (including azalea) and roses and this is only for plants for planting. It is assumed that Pathway (ii) plants for planting (non-hosts) contains some susceptible hosts. The level of uncertainty for Pathway (iv) volume of soil as a contaminant is **high** because there are no data. The level of uncertainty for Pathway (vii) volume of susceptible bark is **high** because the data are part of a general wood waste category in Eurostat with no named genera. The level of uncertainty is **high** for Pathway (iii) volume of soil/growing media as a commodity from non-EU European countries (Norway and Switzerland) as no data are available in the Eurostat database, as well as for Pathway (vii) susceptible bark and Pathway (viii) susceptible wood from these countries too, as no data were obtained.

For Pathway (vi) the volume of seeds and fruits, this has **medium** to **high** uncertainty as only a few genera are named and these data refer to nuts and fruit only.

The only categories where the data on volumes of imports has **low** uncertainty are for Pathway (iii) soil as a commodity from Canada, USA, China and Taiwan as this is banned and Pathway (viii) susceptible wood from these countries as five of the known host genera are named in the Eurostat Comext database including *Quercus* spp.

Establishment and spread

It is **uncertain** as to whether the mating system is fully functional and therefore what risks arise from the introduction of the A2 mating type into the EU.

The potential for adapatation to new hosts or environments is **uncertain.**

There is a lack of high-resolution data on host distribution for Europe. This has limited the determination of the endangered areas outside of nurseries.

The rate of spread in the absence of phytosanitary controls is **uncertain.**

The ability for asymptomatic root infections to become systemic is **uncertain.**

The significance of asymptomatic sporulation is **uncertain.**

The role of inoculum contaminating the growing media of traded plants is **uncertain**.

The suppression of symptoms by the use of fungicides (with fungistatic properties) is based upon observations.

The likelihood of eradication in non-nursery environments is **uncertain**.

Economic impact

The impact in the area or areas of origin is unknown, as this has yet to be identified. This has a **high** level of **uncertainty**.

The impact in the absence of phytosanitary measures is not known (**high uncertainty**) for the EU where measures have been in place since 2002.

The potential for hybridisation with other species of *Phytophthora* is **uncertain**.

The potential for timber plantations to become affected by *P. ramorum* is **uncertain**.

For Pest-Initiated Risk Assessments:	**Go to conclusion of the risk assessment**
For Pathway-Initiated Risk Assessments:	**Go to back to 1.4 to evaluate the next pest, if all pests have been evaluated go to conclusion of the risk assessment**

Conclusion of the pest risk assessment

Entry: *Evaluate the probability of entry and indicate the elements which make entry most likely or those that make it least likely. Identify the pathways in order of risk and compare their importance in practice.*

In the absence of any phytosanitary controls the overall probability of entry is considered to be **high**, mainly due to the wide host range and the ability of *P. ramorum* to persist in a variety of substrates (e.g. soil, growing media, bark, wood, foliage).

The relative importance of the pathways is given below (based upon a 5 word ranking system where **very low** and **very high** are extremes). This does not account for pre-existing phytosanitary measures:

Plants for planting of susceptible hosts (excluding seeds and fruits) from the USA and the unknown area/areas or origin: **high risk.**

Plants for planting of susceptible hosts (excluding seeds and fruits) from Canada and the non-EU countries of Norway and Switzerland: **medium risk.**

Soil as a commodity from the USA, Canada, the unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **medium risk.**

Susceptible isolated bark from the USA and the unknown area/areas or origin: **medium risk.**

Plants for planting of non-hosts (excluding seeds and fruits) accompanied by contaminated growing media from the USA, Canada, the unknown area/areas of origin and the non-EU countries of Norway and Switzerland: **low risk.**

Soil as a contaminant of travellers shoes and imported machinery, vehicles etc from the USA and the unknown area/areas of origin: **low risk.**

Susceptible wood from the USA and the unknown area/areas of origin: **low risk.**

Foliage or cut branches of susceptible hosts from USA, Canada, the unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **very low risk.**

Seeds and fruits of susceptible hosts from the USA, Canada, unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **very low risk**

Susceptible isolated bark from Canada and the non-EU countries of Norway and Switzerland: **very low risk.**

Susceptible isolated wood from Canada and the non-EU countries of Norway and Switzerland: **very low risk.**

Establishment

Evaluate the probability of establishment, and indicate the elements which make establishment most likely or those that make it least likely. Specify which part of the PRA area presents the greatest risk of establishment.

The probability of establishment in the PRA area is **high**.

A wide range of host plants is cultivated on nurseries in the EU. Outside of nurseries, managed parks and gardens growing susceptible host species have already become affected in parts of the EU. In some of these areas (e.g. parts of the UK), containment with a view to suppressing the levels of inoculum, to protect susceptible trees and reduce spread has become necessary. This is because total eradication of the pathogen may not be possible in parts of the PRA area. Some parts of the PRA area have very favourable climatic conditions; certain nursery practices favour the pathogen; long-lived chlamydospores aid survival and establishment.

Economic importance

List the most important potential economic impacts, and estimate how likely they are to arise in the PRA area. Specify which part of the PRA area is economically most at risk.

The potential economic impact for the nursery trade is **high**. Without controls the pathogen has the potential to spread further in the trade network and could potentially expand its host range, which is already very wide. For cultivated plants, damage is principally to the quality of hardy ornamental hosts. Loss of exports may increase if third countries maintain requirements for imports of ornamental plants from the EU.

If controls are lifted, environmental impacts may become locally **major** in the endangered areas but this may take some time (possibly decades) as this relies on further spread of the pathogen.

Social impacts will increase in the endangered areas as a result of damage to plants in managed gardens that are visited by the public firstly impacting on visitor numbers and ultimately affecting the tourism industry where such gardens are part of that economy.

Costs borne by National Plant Protection Organisations will increase if increased phytosanitary controls are recommended in an effort to reduce further spread to the environment. However, there will be environmental benefits if controls focus on removal of foliar sporulating hosts that are invasive species such as *Rhododendron ponticum.*

Overall conclusion of the pest risk assessment

The risk assessor should give an overall conclusion on the pest risk assessment and an opinion as to whether the pest or pathway assessed is an appropriate candidate for stage 3 of the PRA: the selection of risk management options, and an estimation of the associated pest risk.

P. ramorum fulfils the criteria of a quarantine pest. There is a risk of further entry (of known or new lineages and/or mating types), establishment and economic impact. The risk from the pest is considered not to be acceptable

Stage 3: Pest risk management

The pest risk management stage is the third stage in pest risk analysis. It provides a structured analysis of the measures that can be recommended to minimize the risks posed by a pest or pathway. The pest risk management part may be used to consider measures to prevent entry, establishment or spread of a pest. It explores options that can be implemented (i) at origin or in the exporting country, (ii) at the point of entry or (iii) within the importing country or invaded area.

Before considering the available risk management options, a judgement on the acceptability of the risk posed by the pest or pathway is required. In this scheme, the methods whereby risk management options are selected differ according to whether the introduction is intentional or unintentional, whether the organism is absent or already present in the PRA area and the type of entry pathway. The options are structured so that, as far as possible, the least stringent options are considered before the most expensive/disruptive ones. Options to prevent unintentional entry on commodities are distinguished from options to prevent natural spread/movement or entry with other pathways such as passenger luggage. It should be noted that measures recommended for intentional introductions are often restricted to prohibiting imports and to actions that can be taken in the importing country.

The scheme requires a judgement on the reliability of each potential measure identified. A reliable measure is understood to mean one that it is efficient, feasible and reproducible. Limitations of application in practice should be noted. Once all potential measures have been identified, the extent to which they are cost-effective and can be combined with other measures is evaluated. A pest may enter by many different pathways and a pathway may transport many pests. It is therefore important to repeat the process for all relevant pests and pathways of concern.

In considering your responses to the following questions, please note that helpful information may be obtained from the pest risk assessment stage, particularly from the section concerning the entry of a pest (1.1-1.15). References to the relevant sections of the risk assessment stage have been added.

Risk associated with major pathways

Acceptability of the risk

A decision has to be made to determine whether the risk from any pest/pathway combination is an acceptable risk. This decision will be based on the relationship between the level of risk identified in the pest risk assessment stage (i.e. the combination of the probability of introduction and the potential economic impact) and the importance/desirability of the trade that carries the risk of introduction of the pest.

3.1. Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?

If yes STOP

If no Proceed through the risk management scheme following the instructions below.

No. The risk is not acceptable.

Types of pathways

In most cases, the pathways to be studied will be particular commodities of plants and plant products, of stated species, moving in international trade and coming from countries where the pest is known to occur, and the questions are intended primarily for these situations. However, the pathways identified in the pest risk assessment may also include other types of pathways, e.g. natural pathway (pest spread), transport by human travellers, conveyances packing material and traded commodities other than plants and plant products, and these also need to be assessed for suitable measures. Therefore, this section explains how to analyze the other types of pathways. For plants, it is particularly important to prioritize the pathways and to identify their relative importance, as some important pathways may not currently be regulated (grain, wool, hides, sand, gravel...).

Instructions for working through the Risk Management stage

Pest-Initiated Analysis

In the case of an analysis concerning an unintentional introduction of a pest, go to question 3.2 and proceed through steps 3.2-3.10, which relate to different pathways on which the pest being analyzed may be carried. Thereafter continue with the questions concerned with the measures that might be applied to each pathway. Repeat the process for every major pathway. For the intentional import of pest plants, the focus should be on measures preventing the establishment and spread of the organism in unintended habitats within the PRA area. The main pathway for these plants is usually the trade with ornamental plants intended for planting. For such cases go directly to question 3.29 (measures that can be taken in the importing country). This still allows the option of prohibiting import (3.37) to be considered. However, if the organism is also entering the area unintentionally, then measures may be required to prevent introduction through unintentional pathways and steps 3.2-3.28 should also be followed. Options for managing the unintentional introduction of pest plants are covered by following the procedures for pathway-initiated analysis.

Pathway-Initiated Analysis for a commodity of plants and plant products

In the case of a pathway-initiated analysis for a commodity of plants and plant products, since the precise pathway is already known, begin with question 3.11 to consider possible measures for this pathway and repeat the process as far as question 3.41 for each of the pests identified in the pest risk assessment as presenting a risk to the PRA area. When all the pests have been considered, go to 3.42 to integrate the measures for the commodity. (Note that the probabilities for entry of a particular pest with other pathways, including existing pathways, may also need to be investigated).

In considering your responses to the following questions, please note that helpful information may be obtained from the pest risk assessment stage, particularly from the section concerning entry (1.1-1.15). References to the relevant sections of the risk assessment stage have been added.

The eight pathways identified in the probability of entry section (see *Question 1.1*) are dealt with in this section: seven are commodities of plants or plant products; one is not a commodity of plants or plant products, i.e. *soil as a contaminant*. The main potential pathways of entry identified in the risk assessment are as follows:

i. Plants for planting (excluding seeds and fruit) of known susceptible hosts (see Appendix II) that are permitted entry from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin. Plants for planting of known hosts from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a pathway.

ii. Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Plants for planting of non-host plant species with contaminated growing media from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a potential pathway.

iii. Soil/growing medium (with organic matter) as a commodity from the USA and Canada, or from the as yet unknown area/s of origin for *P. ramorum.* Soil/growing media as a commodity from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

iv. Soil as a contaminant (e.g. on footwear, machinery, etc.) from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

v. Foliage or cut branches (for ornamental purposes) of susceptible foliar hosts (Appendix II) from third countries where the pathogen occurs (as detailed in i-iii above).

vi. Seeds and fruits of susceptible host plants (Appendix II) from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

vii. Susceptible (isolated) bark from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

viii. Susceptible wood from third countries where the pathogen occurs or may occur (as detailed in i-iii above).

<u>Pathway (i) – Plants for planting (excluding seeds and fruit) of known susceptible hosts</u> (see Appendix II) that are permitted entry from the USA and Canada, or from undetermined third countries that represent the pathogen's, as yet unknown, area/s of origin. Plants for planting of known hosts from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a pathway.

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes

If yes	**Go to 3.11**
If no	Go to 3.3

Existing phytosanitary measures

Phytosanitary measures (e.g. inspection, testing or treatments) may already be required as a protection against other (quarantine) pests (see stage 2: question 1.10). The assessor should list these measures and identify their efficacy against the pest of concern. The assessor should nevertheless bear in mind that such measures could be removed in the future if the other pests are re-evaluated.

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a pathogen of plants.

If yes	Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself)	**Go to 3.12**

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.

Go to 3.13

Yes, in part. EU provisional emergency phytosanitary measures were put in place in 2002 (2002/757/EC, as amended 2004 and 2007) (Anon., 2002, 2004, 2007) to prevent the introduction and spread of *P. ramorum* within the Community; the measures will be reviewed by the EC Plant Health Standing Committee in association with this PRA produced from the RAPRA Project.

The current emergency phytosanitary measures state the following general requirements in relation to plants for planting (not all of the detail is given):

- *The introduction into the Community and spread within the Community of non-European or European isolates of the harmful organism shall be banned.*

Specific measures in the Annex to the Decision apply as follows for named susceptible plants for planting from the USA:

- *Susceptible plants originating in the USA, other than fruit and seeds, of* Acer macrophyllum *Pursh,* Acer pseudoplatanus *L.,* Adiantum aleuticum *(Rupr.) Paris,* Adiantum jordanii *C. Muell.,* Aesculus californica *(Spach) Nutt.,* Aesculus hippocastanum *L.,* Arbutus menziesii *Pursch.,* Arbutus unedo *L.,* Arctostaphylos *spp. Adans,* Calluna vulgaris *(L.) Hull,* Camellia *spp. L.,* Castanea sativa *Mill.,* Fagus sylvatica *L.,* Frangula californica *(Eschsch.) Gray,* Frangula purshiana *(DC.) Cooper,* Fraxinus excelsior *L.,* Griselinia littoralis *(Raoul),* Hamamelis virginiana *L.,* Heteromeles arbutifolia *(Lindley) M. Roemer,* Kalmia latifolia *L.,* Laurus nobilis *L.,* Leucothoe *spp. D. Don,* Lithocarpus densiflorus *(Hook. & Arn.) Rehd.,* Lonicera hispidula *(Lindl.) Dougl. ex Torr.&Gray,* Magnolia *spp. L.,* Michelia doltsopa *Buch.-Ham. ex DC,* Nothofagus obliqua *(Mirbel) Blume,* Osmanthus heterophyllus *(G. Don) P. S. Green,* Parrotia persica *(DC) C.A. Meyer,* Photinia *x* fraseri *Dress,* Pieris *spp. D. Don,* Pseudotsuga menziesii *(Mirbel) Franco,* Quercus *spp. L.,* Rhododendron *spp. L., other than* Rhododendron simsii *Planch.,* Rosa gymnocarpa *Nutt.,* Salix caprea *L.,* Sequoia sempervirens *(Lamb. ex D. Don) Endl.,* Syringa vulgaris *L.,* Taxus *spp. L.,* Trientalis latifolia *(Hook),* Umbellularia californica *(Hook. & Arn.) Nutt.,* Vaccinium ovatum *Pursh and* Viburnum *spp. L.*

  1a. Without prejudice to the provisions of Annex III, Part A(2) and Annex IV, Part A(1), (11.1), (39) and (40) [dealing with specific measures for certain trees and shrubs for planting] *of Directive 2000/29/EC* [see Table 18], *susceptible plants originating in the United States of America shall be accompanied by a certificate referred to in Article 13 (1) of Directive 2000/29/EC:*

  (a) *stating that they originate in areas in which non-European isolates of the harmful organism are known not to occur. The name of the area shall be mentioned on the certificate under the rubric 'place of origin'; or*

  (b) *issued after official verification that no signs of non–European isolates of the harmful organism have been observed on any susceptible plants at the place of production during official inspections, including laboratory testing of any suspicious symptoms carried out since the beginning of the last complete cycle of vegetation.*

  Further, the certificate shall only be issued after representative samples of the plants have been taken before shipment and have been inspected and found free from non-European isolates of the harmful organism in these inspections. The latter shall be mentioned on the certificate under the rubric 'additional declaration' as 'found free from non-European isolates of Phytophthora ramorum *Werres, De Cock & Man in 't Veld sp. nov.'.*

  1b. The introduced susceptible plants referred to in point 1a may only be moved within the Community if they are accompanied by a plant passport prepared and issued in accordance with the provisions of Directive 92/105/EEC.

- *Plants intended for planting of* Viburnum *spp.,* Camellia *spp. and* Rhododendron *spp., other than* Rhododendron simsii *Planch, other than seeds originating in the Community may be moved within the Community only if they are accompanied by a plant passport prepared and issued in accordance with Commission Directive 92/105/EEC.* (Attesting to pest-free area or place of production freedom for *P. ramorum*).

Non-specific measures that exist in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) for plants of *P. ramorum* hosts are detailed in Table 18.

<u>Efficacy of measures:</u>

Measures for plants for planting of known hosts from the USA:

The emergency phytosanitary measures (Anon., 2002, 2004 and 2007) and other pre-existing measures (Anon., 2000) are likely to be effective. Since emergency measures were introduced in 2002 there have been no reported interceptions of *P. ramorum* on plants from the USA. The emergency measures refer to the main hardy ornamental hosts that are likely to move the pathogen, although the listed susceptible host plants comprise only 38 genera (i.e. those that are known in the USA) and the list is therefore not fully comprehensive; there are at least 75 known susceptible genera (North America plus Europe) and the number of new genera and species continues to grow. Unspecified genera of trees and shrubs from the USA (i.e. third countries excluding European and Mediterranean countries) still require a phytosanitary certificate with an additional declaration under the EU Plant Health Directive (2000/29/EC) (Anon., 2000) under Article 39 of Annex IVAI (Table 18); some would be prohibited absolutely (Annex IIIA) (*Abies*, *Pseudotsuga*) whilst other are prohibited except in either a dormant and/or leaf-less state (*Castanea, Quercus, Prunus, Rosa, Photinia*); all deciduous trees and shrubs for planting (except seeds and plants in tissue culture) from the USA must be dormant and free of leaves (Annex IVA1, Article 40), but this would not be expected to fully effective for dieback hosts where shoots/stems are infected with *P. ramorum.* Most annual and biennial plants, naturally or artificially dwarfed plants and herbaceous perennials for planting also require a phytosanitary certificate with additional declarations (Annex IVA1, Articles 41, 43 and 44 – see Table 18).

Measures for plants for planting of known hosts from Canada:

The emergency measures and other pre-existing measures are likely to be mostly effective in preventing entry from Canada, where *P. ramorum* is present on several nurseries though under eradication. Although the measures applied to listed susceptible hosts from the USA are not applied specifically to the same hosts from Canada, the pre-existing measures in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) requiring phytosanitary certificates for trees and shrubs, annual and biennial plants, dwarfed plants and herbaceous perennials (Annex IVA1, Articles 39, 40, 41, 43 and 44 – see Table 18), are likely to effectively reduce the risk of introduction of *P. ramorum* from Canada and subsequent movement within the Community.

Measures for plants for planting of known hosts from non-EU European countries (i.e. Norway and Switzerland):

The measures applied to plants for planting from Norway and Switzerland are not known.

Measures for plants for planting of known hosts from the area/s of unknown origin:

It is uncertain how effective pre-existing measures are for plants for planting originating in the pathogens unknown area/s of origin. Since the area/s of origin are unknown, together with the hosts present there, there are no specific measures and only the general measures in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) would apply to the exporting county. These are primarily general requirements for all plants from third countries outside of Europe and the Mediterranean area to have a phytosanitary certificate (Annex IVA1, Articles 39, 40, 41, 43 and 44 – see Table 18). These measures are likely to have a moderate to good ability to reduce the probability of further entry of the pathogen from the unknown area/s of origin of *P. ramorum*.

Table 18: Pre-existing <u>non-specific</u> measures in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) that relate to known host plants (in bold) or potential hosts of *Phytophthora ramorum* originating from outside the Community.

Annex	Article	Description	Measure
IIIA	1	Plants of ***Abies*** Mill., *Cedrus* Trew, *Chamaecyparis* Spach, *Juniperus* L., *Larix* Mill., *Picea* A. Dietr., *Pinus* L., ***Pseudotsuga*** Carr. and *Tsuga* Carr., other than fruit and seeds.	Prohibited from Non-European countries
IIIA	2	Plants of ***Castanea*** Mill., and ***Quercus*** L., with leaves, other than fruit and seeds.	Prohibited from Non-European countries
IIIA	9	Plants of *Chaenomeles* Ldl., *Cydonia* Mill., *Crateagus* L., *Malus* Mill., ***Prunus*** L., *Pyrus* L., and ***Rosa*** L., intended for planting, other than dormant plants free from leaves, flowers and fruit.	Prohibited from Non-European countries
IIIA	9.1	Plants of ***Photinia*** Ldl., intended for planting, other than dormant plants free from leaves, flowers and fruit.	Prohibited from USA, China, Japan, the Republic of Korea and Democratic People's Republic of Korea
IIIA	18	Plants of *Cydonia* Mill., *Malus* Mill., ***Prunus*** L. and *Pyrus* L. and their hybrids, and *Fragaria* L., intended for planting, other than seeds.	Without prejudice to the prohibitions applicable to the plants listed in Annex III A (9), where appropriate, prohibited from non-European countries, other than Mediterranean countries, Australia, New Zealand, Canada, the continental states of the USA
IVA1	39	Trees and shrubs, intended for planting, other than seeds and plants in tissue culture, originating in third countries other than European and Mediterranean countries.	Without prejudice to the provisions applicable to the plants listed in Annex III(a)(1), (2), (3), (9), (13), (15), (16), (17), (18), Annex III(B)(1) and Annex IV(A)(I)(8.1), (8.2), (9), (10), (11.1), (11.2), (12), (13.1), (13.2), (14), (15), (17), (18), (19.1), (19.2), (20), (22.1), (22.2), (23.1), (23.2), (24), (25.5), (25.6), (26), (27.1), (27.2), (28), (29), (32.1), (32.2), (33), (34), (36.1), (36.2), (37), (38.1) and (38.2), where appropriate, official statement that the plants: – are clean (i.e. free from plant debris) and free from flowers and fruits, – have been grown in nurseries, have been inspected at appropriate times and prior to export and found free from symptoms of harmful bacteria, viruses and virus-like organisms, and either found free from signs or symptoms of harmful nematodes, insects, mites and fungi, or have been subjected to appropriate treatment to eliminate such organisms.
IVA1	40	Deciduous trees and shrubs, intended for planting, other than seeds and plants in tissue culture, originating in third countries other than European and Mediterranean countries.	Without prejudice to the provisions applicable to the plants listed in Annex III(A)(2), (3), (9), (15), (16), (17) and (18), Annex III(B)(1) and Annex IV(A)(I), (11.1), (11.2), (11.3), (12), (13.1), (13.2), (14), (15), (17), (18), (19.1), (19.2), (20), (22.1), (22.2), (23.1), (23.2), (24), (33), (36.1), (38.1), (38.2), (39) and (45.1) where appropriate, official statement that the plants are dormant and free from leaves.

IVA1	41	Annual and biennial plants other than Gramineae, intended for planting, other than seeds, originating in countries other than European and Mediterranean countries.	Without prejudice to the provisions applicable to the plants, where appropriate, listed in Annex III(A)(11), (13), and Annex IV(A)(I)(25.5), (25.6), (32.1), (32.2), (32.3), (33), (34), (35.1) and (35.2) official statement that the plants:
			– have been grown in nurseries,
			– are free from plant debris, flowers and fruits,
			– have been inspected at appropriate times and prior to export, and
			    – found free from symptoms of harmful bacteria, viruses and virus-like organisms, and
			    – either found free from signs or symptoms of harmful nematodes, insects, mites and fungi, or have been subjected to appropriate treatment to eliminate such organisms.

Annex	Article	Description	Measure
IVA1	43	Naturally or artificially dwarfed plants intended for planting other than seeds, originating in non-European countries.	Without prejudice to the provisions applicable to the plants listed in Annex III(A)(1), (2), (3), (9), (13), (15), (16), (17), (18), Annex III(B)(1), and Annex IV(A)(I)(8.1), (9), (10), (11.1), (11.2), (12), (13.1), (13.2), (14), (15), (17), (18), (19.1), (19.2), (20), (22.1), (22.2), (23.1), (23.2), (24), (25.5), (25.6), (26), (27.1), (27.2), (28), (32.1), (32.2), (33), (34), (36.1), (36.2), (37), (38.1), (38.2), (39), (40) and (42), where appropriate, official statement that: (a) the plants, including those collected directly from natural habitats, shall have been grown, held and trained for at least two consecutive years prior to dispatch in officially registered nurseries, which are subject to an officially supervised control regime, (b) the plants on the nurseries referred to in (a) shall: (aa) at least during the period referred to in (a): – be potted, in pots which are placed on shelves at least 50 cm above ground, – have been subjected to appropriate treatments to ensure freedom from non-European rusts: the active ingredient, concentration and date of application of these treatments shall be mentioned on the phytosanitary certificate provided for in Article 7 of this Directive under the rubric «disinfestation and/or disinfection treatment». – have been officially inspected at least six times a year at appropriate intervals for the presence of harmful organisms of concern, which are those in the Annexes to the Directive. These inspections, which shall also be carried out on plants in the immediate vicinity of the nurseries referred to in (a), shall be carried out at least by visual examination of each row in the field or nursery and by visual examination of all parts of the plant above the growing medium, using a random sample of at least 300 plants from a given genus where the number of plants of that genus is not more than 3 000 plants, or 10% of the plants if there are more than 3 000 plants from that genus, – have been found free, in these inspections, from the relevant harmful organisms of concern as specified in the previous indent. Infested plants shall be removed. The remaining plants, where appropriate, shall be effectively treated, and in addition shall be held for an appropriate period and inspected to ensure freedom from such harmful organisms of concern, – have been planted in either an unused artificial growing medium or in a natural growing medium, which has been treated by fumigation or by appropriate heat treatment and has been of any harmful organisms, – have been kept under conditions which ensure that the growing medium has been maintained free from harmful organisms and within two weeks prior to dispatch, have been: – shaken and washed with clean water to remove the original growing medium and kept bare rooted, or

Annex	Article	Description	Measure
			– shaken and washed with clean water to remove the original growing medium and replanted in growing medium which meets the conditions laid down in (aa) fifth indent, or – subjected to appropriate treatments to ensure that the growing medium is free from harmful organisms, the active ingredient, concentration and date of application of these treatments shall be mentioned on the phytosanitary certificate provided for in Article 7 of this Directive under the rubric «disinfestation and/or disinfection treatment». (bb) be packed in closed containers which have been officially sealed and bear the registration number of the registered nursery; this number shall also be indicated under the rubric *additional declaration* on the phytosanitary certificate provided for in Article 7 of this Directive, enabling the consignments to be identified.
IVA1	44	Herbaceous perennial plants, intended for planting, other than seeds, of the families Caryophyllaceae (except *Dianthus* L.), Compositae (except *Dendranthema* (DC.) Des Moul.), Cruciferae, Leguminosae and **Rosaceae** (except *Fragaria* L.), originating in third countries, other than European and Mediterranean countries	Without prejudice to the requirements applicable to plants, where appropriate, listed in Annex IV(A)(I)(32.1), (32.2), (32.3), (33) and (34) official statement that the plants: – have been grown in nurseries, and – are free from plant debris, flowers and fruits, and – have been inspected at appropriate times and prior to export, and – found free from symptoms of harmful bacteria, viruses and virus-like organisms, and either found free from signs or symptoms of harmful nematodes, insects, mites and fungi, or have been subjected to appropriate treatment to eliminate such organisms.
VB1	1	Plants intended for planting originating outside of the community	Require inspection in country of origin or the consignor country before being permitted to enter the community.

Identification of appropriate risk management options: Plants for planting (excluding seeds and fruit) of known susceptible hosts

This section (questions 3.13 to 3.31) examines the characteristics of the pest to determine if it can be reliably detected in consignments by inspection or testing, if it can be removed from consignments by treatment or other methods, if limitation of use of the commodity would prevent introduction, or if the pest can be prevented from infecting/infesting consignments by treatment, production methods, inspection or isolation. "Reliably" should be understood to mean that a measure is efficient, feasible and reproducible. Measures can be reliable without being sufficient to reduce the risk to an acceptable level. In such cases their combination with other measures to reach the desired level of protection against the pest should be envisaged (see question 3.32). When a measure is considered reliable but not sufficient, the assessor should indicate this. The efficiency, feasibility and reproducibility of the measures should be evaluated by the assessor for each potential management option identified. Limitations of application of measures in practice should be noted. ***Cost effectiveness and impact on trade are considered in the section "evaluation of risk management options" (questions 3.34 to 3.36).***

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. The pathogen cannot be detected by visual inspection alone since symptoms are not unique (see *Question 1.10*). Similarly, although symptoms are likely to be expressed on susceptible aerial plant parts during active growth (the incubation period is considered relatively short), the pathogen could be present but undetectable visually as infections on roots, as cryptic infections in buds or leaf scars, or symptoms could be suppressed by the use of fungicides. The pathogen may also be present as spores in the growing media but measures relates to soil and growing media attached to or accompanying plants (Article 34 of Annex IVA1) (Anon., 2000) would apply to the pathways from the USA, Canada and to the likely (but as yet unknown) area/s of origin for *P. ramorum*, since they apply to plants from non-European countries other than certain specified countries (Table 19).

Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plants, seeds in a consignment)?

If yes **possible measure: specified testing.**

Yes. The pathogen can be reliably detected and identified by testing of most plant substrates. Symptomatic plant material can be tested on-site by inspectors using *Phytophthora* genus-specific lateral flow devices (LFDs). However, these do not identify any potential pathogen to species level. DNA-based (PCR) on-site methods (e.g. SmartCycler) can specifically detect and identify *P. ramorum* but this approach is not routinely used by official inspection services. Laboratory testing is therefore required in almost all situations for species identification; a variety of different methods (see *Question 1.10*) can be used that have a relatively high degree of reliability (DNA-based methods; isolation of the pathogen in culture). DNA-based methods (PCR) can also be used to test asymptomatic bulked leaf samples due to the high sensitivity of these methods (Boonham *et al.*, 2006); selection of test material is problematic though in the absence of symptoms and negative test results may not be reliable. Testing can also be done with other substrates: soil, growing media (and water) can be tested *in situ* or in the laboratory by baiting methods (e.g. with rhododendron leaves), or with direct PCR methods.

Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

> *Note:* ISPM no. 5 *"Glossary of Phytosanitary Terms*" defines quarantine as *"official confinement for observation and research or for further inspection, testing and/or treatment of a consignment after entry"*.

If yes **possible measure: import under special licence/permit and post-entry quarantine.**

Yes. Based on visual detection of suspicious symptoms on host plants and laboratory testing. Post-entry quarantine would allow time for the development of symptoms in asymptomatic material as the incubation period is relatively short.

Go to 3.16

<u>Removal of the pest from the consignment by treatment or other phytosanitary procedures</u>

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

No. The pathogen cannot be effectively destroyed by chemical or other means applied to plants for planting. Fungicides cannot be considered to be completely reliable and few have curative properties. Heat treatments have been investigated for use with key plant genera, but have not proved completely reliable at temperatures which do not damage the plants themselves (Jennings, 2008). The pathogen is very persistent, especially due to its ability to produce chlamydospores.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

If yes **possible measure: removal of parts of plants from the consignment.**

No. For plants for planting, the pathogen can potentially infect a variety of plant parts, depending on the plant species. Some hosts only develop symptoms on leaves (ramorum leaf blight): although leaves could be removed in such cases, especially for deciduous hosts, it is possible that cryptic infections could remain in leaf scars or buds, as shown for magnolia (Denman, 2007); removal of leaves from evergreen hosts would reduce the value of the plants. For hosts that develop symptoms on both leaves and shoots (ramorum dieback), removal of leaves is not likely to be effective in ensuring freedom from the pathogen since it could persist as shoot infections; such infections may be cryptic or not easily detected, especially on woody stems. For hosts which do not develop leaf or shoot symptoms but only develop symptoms on bark (ramorum bleeding canker), removal of woody parts with bark would damage the plant.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing methods.**

No. Not relevant for plants for planting of hosts plants.

Go to 3.19

Prevention of establishment by limiting the use of the consignment

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/ permit and specified restrictions:**

No. Not applicable for plants for planting, since planting is the only end-use.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

Prevention of infestation of the commodity

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No. Chemical or non-chemical treatments are not considered completely reliable in preventing infection of plants of planting.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No. There are no breeding programmes, no known immune cultivars of susceptible species and no identified sources of resistance for use in future breeding programmes.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

No. Even if the plants are grown in sterilised growing media using drip irrigation (even from water supplies decontaminated by sand filtration of chemical means), significant risks of contamination and spread would still exist in areas where the pathogen occurs.

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. Not relevant.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

Yes. Domestic certification schemes for plants for planting of susceptible hosts and best management practices are likely to reduce the risk of infestation, but only if they involve official testing for symptomatic material.

Go to 3.25

<u>Establishment and maintenance of pest freedom of a crop, place of production or area</u>

Note that in this set of questions pest spread capacity is considered without prejudice to any other measure that can be recommended. For some pests, growing the plant in specific conditions can prevent natural spread (e.g. production in a glasshouse may provide protection against pest with high capacity for natural spread). These measures should have been identified in question 3.22. In answering questions 3.25 to 3.27 refer to the answer to question 1.32 of the risk assessment section.

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**
Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area.**

Go to 3.28

If no Go to 3.27

Yes. Natural spread is mostly limited to local splash-dispersal within a few metres. However, longer-distant natural spread by turbulent air can occur more rarely over several kilometres under certain weather conditions. There is also the potential for longer-distance natural spread over about a kilometre via inoculum in watercourses, wind-blown infected debris, or through movement of contaminated soil/debris on the feet of animals; these are less significant pathways of natural spread though.

3.27. The pest has a medium to high capacity for natural spread

Possible measure: pest-free area.
Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

> *Note* : *In order to guarantee freedom of a crop, place of production, place of production and buffer zone, or area, it should be possible to fulfil the requirements outlined in ISPM No. 4 and ISPM No. 10. Consider in particular the degree to which unintentional movement of the pest by human assistance could be prevented (see answer to question 1.33).*

Yes. Pest freedom of the crop, place of production or area could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no — Possible measure identified in questions 3.25-3.27 would not be suitable.

Go to 3.29

<u>Consideration of other possible measures</u>

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

> *Note: For intentionally imported plants, see the EPPO Standard PM/3 67 on Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported. When natural spread is the major pathway, international measures are not justified and risk should be accepted because it is not manageable.*

Yes. EU countries could inspect all plants for planting (particularly trees and shrubs) imported from countries where *P. ramorum* is known to occur, as well as all other third countries, followed by destruction and safe disposal of any plants found to be infected with *P. ramorum.* This would help prevent the introduction of *P. ramorum* lineages not already present in the EU (NA1, NA2 and unknowns) and the further introduction of isolates of the EU1 lineage. Surveillance of semi-natural or natural environments and appropriate eradication/containment measures would also prevent further establishment and spread to new areas within the EU, as well as minimising impacts in those areas where the pathogen has established. Continued surveillance and eradication/containment measures on nurseries within the EU would also continue to reduce further establishment and spread of the pathogen through intra-community trade in plants for planting.

If yes — **Possible measures: internal surveillance and/or eradication campaign**

Go to 3.30

Evaluation of risk management options: Plants for planting (excluding seeds and fruit) of known susceptible hosts

This section evaluates the risk management options selected and considers in particular their cost effectiveness and potential impact on international trade.

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes	**Go to 3.31**
If no	Go to 3.38

Yes. Listed in the order of previous positive responses:

- Detection of the pathogen in consignments by inspection <u>and</u> testing at export and/or import.
- Detection of the pathogen by inspection <u>and</u> testing during post-entry quarantine.
- Domestic certification schemes <u>if</u> supported by testing of symptomatic material.
- Pest freedom for the crop, place of production or area.
- Surveillance and eradication in the importing country of the EU.

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes	Go to 3.34
If no	**Go to 3.32**

No.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

> *Note: The integration of different phytosanitary measures at least two of which act independently and which cumulatively achieve the Appropriate Level of Protection against regulated pests are known as Systems Approaches (see ISPM 14: the use of integrated measures in a systems approach for Pest Risk Management). It should be noted that Pest free places of production identified as phytosanitary measures in questions 3.25 to 3.27 may correspond to a System Approach.*

If yes	**Go to 3.34**
If no	Go to 3.33

Yes.

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

> *Note*: *If this analysis concerns a pest already established in the PRA area but under official control, measures that are applied for international trade should not be more stringent than those applied domestically/internally.*

None of the measures involve the banning of any plants for planting so the measures do not interfere directly with international trade. However, some measures will have impacts on individual exporters and importers. Visual inspections and testing of symptomatic plants at the place of production may delay the movement of plants; this may lead to loss of contracts with the importer. Post-entry quarantine would affect an importers ability to move or trade plants and this may also lead to the possible loss of contracts; impacts will vary with the timing and length of the post-entry quarantine period. Pest-free area or place of production is already a requirement for imports of susceptible plants from the USA.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

The cost-effectiveness of the measures on imports of plants for planting (hosts) in exporting and importing countries have not been evaluated. Reports of the costs and descriptions of the types of costs for the implementation of measures are given for Great Britain (current and future), Oregon and California in 2.1 and 2.4. Discussion of the environmental consequences of implementing measures in semi or unmanaged environments is described in 2.6. Discussion of the social damage arising from implementing measures in managed gardens is described in 2.8.

The main costs for imports of plants for planting are associated with inspections, sampling and testing in the exporting country and surveillance, sampling, testing and eradication and containment measures for outbreaks in the importing country. Measures involving inspections and sampling and testing of suspect plants at nurseries are likely to be beneficial for plant health services in both exporting and importing countries since they should result in reduced numbers of outbreaks if implemented effectively. However, outbreaks on nurseries will incur costs for individual growers through the destruction of infected plant material and any other related measures; costs will be related to the value and quantity of the plants concerned. Where material is held or destroyed there is potential for loss of contracts with customers either directly or through loss in confidence. Access to propagation material of hosts and non-hosts may be hindered by implementation of phytosanitary measures leading to further losses in production and sales. Specialist growers of susceptible hosts may lose their business or have to change the types of plants that they produce, which could lead to loss of income and employment of specialist staff.

Implementation of eradication and containment measures for outbreaks in semi-natural or natural environments arising from imported infected material will also lead to significant costs, depending on the scale of individual outbreaks. Some environmentally important species may need to be removed if they become infected and are sporulating hosts. Conversely, removal of infected invasive species such as *R. ponticum* will have an environmental benefit. Access to infected areas may be restricted while measures are implemented.

In historic gardens, parks or '*public greens*', implementation of eradication and containment measures for outbreaks arising from planting imported infected plants will be costly, and may lead to loss of income from visitors to the gardens and for tourism generally in the affected area. Loss of plant sales from nurseries in the grounds of historic gardens may also occur.

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes — For pathway-initiated analysis, go to 3.
For pest-initiated analysis, go to 3.38
If no — Go to 3.37

Yes.

3.37. Envisage prohibiting the pathway.

Note: Prohibition should be viewed as a measure of last resort. If prohibition of the pathway is the only measure identified for a commodity-initiated analysis, there may be no need to analyze any other pests that may be carried on the pathway. If later information shows that prohibition is not the only measure for this pest, analysis of the other pests associated with the pathway will become necessary.

For pathway-initiated analysis, go to 3.43 (or 3.39)
For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes — Go to 3.41
If no — Go to 3.1 to analyze the next major pathway

Pathway (ii) – Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media from the USA and Canada, or from undetermined third countries that represent the pathogen's area/s of origin. Plants for planting of non-host plant species with contaminated growing media from non-EU European countries where the pathogen occurs (Norway and Switzerland) are also a potential pathway.

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes.

If yes — go to 3.11
If no — go to 3.3

Existing phytosanitary measures

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a pathogen of plants.

If yes — Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself) — go to 3.12

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.
Go to 3.13

Yes, in part. There are measures that exist in the EU Plant Health Directive (2000/29/EC) (Anon., 2000), for plants for planting, that might prevent the introduction of *P. ramorum* as a contaminant of non-host plants. These are the various articles in Annex IVA1 of 2000/29/EC that are detailed in Table 19.

<u>Efficacy of measures:</u>

Measures that relate to soil and growing media attached to or accompanying plants (Article 34 of Annex IVA1) would apply to the pathways from the USA, Canada and to the likely (but as yet unknown) area/s of origin for *P. ramorum*, since they apply to plants from non-EU countries (Table 19). They would reduce the potential for growing media to be contaminated with *P. ramorum*, but would not have any impact on any potential persistence via root colonisation, though this is only known for hosts of *P. ramorum* and not for non-hosts. If treatment options for the soil or growing media are chosen by the exporter, then these will also reduce the risks of potential contamination. These measures do not apply to soil and growing media attached to plants for planting imported from Norway and Switzerland.

General measures (Annex IVAI, Articles 39, 40, 41, 43 and 44) (Table 18), requiring trees, shrubs, annual and biennial plants, dwarfed plants and herbaceous perennials to be clean and free of plant debris, as well as having to have been grown in nurseries, will also reduce the risk of contamination of any growing media attached to non-host plants for planting, e.g. by reducing the likelihood of infected leaves/debris of host plants contaminating the consignment. If treatment options for the non-host plants are chosen by the exporter, then these will also reduce the risk of potential contamination.

Table 19. Pre-existing non-specific measures in the EU Plant Health Directive (29/2000/EC) (Anon., 2000) that relate to non-host plants for planting originating from outside the Community that might be contaminated with *Phytophthora ramorum*. (See also Table 18).

Annex	Article	Description	Measure
IVA1	34	**Soil and growing medium**, attached to or associated with plants, consisting in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark or consisting in part of any solid inorganic substance, intended to sustain the vitality of the plants, originating in: – Turkey – Belarus, Georgia, Moldova, Russia, Ukraine, (0J L 236) – Non-European countries other than Algeria, Egypt, Israel, Libya, Morocco, Tunisia	Official statement that: (a) the growing medium, at the time of planting, was: – either free from soil, and organic matter, or – found free from insects and harmful nematodes and subjected to appropriate examination or heat treatment or fumigation to ensure that it was free from other harmful organisms, or – subjected to appropriate heat treatment or fumigation to ensure freedom from harmful organisms, and (b) since planting: – either appropriate measures have been taken to ensure that the growing medium has been maintained free from harmful organisms, or – within two weeks prior to dispatch, the plants were shaken free from the medium leaving the minimum amount necessary to sustain vitality during transport, and, if replanted, the growing medium used for that purpose meets the requirements laid down in (a).

Identification of appropriate risk management options: Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. Spores contaminating growing media of non-host plants cannot be visually detected. Symptoms will not be present on non-host plants.

Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plants, seeds in a consignment)?

If yes **possible measure: specified testing.**

No, not reliably for growing media. The pathogen can be detected in the laboratory by using baiting methods (e.g. with rhododendron leaves), or with direct PCR methods. Baiting methods rely on spores not being dormant and this is not guaranteed to be the case with *P. ramorum* chlamydospores. Testing growing media is therefore not considered entirely reliable.

Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

If yes **possible measure: import under special licence/ permit and post-entry quarantine.**

No, not reliably for growing media. See 3.14.

Go to 3.16

<u>Removal of the pest from the consignment by treatment or other phytosanitary procedures</u>

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

Yes. The pathogen could be removed or destroyed by treatment of small quantities of the growing media prior to planting and prevention of reinfestation during the growing period and physical removal of any surplus just before export. This is the basis for the pre-existing general EC measures outlined in Table 19. Fumigation or other chemical treatment methods of the growing media prior to planting would most likely destroy any sporangia or zoospores contaminating the growing medium. Large bulks of growing media may not be so effectively treated. The effectiveness of chemicals/fumigants against chlamydospores in growing media is not known. The physical removal of plant debris during the growing period would be one important measure that would reduce the risk of contamination by *P. ramorum*, as would physical removal of the growing medium to minimum levels prior to export that would sustain plant vitality in transit.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

If yes **possible measure: removal of parts of plants from the consignment**

Yes. Only the growing medium is being considered here. The growing medium could be removed to the minimum amount necessary to sustain plant vitality in transit.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing**

methods

Yes, in part. Measures could be taken to prevent the risk of contamination of growing media during its storage and use at the place of production.

Go to 3.19

Prevention of establishment by limiting the use of the consignment

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/ permit and specified restrictions:**

No. Not applicable for plants for planting, since planting is the only end-use.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

Prevention of infestation of the commodity

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No. Since chemical and/or non-chemical treatments applied to plants are not considered completely reliable in preventing infection of plants of planting, they would similarly not be considered effective against spores contaminating growing medium.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No. Not relevant.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

Yes. Contamination of growing media used for planting non-host plants at places of production in areas where the pathogen occurs could be prevented by a variety of measures. These include: growing plants in containers rather than directly in the soil; growing plants on benches to prevent splash-dispersal of spores contaminating the ground; growing plants under protection and away from host plants to minimise the risk of contamination; ensuring that other sources of contamination are minimised or removed in nurseries, e.g. preventing contamination of growing media during storage and use, ensuring water supplies are free of the pathogen by appropriate treatment especially where irrigation water is recycled (e.g. sand filtration) and other measures which would reduce spread of the pathogen in nurseries (e.g. not using over-head irrigation; appropriate hygiene and disinfestations measures etc). See also *Question 3.28 (pest free place of production or area).*

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. Not relevant.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

No. Not relevant. Non-host plants are numerous and could not all be covered by a certification scheme. Requirements for maintaining clean growing media for non-host plants are covered elsewhere.

Go to 3.25

Establishment and maintenance of pest freedom of a crop, place of production or area

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**

Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area.**

Go to 3.28

If no Go to 3.27

Yes. Natural spread is mostly limited to local splash-dispersal within a few metres. However, longer-distant natural spread by turbulent air can occur more rarely over several kilometres under certain weather conditions. There is also the potential for longer-distance natural spread over about a kilometre via inoculum in watercourses, wind-blown infected debris, or through movement of contaminated soil/debris on the feet of animals; these are less significant pathways of natural spread though.

3.27. The pest has a medium to high capacity for natural spread

Possible measure: pest-free area.
Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes. Pest freedom of the crop, place of production or area for non-host plants with growing media attached could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no — Possible measure identified in questions 3.25-3.27 would not be suitable.
Go to 3.29

Consideration of other possible measures

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

None that are additional to those outlined under Pathway (i) for *Question 3.29*.

If yes — **Possible measures: internal surveillance and/or eradication campaign**
Go to 3.30

Evaluation of risk management options: Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes — **Go to 3.31**
If no — Go to 3.38

Yes. Listed in the order of previous positive responses:

- In areas where the pathogen occurs, treatment of the growing media prior to planting and prevention of reinfestation during the growing period and physical removal of any surplus just before export.
- Pest freedom for the crop, place of production or area
- Surveillance and eradication in the importing country of the EU.

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes Go to 3.34
If no Go to 3.32

No.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes Go to 3.34
If no Go to 3.33

Yes.

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The measure for requiring a pest free place or area of production for non-host plants with growing media attached would have a significant impact on international trade and would not be considered proportionate in relation to the risks from contaminated non-host plants. Pre-existing measures that would help prevent or remove potential contamination of growing media associated with non-host plants are those in place within the EU Plant Health Directive 2000/29/EC (Anon., 2000) (see Table 19). Some strengthening of specific measures for *P. ramorum* that go beyond these might be considered in the case of areas (USA/Canada) where *P. ramorum* is known to occur if the current measures are not considered sufficient to reduce the potential risk of further entry into the EU via contaminated growing media associated with non-host plants.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Measures for preventing or eliminating potential contamination from growing media accompanying non-host plants are considered to be cost effective in relation to potential risks and impacts to the EU. Costs associated with measures in the affected exporting countries have not been evaluated, but will incur additional costs if fully-implemented although some of the measures would be applied as part of good practice at places of production.

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes For pathway-initiated analysis, Go to 3.39
For pest-initiated analysis, Go to 3.38
If no Go to 3.37

3.37. Envisage prohibiting the pathway.

For pathway-initiated analysis, go to 3.43 (or 3.39)
For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes — Go to 3.41
If no — Go to 3.1 to analyze the next major pathway

<u>Pathway (iii) – Soil/growing medium (with organic matter) as a commodity</u> from the USA and Canada, or from the as yet unknown area/s of origin for *P. ramorum.* Soil/growing media as a commodity from non-EU European countries where the pathogen occurs (Norway and Switzerland) is also a potential pathway.

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes, in so far as soil and growing media can be considered a product derived in whole or in part from plant material.

If yes — Go to 3.11
If no — Go to 3.3

Existing phytosanitary measures

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a plant pathogen.

If yes — Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself) — Go to 3.12

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.
Go to 3.13

Yes. The introduction of soil and growing media in whole or in part of soil or solid organic substances other than composed entirely of peat is prohibited by the EU Plant Health Directive (2000/29/EC, Annex III) – See Table 20. These measures are entirely effective for preventing the introduction of *P. ramorum* that is contaminating this commodity.

Table 20. Pre-existing measures in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) that relate to soil and growing media as a commodity.

Annex	Article	Description	Measure
IIIA	14	Soil and growing medium as such, which consists in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark, other than that composed entirely of peat.	Prohibited from Turkey, Belarus, Moldavia, Russia, Ukraine and third countries not belonging to continental Europe, other than the following:, Egypt, Israel, Libya, Morocco, Tunisia.

Identification of appropriate risk management options: Soil/growing media as a commodity.

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. Spores contaminating soil or growing media cannot be visually detected.

Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

If yes **possible measure: specified testing.**

No. The pathogen could be detected by testing soil and growing media, but not reliably for large bulks of soil or growing media. Testing can be done in the laboratory by baiting methods (e.g. with rhododendron leaves), or with direct PCR methods. Bait tests rely on inoculum not being dormant, and this may not be the case for chlamydospores of *P. ramorum*. Testing large bulks of soil and growing media is also not considered practical or reliable.

Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

> *Note: ISPM no. 5 "Glossary of Phytosanitary Terms" defines quarantine as "official confinement for observation and research or for further inspection, testing and/or treatment of a consignment after entry".*

If yes **possible measure: import under special licence/ permit and post-entry quarantine.**

No. This is not considered practical or reliable for large bulks of soil or growing media, especially if the pathogen is present in the form of dormant and thick-walled chlamydospores.

Go to 3.16

Removal of the pest from the consignment by treatment or other phytosanitary procedures

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

Yes, in part. The pathogen could potentially be destroyed in soil or growing media by heat treatment or sterilisation methods, but this is not considered reliable or practical for large quantities.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants.)

If yes **possible measure: removal of parts of plants from the consignment**

No. Not relevant for contaminated soil or growing media.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing methods**

No. Not relevant for contaminated soil or growing media.

Go to 3.19

<u>Prevention of establishment by limiting the use of the consignment</u>

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/ permit and specified restrictions:**

No. Not relevant for contaminated soil or growing media.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

<u>Prevention of infestation of the commodity</u>

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No. Not relevant for contaminated soil or growing media.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No. Not relevant for contaminated soil or growing media.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

No. Not relevant for contaminated soil or growing media.

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. Not relevant for contaminated soil or growing media.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

No. Not relevant for contaminated soil or growing media.

Go to 3.25

<u>Establishment and maintenance of pest freedom of a crop, place of production or area</u>

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**

Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area**

Go to 3.28

If no Go to 3.27

Yes. See answer to *Question 3.26* for previous pathways.

3.27. The pest has a medium to high capacity for natural spread

possible measure: pest-free area

Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

> *Note*: *In order to guarantee freedom of a crop, place of production, place of production and buffer zone, or area, it should be possible to fulfil the requirements outlined in ISPM No. 4 and ISPM No. 10. Consider in particular the degree to which unintentional movement of the pest by human assistance could be prevented (see answer to question 1.33).*

Yes. Pest freedom of the place of production or area could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no — Possible measure identified in questions 3.25-3.27 would not be suitable. **Go to 3.29**

<u>Consideration of other possible measures</u>

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

> *Note: For intentionally imported plants, see the EPPO Standard PM/3 67 on Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported. When natural spread is the major pathway, international measures are not justified and risk should be accepted because it is not manageable.*

None that are additional to those outlined under Pathway (i) for *Question 3.29*.

If yes — **Possible measures: internal surveillance and/or eradication campaign** **Go to 3.30**

Evaluation of risk management options: Soil/growing media as a commodity

This section evaluates the risk management options selected and considers in particular their cost effectiveness and potential impact on international trade.

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes — **Go to 3.31**
If no — Go to 3.38

Yes. Listed in the order of previous positive responses:

- Pest free crop, place of production or area.
- Surveillance and eradication in the importing country of the EU.

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes — **Go to 3.34**
If no — Go to 3.32

Yes.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes — Go to 3.34
If no — Go to 3.33

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The measures do not interfere with international trade since soil and growing media are already prohibited (see Table 19).

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Not relevant, since soil and growing media as a commodity are prohibited (See Table 19).

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes — For pathway-initiated analysis, go to 3.
For pest-initiated analysis, go to 3.38
If no — Go to 3.37

Yes.

3.37. Envisage prohibiting the pathway.

The pathway is already prohibited.

For pathway-initiated analysis, go to 3.43 (or 3.39)

For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes — Go to 3.41
If no — **Go to 3.1 to analyze the next major pathway**

<u>Pathway (iv) – Soil as a contaminant</u> (e.g. on footwear, machinery, etc.) from the USA and Canada, or from the as yet unknown area/s of origin for *P. ramorum* as well as from non-EU European countries where the pathogen occurs (Norway and Switzerland).

3.2. Is the pathway that is being considered a commodity of plants and plant products?

No.

If yes — Go to 3.11
If no — Go to 3.3

3.3. Is the pathway that is being considered the natural spread of the pest? (see answer to question 1.32)

No.

If yes — Go to 3.4
If no — Go to 3.9

3.9. Is the pathway that is being considered the entry with human travellers?

If yes — possible measures: inspection of human travellers, their luggage, publicity to enhance public awareness on pest risks, fines or incentives. Treatments may also be possible
Go to 3.29
If no — Go to 3.10

Yes, as well as with contaminated machinery etc.

3.10. Is the pathway being considered contaminated machinery or means of transport?

If yes — possible measures: cleaning or disinfection of machinery/vehicles
Go to 3.29

Yes, in addition to human travellers.

For other types of pathways (e.g. commodities other than plants or plant products, exchange of scientific material, packing material, grain, wool, hides, sand, gravel ...), not all of the following questions may be relevant; adapt the questions to the type of pathway.

<u>Consideration of other possible measures</u>

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

Note: For intentionally imported plants, see the EPPO Standard PM/3 67 on Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported. When *natural spread is the major pathway, international measures are not justified and risk should be accepted because it is not manageable.*

Yes. Effective measures would be a requirement for clean footwear where travellers have been in an area where *P. ramorum* occurs (either cleaned before entry or at entry) and for imports of used machinery or vehicles (if these are imported into the EU), particularly agricultural and forestry machinery to be cleaned and decontaminated prior to export.

If yes	**Possible measures: internal surveillance and/or eradication campaign Go to 3.30**

Evaluation of risk management options: Soil as a contaminant

This section evaluates the risk management options selected and considers in particular their cost effectiveness and potential impact on international trade.

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes	**Go to 3.31**
If no	Go to 3.38

Yes. Listed in the order of previous positive responses:

- Inspection of human travellers footwear and possible treatment at the point of entry where travellers have entered from an area where *P. ramorum* occurs
- Cleaning and (if feasible without damage to the machinery) disinfection of used machinery or vehicles imported from an area where *P. ramorum* occurs.
- Surveillance and eradication in the importing country of the EU.

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

Yes.

If yes	**Go to 3.34**
If no	Go to 3.32

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes	Go to 3.34
If no	Go to 3.33

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The measures do not interfere with international trade.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Measures applied to travellers are likely to be considered socially undesirable in the EU, but these requirements are in place in a generic form in third countries such as New Zealand, where for example, declarations have to be made on arrival of '*biosecurity risk items*' including soil, water, articles with soil attached or equipment use with soil.
http://www.customs.govt.nz/nr/rdonlyres/75fd14e8-59b5-4e97-92bb-d73e87de5e62/0/arrivalcardmar2008.pdf
Such declarations are followed up at the point of entry and can require shoes to be cleaned before onward travel within the country.

With respect to imports of used agricultural or forestry machinery or vehicles, the requirement for cleaning/decontamination prior to export will incur a cost for the exporter but the benefit is a reduction in the risk of further entry of *P. ramorum* into the EU.

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes For pathway-initiated analysis, go to 3.

For pest-initiated analysis, go to 3.38

If no Go to 3.37

3.37. Envisage prohibiting the pathway.

For pathway-initiated analysis, go to 3.43 (or 3.39)

For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes Go to 3.41

If no Go to 3.1 to analyze the next major pathway

<u>Pathway (v) – Foliage or cut branches</u> (for ornamental purposes) of susceptible foliar hosts (Appendix II) from the USA and Canada, or from the as yet unknown area/s of origin for *P. ramorum* as well as from non-EU European countries where the pathogen occurs (Norway and Switzerland).

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes

If yes Go to 3.11

If no Go to 3.3

Existing phytosanitary measures

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a plant pathogen.

If yes Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself) Go to 3.12

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.
Go to 3.13

Yes, but very limited. There are no specific measures applied to foliage or cut branches of host plants in the emergency phytosanitary measures laid down for *P. ramorum* in 2002 (2002/757/EC as amended 2004 and 2007) (Anon., 2002, 2004 and 2007). There are some limited measures that exist in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) that might prevent the introduction of *P. ramorum* on this commodity, but only based upon inspection of *Castanea*, *Quercus*, *Prunus*, *Rosa* and conifers (Table 21). This would apply to cut foliage or branches from the USA, Canada, non-EU European countries (Norway/Switzerland) and to the likely (but as yet unknown) area/s of origin for *P. ramorum*, since they apply to parts of plants from non-EU countries. They would have only a very limited ability to reduce the potential for *P. ramorum* to enter on this pathway.

Table 21. Pre-existing non-specific measures in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) that relate to foliage and cut branches of host plants (emboldened) of *Phytophthora ramorum* originating from outside the Community.

Annex	Article	Description	Measure
VB	2	Parts of plants, other than fruits and seeds of: – ***Castanea*** Mill., *Dendranthema* (DC) Des. Moul., *Dianthus* L., *Gypsophila* L., *Pelargonium* l'Herit. ex Ait, *Phoenix* spp., *Populus* L., ***Quercus*** L., *Solidago* L. and cut flowers of Orchidaceae, – **Conifers** (*Coniferales*), – *Acer saccharum* Marsh., originating in the USA and Canada – ***Prunus*** L., originating in non-European countries, – cut flowers of *Aster* spp., *Eryngium* L., *Hypericum* L., *Lisianthus* L., ***Rosa*** L. and *Trachelium* L., originating in non-European countries, – leafy vegetables of *Apium graveolens* L. and *Ocimum* L.	Non-EU countries Inspection in the country of origin required before export

Identification of appropriate risk management options: Foliage and cut branches of host plants

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. Symptoms are not unique.

Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

If yes **possible measure: specified testing.**

Yes. The pathogen can be reliably detected and identified by testing.

Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

If yes **possible measure: import under special licence/ permit and post-entry quarantine.**

Yes. Based on laboratory testing.

Go to 3.16

Removal of the pest from the consignment by treatment or other phytosanitary procedures

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

Yes. The pathogen could be effectively destroyed with sufficient heat treatment, but this would affect the quality of the product which is used for ornamental purposes.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

If yes **possible measure: removal of parts of plants from the consignment**

No. The plant parts are the consignment.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing methods**

No. Not relevant.

Go to 3.19

Prevention of establishment by limiting the use of the consignment

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/ permit and specified restrictions:**

Yes. The end-use is only for ornamental purposes so the pathway is self-limiting anyway. Limiting distribution in the PRA area or limiting periods of entry are not appropriate or relevant for this type of material. However, it is possible that when such material is disposed of it could be recycled. The main concern is that if the material is composted, chlamydospores embedded in plant tissue may not be destroyed and could, if reused for planting purposes, lead to new infections.

Studies on the efficacy of treatments for eradicating *P. ramorum* in plant material are affected by the difficulties of determining the viability of chlamydospores which may be dormant rather than dead. In addition, experiments reporting the efficacy of such treatments may have been conducted using newly-inoculated plant material which may not contain chlamydospores when tested. For example, Tooley *et al*. (2008) showed that it took 2 to 3 weeks for chlamydospores to form in rhododendron leaves after inoculation with sporangia and incubation at 20ºC. Thus, the reported efficacy of a heat or composting treatment may only pertain to other structures such as hyphae, mycelium or sporangia which are less robust. For these reasons results of such studies should be treated with caution. However, Swain *et al*. (2006) indicated that composting can effectively eliminate *P. ramorum* from green-waste. In laboratory tests the pathogen could not be isolated from infested leaves of *U. californica* and wood chips and cankered stems of Coast live oak (*Q. agrifolia*) after a 24 hour exposure at 40°C or a 1-hour exposure at 55°C. In field composting trials the same type of material was considered free from *P. ramorum* after 2 weeks at 55–60°C. This was confirmed by isolation and by polymerase chain reaction (PCR) assay. The absence of *P. ramorum* DNA led the authors to conclude that the pathogen was absent and not merely suppressed or dormant. The use of the EPPO Phytosanitary Procedure for the management of plant health risks of biowaste of plant origin (EPP0, 2008) could be used where waste disposal of known infected material is to be undertaken.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

Prevention of infestation of the commodity

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No. It is assumed that foliage and cut branches are sourced from wild plants, rather than from nursery grown material. If the latter, treatments would not be considered to be fully effective and would not be considered practical or appropriate to such a commodity or level of risk.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

No, assuming that foliage and cut branches are sourced from wild plants, rather than from nursery grown material.

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. The pathogen can potentially infect plant material all-year round, depending on climatic conditions.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

No. Not relevant for foliage and cut branches which are likely to be sourced from wild plants.

Go to 3.25

<u>Establishment and maintenance of pest freedom of a crop, place of production or area</u>

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**

Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area.**

Go to 3.28

If no Go to 3.27

Yes. Natural spread is mostly limited to local splash-dispersal within a few metres. However, longer-distant natural spread by turbulent air can occur more rarely over several kilometres under certain weather conditions. There is also the potential for longer-distance natural spread over about a kilometre via inoculum in water courses, wind-blown infected debris, or through movement of contaminated soil/debris on the feet of animals; these are less significant pathways of natural spread though.

3.27. The pest has a medium to high capacity for natural spread

Possible measure: pest-free area.

Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes. Pest freedom of the place of production or area could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no Possible measure identified in questions 3.25-3.27 would not be suitable.

Go to 3.29

<u>Consideration of other possible measures</u>

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

Yes, in part; a requirement for safe disposal of known infected material as per 3.19. However, this is likely to be impractical given the volume of material that is imported (see Table 8), albeit that the host species for imported foliage and cut branches are unknown. Pest-free area or pest-free place of production would be more appropriate. *See 3.27.*

If yes **Possible measures: internal surveillance and/or eradication campaign**

Go to 3.30

Evaluation of risk management options: Foliage or cut branches of susceptible foliar hosts

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes **Go to 3.31**
If no Go to 3.38

Yes. Listed in the order of previous positive responses:

- Detection of the pathogen in consignments by testing at export and post-entry
- Removal of the pest from the consignment by suitable heat treatment (affects quality)
- Safe disposal of known infected material as per EPPO (2008) (this should be a requirement for all known-infested material)
- Pest–free area for the crop, place of production or area
- Surveillance and eradication in the importing country of the EU

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes **Go to 3.34**
If no Go to 3.32

Yes.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes Go to 3.34
If no Go to 3.33

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The quantity of imports of foliage and cut branches is rated as major to massive (albeit the genera of imported material are not specified in the data) (Table 8 and 12). Requirements for testing at export and post-entry would interfere with international trade. A requirement for imports from a pest-free area or place of production would cause less difficulties given the known current distribution outside of the EU. Heat treatment of material would affect quality and the end-use (for ornamental purposes) would not be achieved. If pest-free area or place of production is required, there would be no need for further requirements such as safe disposal at the end of its use.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Costs associated with measures in the affected exporting countries have not been evaluated, but would have some social consequences should a requirement for pest-free area or pest-free place of production for foliage and cut branches be implemented because of the size of the trade. The biggest exporter of this material to the EU is the USA (see Tables 8 and 12). It is not known which genera are exported and from which parts of the USA but there may be impacts for California and for Oregon if pest-free area or place of production became a phytosanitary requirement. However, the level of risk of establishment from *P. ramorum* arising from these commodities is low, given the end-use, and regulation of this pathway may not be justified.

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes	For pathway-initiated analysis, go to 3.39 **For pest-initiated analysis, go to 3.38**
If no	Go to 3.37

3.37. Envisage prohibiting the pathway.

For pathway-initiated analysis, go to 3.43 (or 3.39)
For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes	Go to 3.41
If no	**Go to 3.1 to analyze the next major pathway**

<u>Pathway (vi) – Seeds and fruits</u> of susceptible host plants (Appendix II) from third countries where the pathogen occurs or may occur (as detailed in pathways i-iii above).

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes

If yes	**Go to 3.11**
If no	Go to 3.3

Existing phytosanitary measures

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a plant pathogen.

If yes	Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself)	**go to 3.12**

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.
Go to 3.13

No. There are no pre-existing measures specific to seeds or fruits under the emergency phytosanitary measures laid down for *P. ramorum* in 2002 (2002/757/EC as amended 2004 and 2007) (Anon., 2002, 2004 and 2007) or more generally in the EC Plant Health Directive (2000/29/EC; Anon., 2000).

Identification of appropriate risk management options: Seeds and fruit of susceptible host plants

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. Seeds (or accompanying plant debris) and fruits will not show any unique symptoms.
Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

If yes **possible measure: specified testing.**

Yes. The pathogen could be detected and identified by testing seeds or fruits. However, there are no pathogen-specific seed (or fruit) testing methods that have been developed and validated.
Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

If yes **possible measure: import under special licence/ permit and post-entry quarantine.**

Yes. The pathogen could be detected and identified by testing seeds or fruits. However, there are no pathogen-specific seed (or fruit) testing methods that have been developed and validated.
Go to 3.16

Removal of the pest from the consignment by treatment or other phytosanitary procedures

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

No. Infected plant debris can be physically removed from seeds by physical cleaning methods. However, treatment of seeds or fruits is not likely to be effective without affecting the commodity itself.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed <u>without reducing the value of the consignment</u>? (This question is not relevant for pest plants)

If yes **possible measure: removal of parts of plants from the consignment**

Yes in part. Although seed-bearing fruits of many hosts can be infected, there is no evidence that the pathogen can colonise the seed (seed-borne) or be directly seed transmitted. If this remains the case, the main risk would be contamination of the seed lot with colonised plant debris of the host plant, which could be removed by physical cleaning. In the case of fruits, the fruit is the consignment, so removal of plant parts is not appropriate, although measures could be required to ensure that no leaves are attached. Although fruits, in the botanical sense, of various shrub hosts have been shown experimentally to become infected by *P. ramorum*, there is no record of *P. ramorum* infecting fruits for human consumption of any of the key fruit producing plant species (e.g. citrus, apple, pear, etc); none of these are known natural hosts.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing methods**

No. Not relevant for seeds or fruits.

Go to 3.19

<u>Prevention of establishment by limiting the use of the consignment</u>

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/ permit and specified restrictions:**

No. The end-use for seeds is only for planting, so the end-use cannot be restricted. Limiting periods or areas of entry are not appropriate or relevant. The same applies to fruits.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

<u>Prevention of infestation of the commodity</u>

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No. Treatment of the crop would not be considered to be fully effective and would not be considered practical or appropriate for seeds and fruit, or to the low level of risk which these pose.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No. There are no known immune cultivars of host plant species.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

No. Spread to the fruiting and seed-producing parts of the plant would be difficult to prevent for hosts with susceptible fruits (although there are no records of natural infection of these plant parts to date).

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. The pathogen can potentially infect plant material all-year round, depending on environmental conditions.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

Yes. A seed certification scheme involving testing is possible, but not practical or appropriate to the level of risk arising from seed given that true seed transmission has not been proven. Certification schemes for plants for planting (see *Question 3.24*, pathway (i)) could possibly prevent infestation of fruits.

Go to 3.25

Establishment and maintenance of pest freedom of a crop, place of production or area

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**
Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area.**
Go to 3.28
If no Go to 3.27

Yes. Natural spread is mostly limited to local splash-dispersal within a few metres. However, longer-distant natural spread by turbulent air can occur more rarely over several kilometres under certain weather conditions. There is also the potential for longer-distance natural spread over about a kilometre via inoculum in water courses, wind-blown infected debris, or through movement of contaminated soil/debris on the feet of animals; these are less significant pathways of natural spread though.

3.27. The pest has a medium to high capacity for natural spread
Possible measure: pest-free area.
Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes. Pest freedom of the crop, place of production or area could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no Possible measure identified in questions 3.25-3.27 would not be suitable.
Go to 3.29

Consideration of other possible measures

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

None that are additional to those outlined under Pathway (i) for *Question 3.29*.

If yes **Possible measures: internal surveillance and/or eradication campaign**
Go to 3.30

Evaluation of risk management options: Seeds and fruits of susceptible host plants

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes	**Go to 3.31**
If no	Go to 3.38

Yes. Listed in the order of previous positive responses:

- Detection of the pathogen in consignments by inspection and testing at export and import
- For contaminated seed lots, removal of the pest from seed consignments by physical removal of contaminating plant debris
- Pest-free crop, place or area of production
- Surveillance and eradication in the importing country of the EU

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes	Go to 3.34
If no	**Go to 3.32**

No.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes	**Go to 3.34**
If no	Go to 3.33

Yes.

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

None of the measures prevent trade, but they will incur additional costs.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Measures for preventing or eliminating potential contamination on imports of seeds or fruits are considered to be cost-effective in relation to potential risks and impacts to the EU. Costs associated with measures in the affected exporting countries have not been evaluated, but will incur additional costs. However, the level of risk is very low from these commodities, given that there is no evidence that the pathogen can be seed-borne, and no fruits that are imported into the EU are known natural hosts. Regulation of these pathways may therefore not be justified.

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes For pathway-initiated analysis, go to 3.:
For pest-initiated analysis, go to 3.38
If no Go to 3.37

3.37. Envisage prohibiting the pathway.

For pathway-initiated analysis, go to 3.43 (or 3.39)
For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?
If yes Go to 3.41
If no Go to 3.1 to analyze the next major pathway

<u>**Pathway (vii) – Susceptible (isolated) bark**</u> from third countries where the pathogen occurs or may occur (as detailed in pathways i-iii above).

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes

If yes Go to 3.11
If no Go to 3.3

Existing phytosanitary measures

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a plant pathogen.

If yes Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself) Go to 3.12

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.
Go to 3.13

Yes. There are pre-existing measures specific for imports of isolated bark under the emergency phytosanitary measures laid down for *P. ramorum* in 2002 (2002/757/EC as amended 2004 and 2007), (Anon., 2002, 2004 and 2007) as follows:

> *Susceptible isolated bark of* Acer macrophyllum *Pursh,* Aesculus californica *(Spach) Nutt.,* Lithocarpus densiflorus *(Hook. & Arn.) Rehd.,* Quercus *spp. L. and* Taxus brevifolia *Nutt.'*
>
> *Susceptible bark originating in the United States of America shall not be permitted entry in the Community.*

Acer macrophyllum, *Aesculus californica* are not canker hosts but the remaining species are. *P. ramorum* is constrained from entering on bark from the USA on the majority of canker hosts (excluding *Toxicodendron diversilobum*, Pacific poison oak, which is unlikely to be harvested).

Non-specific measures for bark that exist in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) are detailed in Table 22. Bark of *Castanea* is prohibited entry into the EU from third countries. Bark of *Quercus* spp. (other than cork oak, *Q. suber*) is prohibited entry from North America. Thus, in addition to the emergency phytosanitary measures, *P. ramorum* is also constrained from entering on bark of *Castanea* spp. from the USA, and on bark of *Castanea* spp. and *Quercus* spp. from Canada. *Castanea* spp. are currently not canker hosts outside of Europe and *P. ramorum* is not present in forests and woods in Canada so these are not currently pathways of entry to the EU. Entry from the unknown country or countries of origin on bark of susceptible species is prohibited on *Castanea* spp. but as the origin/origins and therefore the hosts on this pathway are not known, there may still be pathway of entry. Isolated bark of conifers requires either fumigation or heat treatment at 56°C for 30 minutes before it can enter the EU from non-European countries. The efficacy of these treatments against cankered bark is unknown. Tubajika *et al*. (2008) found that a treatment at 56°C for 30 minutes might not be adequate to kill *P. ramorum* in wood of tanoak (*L. densiflorus*). However, the results were inconclusive, particularly because the detection of *P. ramorum* in the controls was low. Swain *et al*. (2006) showed that a 1-hour exposure at 55°C was required to no longer detect *P. ramorum* in wood chips and cankered stems of Coast live oak (*Q. agrifolia*). Stronger measures may be required; or the list of susceptible species and origins on which bark is prohibited entry may need to be extended should new canker hosts emerge other than those listed in the emergency phytosanitary measures.

Table 22. Pre-existing measures in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) that relate to susceptible isolated bark as a commodity.

Annex	**Article**	**Description**	**Measure**
IIIA	5	Isolated bark of ***Castanea*** Mill.	Prohibited from third countries
	6	Isolated bark of ***Quercus*** L., other than *Quercus suber* L.	Prohibited from North American countries
IVAI	7.3	Isolated bark of conifers (Coniferales), originating in non-European countries	Official statement that the isolated bark: (a) has been subjected to an appropriate fumigation with a fumigant approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum bark temperature, the rate (g/m3) and the exposure time (h), or (b) has undergone an appropriate heat treatment to achieve a minimum core temperature of 56°C for at least 30 minutes, the latter to be indicated on the certificates referred to in Article 13.1.(ii). (added by 2004/102/EC)

Identification of appropriate risk management options: Susceptible isolated bark

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. Bark will not show any unique symptoms.

Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

If yes **possible measure: specified testing.**

No. The pathogen could potentially be detected by testing bark, but this is not considered practical or reliable given the volume of material that is likely to be imported (see Tables 10 and 12) and the need for representative samples.

Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

If yes **possible measure: import under special licence/permit and post-entry quarantine.**

No. The pathogen could potentially be detected by testing bark, but this is not considered practical or reliable. Post-entry quarantine is not appropriate for a plant product.

Go to 3.16

Removal of the pest from the consignment by treatment or other phytosanitary procedures

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

Not known. See 3.12. The efficacy of fumigation is not known and the efficacy of heat treatments for bark of a range of species is untested.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

If yes **possible measure: removal of parts of plants from the consignment**

No. Bark is the commodity.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing methods**

No. Not relevant for susceptible isolated bark.

Go to 3.19

<u>Prevention of establishment by limiting the use of the consignment</u>

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/permit and specified restrictions:**

Yes. Only if known infected bark was not permitted to be used in the nursery or landscaping industries. This may be impractical to enforce. Limited periods of entry are not appropriate as the pathogen can infect all year round.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

<u>Prevention of infestation of the commodity</u>

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No. There are no known resistant cultivars of host plant species.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

No. The commodity originates from trees grown outside.

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. The pathogen can potentially infect plant material all-year round, depending on environmental conditions.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

No. Bark originates from timber harvested outdoors.

Go to 3.25

<u>Establishment and maintenance of pest freedom of a crop, place of production or area</u>

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**

Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area.**

Go to 3.28

If no Go to 3.27

Yes. Natural spread is mostly limited to local splash-dispersal within a few metres. However, longer-distant natural spread by turbulent air can occur more rarely over several kilometres under certain weather conditions. There is also the potential for longer-distance natural spread over about a kilometre via inoculum in watercourses, wind-blown infected debris, or through movement of contaminated soil/debris on the feet of animals; these are less significant pathways of natural spread though.

3.27. The pest has a medium to high capacity for natural spread

possible measure: pest-free area.
Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes. Pest freedom of the place of production or area could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no — possible measure identified in questions 3.25-3.27 would not be suitable.
Go to 3.29

<u>Consideration of other possible measures</u>

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

None that are additional to those outlined under Pathway (i) for *Question 3.29*.

If yes — **possible measures: internal surveillance and/or eradication campaign**
Go to 3.30

Evaluation of risk management options: Susceptible isolated bark

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes — **Go to 3.31**
If no — Go to 3.38

Yes. Listed in the order of previous positive responses:

- Limited end-use of known infected bark (i.e. not to be used in the nursery trade or the landscaping industry).
- Pest-free crop, place of production or area.
- Surveillance and eradication in the importing country of the EU.

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes — **Go to 3.34**
If no — Go to 3.32

Yes.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes — Go to 3.34
If no — Go to 3.33

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Limiting the end-use would interfere with trade but only where this is not already prohibited. Prohibited imports of bark already exist under the emergency phytosanitary measures for *P. ramorum* of known canker hosts from the USA, and under the EC Plant Health Directive (2000/29/EC; Anon., 2000) for imports of bark of *Quercus* spp. from North America and imports of *Castanea* (*C. sativa* is a known canker host in the UK) from third countries. A requirement for a pest-free crop, area or place of production for bark would not interfere with international trade.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

The cost-effectiveness of the measures being considered has not been calculated but as measures already exist for imports of susceptible bark from the USA there would be no additional social or environmental consequences. A requirement for a pest-free crop, area or place of production would be an alternative to a prohibition but given the potential quantities of imports this would be costly to enforce for bark harvested in the affected areas (currently known to be forests in California and Oregon, and an unknown area or areas of origin).

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes — For pathway-initiated analysis, go to 3.
For pest-initiated analysis, go to 3.38
If no — Go to 3.37

Yes.

3.37. Envisage prohibiting the pathway.

For pathway-initiated analysis, go to 3.43 (or 3.39)
For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes — Go to 3.41

If no **Go to 3.1 to analyze the next major pathway**

<u>Pathway (viii) – Susceptible wood</u> from third countries where the pathogen occurs or may occur (as detailed in pathways i-iii above).

3.2. Is the pathway that is being considered a commodity of plants and plant products?

Yes

If yes **Go to 3.11**
If no Go to 3.3

Existing phytosanitary measures

3.11. If the pest is a plant, is it the commodity itself?

No. The pest is a plant pathogen.

If yes Go to 3.29
If no (the pest is not a plant or the pest is a plant but is not the commodity itself) **Go to 3.12**

3.12. Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

if appropriate, list the measures and identify their efficacy against the pest of concern.
Go to 3.13

Yes. There are pre-existing measures specific for imports of susceptible wood under the emergency phytosanitary measures laid down for *P. ramorum* in 2002 (2002/757/EC as amended 2004 and 2007), (Anon., 2002, 2004 and 2007) as follows:

<u>Under Article 3 of the emergency measures</u>:

- *Susceptible plants and **susceptible wood** may only be introduced into the territory of the Community if they comply with the emergency phytosanitary measures laid down in points 1a (susceptible plants) and **2** (**susceptible wood**) of the Annex* [see below] *to the Decision and if they are inspected on entry into the Community for the presence of non-European isolates of the harmful organism, in accordance with Article 13(1)(a) of Directive 2000/29/EC, and found free from the harmful organism in this inspection.*

- *The provisions specified in points 1a and **2** of the Annex to the Decision (see below) shall apply only to susceptible plants and **susceptible wood** originating in the United States of America destined for the Community and leaving on or after 1 November 2002.*

- *The measures laid down in Part A, Section I (3) of Annex IV* [of the EC Plant Health Directive, 2000/29/EC; Anon., 2000 – see Table 23] *as regards wood of* Quercus *L., including wood which has not kept its natural round surface, originating in the United States of America, shall not apply to susceptible wood of* Quercus *L. which satisfies the requirements of point **2(b)** of the Annex to the Decision.*

Under Article 1 of the emergency measures:

Susceptible wood is defined in paragraph 3 as:

- ***Susceptible wood*** *of* Acer macrophyllum *Pursh, Aesculus californica (Spach) Nutt., Lithocarpus densiflorus (Hook. & Arn.) Rehd., Quercus spp. L. and Taxus brevifolia Nutt.*

Specific requirements for wood in the Annex :

2. *Susceptible wood originating in the United States of America may only be imported into the Community if, it is accompanied by a certificate referred to in Article 13 (1) of Directive 2000/29/EC:*
   (a) stating that it originates in areas in which non–European isolates of the harmful organism is known not to occur. The name of the area shall be mentioned on the certificate under the rubric 'place of origin'; or
   (b) issued after official verification that the wood has been stripped of its bark and:
      (i) that it has been squared so as to remove entirely the rounded surface; or
      (ii) that the water content of the wood does not exceed 20% expressed as a percentage of the dry matter, or
      (iii) that the wood has been disinfected by an appropriate hot-air or hot-water treatment;

   or

   (c) in the case of sawn wood with or without residual bark attached, if there is evidence by a mark 'Kiln-dried', 'KD' or another internationally recognised mark put on the wood or on its packaging in accordance with current commercial usage, that it has undergone kiln-drying to below 20 % moisture content, expressed as a percentage of dry matter, at time of manufacture, achieved through an appropriate time/temperature schedule.

With respect to the list of susceptible wood, *Acer macrophyllum*, *Aesculus californica* are listed but they are not canker hosts; the remaining species are. *P. ramorum* is constrained from entering on wood from the USA on the majority of canker hosts (excluding *Toxicodendron diversilobum*, Pacific poison oak, which is unlikely to be harvested).

Non-specific measures that exist in the EU Plant Health Directive (2000/29/EC) (Anon., 2000) and that apply to wood of hosts of *P. ramorum* include those detailed in Table 23. Many of these are for specific pests of wood (i.e. Annex IVAI, Articles 1.1, 1.2, 1.5, 1.6, 1.7); 1.5 only refers to material from Russia, Kazakhstan and Turkey which are not considered to be countries where *P. ramorum* may occur. However, the requirements for imports of wood under these articles have various options some of which may affect *P. ramorum*. However, their efficacy is untested (kiln-drying below 20% moisture, fumigation or chemical pressure impregnation) with some doubt over the efficacy of heat treatment to 56°C for 30 minutes (see 3.12, pathway vii). Annex IVAI, Article 3 has requirements for *Quercus* spp. from the USA but, as alluded to in the emergency phytosanitary measures for *P. ramorum*, this does not apply to imports of wood of *Quercus* from the USA if it complies with Annex 2(b) of the emergency measures. Annex IVAI, Article 2 is for wood packaging material (no genera specified) and Article 7.2 is for wood chips, particles, sawdust, shaving, wood waste and scrap of *Quercus* from the USA.

Table 23. Pre-existing measures in the EU Plant Health Directive (2000/29/EC) that relate to susceptible wood.

Annex	Article	Description	Measure
IVAI	1.1	Whether or not listed among the CN codes in Annex V, Part B, **wood of conifers (Coniferales)**, except that of *Thuja* L., other than in the form of: - *chips, particles, sawdust, shavings, wood waste, and scrap obtained in whole or part from these conifers,* - *wood packaging material, in the form of packing cases, boxes, crates, drums and similar packings, pallets, box pallets and other load boards, pallet collars, actually in use in the transport of objects of all kinds,* - *wood used to wedge or support non-wood cargo,* - *wood of Libocedrus decurrens Torr. where there is evidence that the wood has been processed or manufactured for pencils using heat treatment to achieve a minimum temperature of 82°C for a seven to eight-day period,* but including that which has not kept its natural round surface, originating in Canada, China, Japan, the Republic of Korea, Mexico, Taiwan and the USA where *Bursaphelenchus xylophilus* (Steiner et Bührer) Nickle et al. is known to occur.	Official statement that the wood has undergone an appropriate: (a) heat treatment to achieve a minimum core temperature of 56°C for at least 30 minutes. There shall be evidence thereof by a mark "HT" put on the wood or on any wrapping in accordance with current usage, and on the certificates referred to in Article 13.1.(ii), or (b) fumigation to a specification approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum wood temperature, the rate (g/m^3) and the exposure time (h), or (c) chemical pressure impregnation with a product approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii) , the active ingredient, the pressure (psi or kPa) and the concentration (%). (2004/102/EC)
IVAI	1.2	Whether or not listed among the CN codes in Annex V, Part B, **wood of conifers (Coniferales)**, except that of *Thuja* L., in the form of: - *chips, particles, sawdust, shavings, wood waste and scrap obtained in whole or part from these conifers,* originating in Canada, China, Japan, the Republic of Korea, Mexico, Taiwan and the USA, where *Bursaphelenchus xylophilus* (Steiner et Bührer) Nickle et al. is known to occur.	Official statement that the wood has undergone an appropriate: (a) heat treatment to achieve a minimum core temperature of 56 °C for at least 30 minutes, the latter to be indicated on the certificates referred to in Article 13.1.(ii), or (b) fumigation to a specification approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum wood temperature, the rate (g/m^3) and the exposure time (h), (2004/102/EC)
IVAI	1.5	Whether or not listed among the CN codes in Annex V, Part B, **wood of conifers (Coniferales)**, other than in the form of: - *chips, particles, sawdust, shavings, wood waste and scrap obtained in whole or part from these conifers,* - *wood packaging material, in the form of packing cases, boxes, crates, drums and similar packings, pallets, box pallets and other load boards, pallet collars, actually in use in the transport of objects of all kinds,* - *wood used to wedge or support non-wood cargo,* but including that which has not kept its natural round surface, originating in Russia, Kazakhstan and Turkey	Official statement that the wood: (a) originates in areas known to be free from: - *Monochamus* spp. (non-European) - *Pissodes* spp. (non-European) - *Scolytidae* spp. (non-European) The area shall be mentioned on the certificates referrred to in Article 13.1.(ii), under the rubric "place of origin," or (b) is bark-free and free from grub holes, caused by the genus *Monochamus* spp. (non-European), defined for this purpose as those which are larger than 3mm across, or (c) has undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, achieved through an appropriate time/temperature schedule. There shall be evidence thereof by a mark "kiln-dried" or "K.D". or another internationally recognised mark, put on the wood or on any wrapping in accordance with the current usage, or (d) has undergone an appropriate heat treatment to achieve a minimum core temperature of 56°C

			for at least 30 minutes. There shall be evidence thereof by a mark "HT" put on the wood or on any wrapping in accordance with current usage, and on the certificates referred to in Article 13.1.(ii), or (e) has undergone an appropriate fumigation to a specification approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum wood temperature, the rate (g/m3) and the exposed time (h), or (f) has undergone an appropriate chemical pressure impregnation with a product approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the pressure (psi or kPa) and the concentration (%). (2004/102/EC)
IVAI	1.6	Whether or not listed among the CN codes in Annex V, Part B, **wood of conifers (Coniferales)**, other than in the form of: - *chips, particles, sawdust, shavings, wood waste and scrap obtained in whole or part from these conifers,* - *wood packaging material, in the form of packing cases, boxes, crates, drums and similar packings, pallets, box pallets and other load boards, pallet collars, actually in use in the transport of objects of all kinds,* - wood used to wedge or support non-wood cargo, but including that which has not kept its natural round surface, originating in third countries, other than: - Russia, Kazakhstan and Turkey, - European countries, - Canada, China, Japan, the Republic of Korea, Mexico, Taiwan and the USA, where Bursaphelenchus xylophilus (Steiner et Bührer) Nickle et al. is known to occur.	Official statement that the wood: (a) is bark-free and free from grub holes, caused by the genus *Monochamus* spp. (non-European), defined for this purpose as those which are larger than 3mm across, or (b) has undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, achieved through an appropriate time/temperature schedule. There shall be evidence thereof by a mark "kiln-dried" or "K.D". or another internationally recognised mark, put on the wood or on any wrapping in accordance with the current usage, or (c) has undergone an appropriate fumigation to a specification approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum wood temperature, the rate (g/m^3) and the exposed time (h), or (d) has undergone an appropriate chemical pressure impregnation with a product approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the pressure (psi or kPa) and the concentration (%), or (e) has undergone an appropriate heat treatment to achieve a minimum core temperature of 56^oC for at least 30 minutes. There shall be evidence thereof by a mark "HT" put on the wood or on any wrapping in accordance with current usage, and on the certificates referred to in Article 13.1.(ii). (Added by 2004/102/EC)
IVAI	1.7	Whether or not listed among the CN codes listed in Annex V, Part B, **wood in the form of chips, particles, sawdust, shavings, wood waste and scrap obtained in whole or in part from conifers (Coniferales)**, originating in	Official statement that the wood: (a) originates in areas known to be free from: - *Monochamus* spp. (non-European) - *Pissodes* spp. (non-European) - *Scolytidae* spp. (non-European)

		- Russia, Kazakhstan and Turkey, - non-European countries other than Canada, China, Japan, the Republic of Korea, Mexico, Taiwan and the USA, where *Bursaphelenchus xylophilus* (Steiner et Bührer) Nickle et al. is known to occur.	The area shall be mentioned on the certificates referrred to in Article 13.1.(ii), under the rubric "place of origin," or (b) has been produced from debarked round wood, or (c) has undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, achieved through an appropriate time/temperature schedule, or (d) has undergone an appropriate fumigation to a specification approved in accordance with the procedure laid down in Article 18.2. There shall be evidence thereof by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum wood temperature, the rate (g/m^3) and the exposed time (h), or (e) has undergone an appropriate heat treatment to achieve a minimum core temperature of 56°C for at least 30 minutes, the latter to be indicated on the certificates referred to in Article 13.1.(ii). (Added by 2004/102/EC)
IVAI	2	**Wood packaging material**, in the form of packing cases, boxes, crates, drums and similar packings, pallets, box pallets and other load boards, pallet collars, actually in use in the transport of objects of all kinds, except raw wood of 6mm thickness or less, and processed wood produced by glue, heat and pressure, or a combination thereof, coming from third countries, except Switzerland.	The wood packaging material shall: - be made from debarked round wood, and - be subject to one of the approved measures as specified in Annex I to FAO International Standard for Phytosanitary Measures No 15 on *Guidelines for regulating wood packaging material in international trade,* and - display a mark with: (a) the two-letter ISO country code, a code identifying the producer and the code identifying the approved measure applied to the wood packaging material in the mark as specified in Annex II to FAO International Standard of Phytosanitary Measures No 15 on *Guidelines for regulating wood packaging material in international trade*. The letters "DB" shall be added to the abbreviation of the approved measure included in the said mark. and (b) in the case of wood packaging material manufactured, repaired or recycled as of 1 March 2005, also the logo as specified in Annex II to the said FAO Standard. However the requirement is not applicable on a temporary basis until 31 December 2007 in the case of wood packaging material manufactured, repaired or recycled before 28 February 2005. (Added by 2004/102/EC) The first indent, requiring wood packaging material to be made from debarked round wood, shall only apply from 1 January 2009. This paragraph shall be reviewed by 1 September 2007. (2006/14/EC)
IVAI	3	**Wood of *Quercus*** L., other than in the form of: - chips, particles, sawdust, shavings, wood waste and scrap, - casks, barrels, vats, tubs and other coopers' products and parts thereof, of wood, including staves where there is documented evidence that the wood has been produced or manufactured using heat treatment to achieve a minimum temperature of 176°C for 20 minutes	Official statement that the wood: (a) is squared so as to remove entirely the rounded surface, or (b) is bark-free and the water content is less than 20% expressed as a percentage of the dry matter, or (c) is bark-free and has been disinfected by an appropriate hot-air or hot water treatment,

		but including wood which has not kept its natural round surface, originating in the USA.	or (d) if sawn, with or without residual bark attached, has undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, achieved through an appropriate time/temperature schedule. There shall be evidence thereof by a mark "Kiln-dried" or "KD" or another internationally recognised mark, put on the wood or on any wrapping in accordance with current usage. (Replaced by 2004/102/EC)
IVAI	7.2	Whether or not listed among the CN codes in Annex V, Part B, **wood in the form of chips, particles, sawdust, shavings, wood waste and scrap and obtained in whole or part from *Quercus*** L. originating in the USA.	Official statement that the wood: *(a) has undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, at time of manufacture, achieved through an appropriate time/temperature schedule,* or (b) has undergone an appropriate fumigation to a specification approved in accordance with the procedure laid down in Article 18.2. There shall be evidence of the fumigation by indicating on the certificates referred to in Article 13.1.(ii), the active ingredient, the minimum wood temperature, the rate (g/m^3) and the exposure time (h), or (c)..has undergone an appropriate heat treatment to achieve a minimum core temperature of 56^{o}C for at least 30 minutes, the latter to be indicated on the certificates referred to in Article 13.1.(ii). (Replaced by 2004/102/EC)

Identification of appropriate risk management options: Susceptible wood

Options for consignments

Detection of the pest in consignments by inspection or testing

3.13. Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes **possible measure: visual inspection.**

No. Wood will not show any unique symptoms.

Go to 3.14

3.14. Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?

If yes **possible measure: specified testing.**

No. The pathogen could potentially be detected by testing wood, but this is not considered practical or reliable given the volume of material that is likely to be imported (see Tables 10 (wood waste), 11 and 12) and the need for representative samples.

Go to 3.15

3.15. Can the pest be reliably detected during post-entry quarantine?

If yes **possible measure: import under special licence/permit and post-entry quarantine.**

No. The pathogen could potentially be detected by testing wood, but this is not considered practical or reliable. Post-entry quarantine is not appropriate for a plant product.

Go to 3.16

Removal of the pest from the consignment by treatment or other phytosanitary procedures

3.16. Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes **possible measure: specified treatment.**

Not known. See 3.12. The efficacy of such treatments is not known and the efficacy of heat treatments for wood of a range of species is untested.

Go to 3.17

3.17. Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

If yes **possible measure: removal of parts of plants from the consignment**

No. Wood is the commodity.

Go to 3.18

3.18. Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes **possible measure: specific handling/packing methods**

No. Not relevant for susceptible wood.

Go to 3.19

Prevention of establishment by limiting the use of the consignment

3.19. Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes **possible measure: import under special licence/permit and specified restrictions:**

Yes. The end use of wood is only indirectly linked to businesses related to the production of plants in terms of (e.g.) benches that may be constructed from wood. The risk of entry on wood is low or very low (see Table 14) and the risk of establishment from entry on wood is also low. Limited periods of entry are not appropriate as the pathogen can infect all year round.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

Prevention of infestation of the commodity

3.20. Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes **possible measure: specified treatment and/or period of treatment**

No. Treatment of forestry-grown species of tree to prevent infection of the stems is not feasible.

Go to 3.21

3.21. Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes **possible measure: consignment should be composed of specified cultivars**

No. There are no known resistant cultivars of host tree species.

Go to 3.22

3.22. Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

If yes **possible measure: specified growing conditions**

No. The commodity originates from trees grown outside.

Go to 3.23

3.23. Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes **possible measure: specified age of plant, growth stage or time of year of harvest**

No. The pathogen can potentially infect plant material all-year round, depending on environmental conditions.

Go to 3.24

3.24. Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes **possible measure: certification scheme**

No. Wood originates from timber harvested outdoors.

Go to 3.25

Establishment and maintenance of pest freedom of a crop, place of production or area

3.25. Has the pest a very low capacity for natural spread?

If yes **possible measures: pest freedom of the crop, or pest-free place of production or pest-free area**

Go to 3.28

If no **Go to 3.26**

No. See *Question 3.26.*

3.26. Has the pest a low to medium capacity for natural spread?

If yes **possible measures: pest-free place of production or pest free area.**

Go to 3.28

If no Go to 3.27

Yes. Natural spread is mostly limited to local splash-dispersal within a few metres. However, longer-distant natural spread by turbulent air can occur more rarely over several kilometres under certain weather conditions. There is also the potential for longer-distance natural spread over about a kilometre via inoculum in watercourses, wind-blown infected debris, or through movement of contaminated soil/debris on the feet of animals; these are less significant pathways of natural spread though.

3.27. The pest has a medium to high capacity for natural spread

Possible measure: pest-free area.

Go to 3.28

3.28. Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes. Pest freedom of the crop, place of production or area could be reliably guaranteed with suitable surveillance, monitoring and testing regimes in place. Suitable phytosanitary measures in the country of production would be essential to reduce human mediated spread.

If no Possible measure identified in questions 3.25-3.27 would not be suitable.

Go to 3.29

Consideration of other possible measures

3.29. Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

None that are additional to those outlined under Pathway (i) for *Question 3.29*.

If yes **Possible measures: internal surveillance and/or**

eradication campaign

Go to 3.30

Evaluation of risk management options: Susceptible wood

3.30. Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest? List them.

If yes **Go to 3.31**
If no Go to 3.38

Yes. Listed in the order of previous positive responses:

- Limited end-use of known infected wood (i.e. not to be used in the nursery trade or the landscaping industry) (but the risk of establishment from such a use is extremely low)
- Pest freedom of the crop, place of production or area
- Surveillance and eradication in the importing country of the EU.

3.31. Does each of the individual measures identified reduce the risk to an acceptable level?

If yes **Go to 3.34**
If no Go to 3.32

Yes.

3.32. For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes Go to 3.34
If no Go to 3.33

3.33. If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.34

3.34. Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Limiting the end-use would not interfere with trade as wood is unlikely to be a route of transfer of *P. ramorum* to plants for planting so in fact there would be no need for additional measures predirecting end-use. Controls on imports of wood already exist under the emergency phytosanitary measures for *P. ramorum* for known canker hosts from the USA (Anon., 2002, 2004 and 2007), and under the EC Plant Health Directive (2000/29/EC; Anon., 2000) for imports of wood of *Quercus* spp. from the USA and imports of conifers from various countries including the USA and Canada and some Asian countries (China, Korea, Taiwan). The efficacy of the choice of treatment requirements if selected from this Directive against *P. ramorum* is not known. A requirement for a pest-free crop, area or place of production for wood would not interfere with international trade. Pest-free area is a requirement for *P. ramorum* for susceptible wood originating in the USA, as an alternative to treatment.

Go to 3.35

3.35. Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

The cost-effectiveness of the measures being considered has not been calculated but as measures already exist for imports of susceptible wood from the USA there would be no additional social or environmental consequences as there are currently no other known areas of origin for *P. ramorum* where wood may become infected (i.e. no other countries which could be specified in the legislation).

Go to 3.36

3.36. Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes For pathway-initiated analysis, go to 3.:
For pest-initiated analysis, go to 3.38
If no Go to 3.37

Yes.

3.37. Envisage prohibiting the pathway.

For pathway-initiated analysis, go to 3.43 (or 3.39)
For pest-initiated analysis go to 3.38

3.38. Have all major pathways been analyzed (for a pest-initiated analysis)?
If yes Go to 3.41

3.39. Have all the pests been analyzed (for a pathway-initiated analysis)?

If yes Go to 3.40
If no Go to 3.1 (to analyze next pest)

3.40. For a pathway-initiated analysis, compare the measures appropriate for all the pests identified for the pathway that would qualify as quarantine pests, and select only those that provide phytosanitary security against all the pests.

> *Note:* the minimum effective measures against one particular pest may reduce the risk from other pests far more than necessary, but these measures would be the only ones appropriate for the pathway as a whole.

This is not a pathway-initiated analysis.

Go to 3.41

3.41. Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment

> *Note*: *the relative importance of the pathways is an important element to consider in formulating phytosanitary regulation. Regulation of pathways presenting similar risks should be consistent .*

Starting from the four main sources of introduction (US, Canada, unknown area/areas of origin, non-EU countries of Norway and Switzerland) and assuming that the different commodity types are coming from areas where the pathogen occurs, the relative importance of the 8 main pathways of entry without any phytosanitary measures can be described as follows (noting that the lowest risk rating in the EPPO scheme is **very low** and the highest is **very high**):

Plants for planting of susceptible hosts (excluding seeds and fruits) from the USA and the unknown area/areas or origin: **high risk.**

Plants for planting of susceptible hosts (excluding seeds and fruits) from Canada and the non-EU countries of Norway and Switzerland: **medium risk.**

Soil as a commodity from the USA, Canada, the unknown area/areas of origin, and the non-EU countries of Norway and Switzerland: **medium risk.**

Susceptible isolated bark from the USA and the unknown area/areas or origin: **medium risk.**

Plants for planting of non-hosts (excluding seeds and fruits) accompanied by contaminated growing media from the USA, Canada, the unknown area/areas of origin, and the non-EU countries of Norway and Switzerland: **low risk.**

Soil as a contaminant of travellers shoes and imported machinery, vehicles etc from the USA and the unknown area/areas of origin: **low risk.**

Susceptible wood from the USA and the unknown area/areas of origin: **low risk.**

Foliage or cut branches of susceptible hosts from USA, Canada, the unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **very low risk.**

Seeds and fruits of susceptible hosts from the USA, Canada, unknown area/areas of origin, and non-EU countries of Norway and Switzerland: **very low risk.**

Susceptible isolated bark from Canada and the non-EU countries of Norway and Switzerland: **very low risk.**

Susceptible isolated wood from Canada and the non-EU countries of Norway and Switzerland: **very low risk.**

Go to 3.42

3.42. All the measures or combination of measures identified as being appropriate for each pathway or for the commodity can be considered for inclusion in phytosanitary regulations in order to offer a choice of different measures to trading partners.

> *Note: only the least stringent measure (or measures) capable of performing the task should be selected. Thus, if inspection is truly reliable, it should not be necessary to*

consider treatment or testing. Note also that some measures may counteract each other; for example the requirement for resistant cultivars may make detection more difficult. It may be that some or all of these measures are already being applied to protect against one or more other pests, in which case such measures need only be applied if the other pest(s) is/are later withdrawn from the legislation.

The minimum phytosanitary measure applied to any pest is the declaration in phytosanitary regulations that it is a quarantine pest. This declaration prohibits both the entry of the pest in an isolated state, and the import of consignments infested by the pest. If other phytosanitary measures are decided upon, they should accompany the declaration as a quarantine pest. Such declaration may occasionally be applied alone, especially: (1) when the pest concerned may be easily detected by phytosanitary inspection at import (see Question 3.13), (2) where the risk of the pest's introduction is low because it occurs infrequently in international trade or its biological capacity for establishment is low, or (3) if it is not possible or desirable to regulate all trade on which the pest is likely to be found. The measure has the effect of providing the legal basis for the NPPO to take action on detection of the pest (or also for eradication and other internal measures), informing trading partners that the pest is not acceptable, alerting phytosanitary inspectors to its possible presence in imported consignments, and sometimes also of requiring farmers, horticulturists, foresters and the general public to report any outbreaks.

Without prejudice to the requirements that are already in existence under the emergency phytosanitary measures for *P. ramorum* (Anon., 2002, 2004 and 2007) as well as those in the EC Plant Health Directive 2000/29/EC (Anon., 2000) the measures that may be appropriate to the pathways listed under 3.41 are identified in Table 24 in the same relative order as presented above.

Table 24. Potential measures selected for managing the risks posed by the pathways of entry for *P. ramorum* into the EU for consideration by the policy makers (some measures may need to be combined).

Pathway type	**Origin**	**Pathogen testing: Export Import Post-entry quarantine**	**Domestic certification schemes (to include pathogen testing)**	**Surveillance and eradication of findings in the PRA area**	**Pest free crop, place of production or area.**	**Treatment**	**End-use**	**Comment**
Plants for planting of susceptible hosts (excluding seeds and fruits)	USA Unknown area/areas or origin	Export or Import and Post-entry quarantine	Yes	Yes	Yes	No	No	
Plants for planting of susceptible hosts (excluding seeds and fruits)	Canada Norway Switzerland	Export or Import and Post-entry quarantine	Yes	Yes	Yes	No	No	
Soil/growing media as a commodity	USA Canada Norway Switzerland	No	No	Yes	Yes	No	No	Prohibition is appropriate as per 2000/29/EC to prevent entry of other pests
Susceptible bark	USA Unknown area/areas or origin	No	No	Yes	Yes	No	Not to be used in the nursery trade or the landscaping industry	Efficacy of treatments for bark is not known

Pathway type	Origin	Pathogen testing: Export Import Post-entry quarantine	Domestic certification schemes (to include pathogen testing)	Surveillance and eradication of findings in the PRA area	Pest free crop, place of production or area.	Treatment	End-use	Comment
Plants for planting of non-hosts (excluding seeds and fruits) with contaminated growing media	USA Canada Norway Switzerland	No	No	Yes	Yes	Growing media – pre-planting treatment, prevention of reinfestation, removal of excess pre-export of plants	No	Efficacy of treatments for growing media will vary with the substrate
Soil as a contaminant of footwear, machinery etc	USA Unknown area/areas or origin	No	No	Yes	No	Inspection of footwear, treatment at the point of entry Cleaning and disinfection of imports of used machinery or vehicles	No	
Susceptible wood	USA Unknown area/areas or origin	No	No	Yes	Yes	No	The risk of transmission from wood is low	Efficacy of treatments for wood is not known
Foliage, cut branches of susceptible hosts	USA Canada Norway Switzerland	Export or Import	No	Yes	YES	Heat treatment (affects quality)	End-use is already for ornamental purposes	Recycling through composting poses a small risk
Seeds and fruits of susceptible hosts	USA Canada Norway Switzerland	Export or Import for seeds	No	Yes	Yes	Removal of contaminating plant debris from seed lots	End use of fruits is for consumption	No natural seed or fruit infection reported
Susceptible isolated bark	Canada Norway Switzerland	No	No	Yes	Yes	No	The risk of transmission from wood is low	There are no forests affected in Canada, Norway or Switzerland Efficacy of treatments for wood is not known
Susceptible isolated wood	Canada Norway Switzerland	No	No	Yes	Yes	No	The risk of transmission from wood is low	There are no forests affected in Canada, Norway or Switzerland Efficacy of treatments for wood is not known

Go to 3.43

3.43. In addition to the measure(s) selected to be applied by the exporting country, a phytosanitary certificate (PC) may be required for certain commodities. The PC is an attestation by the exporting country that the requirements of the importing country have been fulfilled. In certain circumstances, an additional declaration on the PC may be needed (see EPPO Standard PM 1/1(2): Use of phytosanitary certificates).

According to which measures are selected a phytosanitary certificate may be required to accompany the commodity imported into the EU with an appropriate additional declaration completed.

Go to 3.44

3.44. If there are no measures that reduce the risk for a pathway, or if the only effective measures unduly interfere with international trade (e.g. prohibition), are not cost-effective or have undesirable social or environmental consequences, the conclusion of the pest risk management stage may be that introduction cannot be prevented. In the case of pest with a high natural spread capacity, regional communication and collaboration is important.

Measures are available for all of the pathways. However, the area or areas of origin has yet to determined and so regulation of this pathway is not possible.

Conclusion of pest risk management.

Summarize the conclusions of the Pest Risk Management stage. List all potential management options and indicate their effectiveness. Uncertainties should be identified.

Recommendation for possible measures:

The measures below do not account for pre-existing EC phytosanitary measures for *P. ramorum* or any measures that may have an impact on the risks posed by *P. ramorum* under the EC Plant Health Directive (200/29/EC.)

Because of the uncertainty surrounding the origin or origins of *Phytophthora ramorum* it is not possible to regulate the 8 main '*commodity types*' from this origin, albeit this continues to present a risk of entry of *P. ramorum* to the EU.

For foliage and cut branches, measures may only be necessary for areas where *P. ramorum* occurs if material is harvested there. This is likely to be only California and Oregon in the USA. Norway and Switzerland may only need to be regulated if the pathogen occurs in areas where foliage and cut branches are harvested and if these are exported to the EU. These measures could be recommended but the risk of establishment from this pathway is likely to be low.

It is thought that measures are not necessary for seeds and fruit of susceptible host plants as there are no records of infection in the field and plants with edible fruit that are likely to be traded are not hosts. There are no data to show that seed transmission is possible.

For susceptible bark, measures are only necessary for parts of the USA where *P. ramorum* occurs in woodlands and forests (California and Oregon) as there are no woodlands/forests affected in Canada, Norway or Switzerland.

For susceptible wood, measures seem not to be necessary because of the end-use of the material. If measures are maintained then they are only necessary for parts of the USA where *P. ramorum* occurs in woodlands and forests (California and Oregon) as there are no woodlands/ forests affected in Canada, Norway or Switzerland

The recommended measures are listed below:

Pathway 1: <u>Plants for planting (excluding seeds and fruit) of known susceptible hosts</u> that are permitted entry from the USA and Canada, Norway and Switzerland	Phytosanitary Certificate (PC) and, if appropriate, Re-export Certificate (RC) *Measures related to consignments:* Detection of the pathogen in consignments by inspection <u>and</u> testing at export and/or import *or* Detection of the pathogen by inspection <u>and</u> testing during post-entry quarantine *Measures related to the crop or to places of production:* Pest freedom for the crop, place of production or area. Domestic certification schemes <u>if</u> supported by testing of symptomatic material. *Other possible measures* Surveillance and eradication in the importing country of the EU

Pathway 2: <u>Plants for planting (excluding seeds and fruit) of non-host plant species accompanied by contaminated, attached growing media</u> from the USA and Canada, Norway and Switzerland	PC and, if appropriate, RC *Measures related to consignments:* Physical removal of any surplus growing media just before export. *Measures related to the crop or to places of production:* In areas where the pathogen occurs, treatment (sterilisation) of the growing media prior to planting and prevention of reinfestation during the growing period Pest freedom for the crop, place of production or area (i.e. non-host plants to be produced away from host-plants to avoid contamination) *Other possible measures* Surveillance and eradication in the importing country of the EU

Pathway 3: <u>Soil/growing medium (with organic matter) as a commodity</u> from the USA and Canada, and Norway and Switzerland	PC and, if appropriate, RC *Measures related to consignments:* Depending upon the volume of material heat treatment could be considered but may not be practical. *Measures related to the crop or to places of production:* Pest free crop, place of production or area. (For the area where soil or growing media are collected). *Other possible measures* Surveillance and eradication in the importing country of the EU.

Pathway 4: <u>Soil as a contaminant</u> (e.g. on footwear, machinery, etc.) from the USA and Canada, Norway and Switzerland	*Measures related to consignments:* Cleaning and disinfection of used machinery or vehicles imported from an area where *P. ramorum* occurs. *Measures related to the crop or to places of production:* Not applicable *Other possible measures* Inspection of human travellers footwear and possible treatment at the point of entry where travellers have entered from an area where *P. ramorum* occurs

Pathway 5: <u>Foliage or cut branches</u> (for ornamental purposes) of susceptible foliar hosts from the USA (Norway and Switzerland – but only if foliar hosts are affected where harvesting and export to the EU occurs)	PC and, if appropriate, RC *Measures related to the crop or to places of production:* Pest–free area for the crop, place of production or area. *Other possible measures* Controls on recycling for known infected material Surveillance and eradication in the importing country of the EU

Pathway 7: <u>Susceptible (isolated) bark</u> from the USA .	PC and, if appropriate, RC *Measures related to consignments:* Limited end-use of known infected bark (i.e. not to be used in the nursery trade or the landscaping industry) *Measures related to the crop or to places of production:* Pest-free crop, place of production or area

Degree of uncertainty for risk management options

- The area of origin or origins has not been identified and although it has been speculated to be Asia (possibly Yunnan, Taiwan or the eastern Himalayas) this is still not proven. Because of this it is not possible to regulate all of the pathways.

- The efficacy of fungicide treatments for host plants is not 100%.

- The potential for spread in asymptomatic roots of host plants is a possibility, but is not proven to have led to new findings.

- The significance of asymptomatic sporulation is uncertain.

- The potential for spread in growing media has not been shown to occur in practice, but it has the potential to do so.

- The significance of asymptomatic sporulation is not yet fully known

- It is not known whether there are imports of machinery or vehicles from area where *P. ramorum* occurs

- It is not known whether areas where foliage or cut branches are harvested for export to the EU are affected by *P. ramorum.*

- There is no evidence of seed-borne infection to date so the potential for this to be a pathway is uncertain.

- The evidence for fruit-borne infection is only experimental so the potential for this to be a pathway is uncertain.

- The efficacy of phytosanitary treatments that are routinely prescribed for bark and wood are not known but there is doubt as to the efficacy of 56ºC for 30 minutes.

- The potential for spread from infected bark and wood to host plants is not known; spread from bark is more likely than from wood.

DISSEMINATION AND EXPLOITATION OF RESULTS

This Pest Risk Analysis (PRA) for *Phytophthora ramorum* for the EU has been disseminated to the EC Standing Committee for Plant Health (DG SANCO) (in addition to DG Research), from where (the second version) was distributed to all EU Member States via CIRCA. It is anticipated that it will be considered by the EC Expert Working Group for *P. ramorum*. The PRA will be placed on the RAPRA project website: http://rapra.csl.gov.uk/

The PRA will be used, in conjunction with other information (Member State Surveys, efficacy of existing measures etc) to review the current EC emergency phytosanitary measures (2002/757/EC as amended) and to determine the appropriate level of protection for the EU in relation to the assessed level of risk, whilst minimising disruption to trade.

Consideration will be given to publication of some of the information presented in this PRA in a peer-reviewed journal.

POLICY RELATED BENEFITS

The main policy related benefit arising from this Deliverable Report is that a fully revised PRA has been prepared for *P. ramorum* for the European Union taking into account the most recent scientific and economic information arising from the RAPRA project as well as from the published literature.

This PRA (second version) has been presented to the EC Standing Committee for Plant Health who met on 2 and 3rd February 2009. It is anticipated that it will be used by the EC Expert Working Group for *Phytophthora ramorum* to revise the current emergency phytosanitary measures (2002/757/EC as amended). These measures are due for review in 2009, on the basis of the results of Member States Surveys, the efficacy of the implementation of the measures and the scientific opinions delivered by the Member States, which include this PRA.

The PRA has identified the endangered areas of the EU and concluded that the risk from *P. ramorum* is not acceptable. The existing measures (2002/257/EC and selected measures in 2000/29/EC, as amended) have been reviewed in this PRA. Suggestions for risk management options have been identified. Policy makers can use this information to determine the appropriate level of protection for future management of *P. ramorum* in the EU in relation to the assessed level of risk and the current trade pathways (imports and exports), as well as those non-trade pathways that may move the pathogen into and within the EU.

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APPENDIX I : RAPRA Workpackage 8 – Description of Work

WP 8. Pest risk analysis for *Phytophthora ramorum* for the EU

WP number	8	**Start date or starting event:**				Month 6		
Participant id	FR	**CSL**	PRI	BBA-IPP	PD	INRA	CSIC	BBA-NIH	USDA
Person-months per participant:	0.5	**10.75**	0	0.5	0	0	1.0	1.0	1.0

Objectives

To produce a new Pest Risk Analysis for *P. ramorum* for the EU assessing and managing the risk from both the A1 and A2 mating types. Specific objectives of WP6 are to:

a. Determine the risk of entry, establishment, spread and socio-economic and environmental loss from *P. ramorum* for the EU.
b. Determine the appropriate level of risk management for Europe for *P. ramorum* in relation to the assessed level of risk determined by the Project.

See also Goal 8 in Table 2.1 – Logical Framework Analysis Matrix

Description of work

WP 8.1 ***Map the risks posed by P. ramorum to cultivated and uncultivated plants in Europe***
WP 1, 2, 3 and 4 will refine the list of susceptible hosts and identify the environmental conditions suitable for infection and disease expression. WP 8.1 will prepare maps highlighting the areas of Europe where combinations of climate, hosts, host associations and other factors significant in the epidemiology of this pathogen are present. A database of *P. ramorum* distribution records, both in Europe (in part from WP 1) and worldwide, will be set up and maintained. Depending on their availability, the key circumstances of each finding will also be recorded and analysed to determine common factors and the extent to which the potential distribution and impacts can be extrapolated from its known range. Results from other research programmes, e.g. in the USA, will also be taken into account. European climate will be characterised by databases of climatic data interpolated over the European landscape, e.g. the World Climate Database [26], which provides 1961-90 monthly data variables interpolated to a 0.5º latitude/longitude grid. Land-cover databases, e.g. the pan-European land cover database (PELCOM) [27], will be used to map habitat types. European [28] and national floras, e.g. Preston *et al.* [29] will be applied to map host distributions. For areas identified as especially endangered, contact will be made with national organisations in order to identify and obtain additional datasets to assist in preparing maps of the risks posed by *P. ramorum* to plant species at higher resolutions. Such national datasets will supplement high resolution datasets which are already widely available such as data from meteorological stations, e.g. from the National Climate Data Center [30].

WP 8.2 ***Risk Assessment***
Using the maps from WP8.1 and the Deliverable Reports from WP 1, 2, 3 and 4: the assessment will evaluate the risk of entry and establishment of the A2 mating type; the risk of further spread of the A1 mating type within the EU. Also evaluate the risk of sexual reproduction and the potential risks from any resulting progeny which might arise from sexual recombination between European A1s and American A2s.

WP 8.3 ***Pest Risk Analysis***
The Pest Risk Analysis will be based on information from WP 8.1 and 8.2 and the Deliverable Reports from WPs 5, 6 and 7. It will assess the overall risk of entry, establishment and socio-economic and environmental impact of *P. ramorum* for the EU and determine the appropriate level of risk management for the EU for *P. ramorum* in relation to the assessed level of risk using the framework of the published international standard for Pest Risk Analysis (International Standards for Phytosanitary Measures FAO ISPM Publication no. 11 "Pest Risk Analysis for Quarantine Pests" – http://www.ippc.int/IPP/En/ispm.jsp; as well as EPPO Standards (PM5): Pest Risk Analysis.

Deliverables

D13 Compile a database of *P. ramorum* distribution records for Europe, the USA and any other reported findings (month 24)

D26 Produce map(s) highlighting areas endangered by *P. ramorum* in Europe (month 30)

D28 Report on the risk of entry, establishment, spread and socioeconomic loss and environmental impact and the appropriate level of risk management for *P. ramorum* for Europe using the framework of the published international standard for Pest Risk Analysis (FAO ISPM Publication No. 11, Pest Risk Analysis for Quarantine Pests and EPPO Standards (PM5): Pest Risk Analysis) (month 34).

Milestones and expected result

MS 8.1 Database of *P. ramorum* records for European and worldwide distribution compiled (month 24).
MS 8.2 Map(s) of areas endangered by *P. ramorum* Europe produced (month 27).
MS 8.3 Revised European Pest Risk Analysis for *P. ramorum* completed (month 31).

APPENDIX II. Natural hosts of *Phytophthora ramorum*

Last updated 9 October 2008

Family	Latin name	Common name	Damage type[*]			Location(s)[†]	References
			F	D	C		
Aceraceae	*Acer circinatum*	Vine maple	✔			USA (outdoor)	COMTF (undated)
	Acer davidii	Striped bark maple	✔			Canada (nursery)	COMTF (undated)
	Acer macrophyllum[1]	Big leaf maple	✔			USA (outdoor)	Garbelotto *et al*. (2003)
	Acer laevigatum	Evergreen maple	✔			UK (outdoor)	Forest Research records
	Acer pseudoplatanus[1]	Sycamore			✔	UK (outdoor)	Forest Research records
Anacardaceae	*Toxicodendron diversilobum*	Pacific poison oak	✔		✔	USA (outdoor)	Rizzo (2003)
Apiaceae	*Osmorhiza berteroi*	Sweet cicely	✔			USA (outdoor)	COMTF (undated)
Apocynaceae	*Nerium oleander*	Oleander	✔			USA (nursery)	COMTF (undated)
Aquifoliaceae	*Ilex purpurea*	Oriental holly	✔			Canada (nursery)	APHIS records
Berberidaceae	*Vancouveria planipetala*	Redwood ivy	✔			USA (outdoor)	COMTF (undated)
	Mahonia aquifolium	Holly leaved barberry Oregon grape	✔			Canada (nursery)	CFIA (Aug 2007)
Betulaceae	*Corylus cornuta*	California hazelnut		✔		USA (outdoor)	Murphy & Rizzo (2002)
Calycanthaceae	*Calycanthus occidentalis*	Spicebush, western sweetshrub	✔			USA (outdoor)	COMTF (undated)
Caprifoliaceae	*Lonicera hispidula*[1]	Californian honeysuckle	✔			UK (nursery)[2], USA (outdoor)	Garbelotto *et al*. (2003), CSL records
	Lonicera periclymenum	Honeysuckle	✔			Canada (nursery)	CFIA records
	Viburnum spp.[1]	Viburnum	✔	✔		UK (nursery and outdoor), Belgium (nursery), the Czech Republic (nursery), France (nursery), Germany (nursery), Ireland (nursery), the Netherlands (nursery), Norway (outdoor), Slovenia (nursery and outdoor), Spain (nursery), Switzerland (nursery and outdoor), Canada (nursery), USA, (nursery).	Lane *et al*. (2003), Cahalane (2004), De Merlier *et al*. (2003), Běhalová (2006), Werres *et al*. (2001), Pintos Varela *et al*. (2004), Žerjav *et al*. (2004), Heiniger *et al*. (2004), RAPRA (undated), COMTF (undated), Anon. (2006a) Parke *et al*. (2004).

[*]F = Ramorum leaf blight (including petiole), D = Ramorum dieback, C = Ramorum canker
[†]Also includes situation: nursery and/or out door
[1] Koch's postulates have been successfully completed for this host.
NB Koch's postulates for *Gaultheria shallon* could only be completed on wounded leaves on the whole plant.
[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

Family	Latin name	Common name	Damage type[*]			Location(s)[†]	References
			F	D	C		
Celastraceae	*Euonymus kiautschovicus*	Spreading euonymus, creeping strawberry bush	✔	✔		Canada (nursery)	CFIA records
Cornaceae	*Griselinia littoralis*[1]	New Zealand privet	✔	✔		UK (outdoor)	Giltrap *et al.* (2006)
	Cornus kousa x *cornus capitata* “Norman haddon”			✔		UK (outdoor)	Forest Research records
	Cornus capitata	Bentham’s dogwood	✔			UK (outdoor)	PHSI, CSL Records
Dryopteridiaceae	*Dryopteris arguta*	Californian wood fern, coastal woodfern	✔			USA (outdoor)	COMTF (undated)
Ericaceae	*Arbutus menziesii*[1]	Madrone	✔	✔		USA (outdoor)	Garbelotto *et al.* (2003)
	Arbutus unedo	Strawberry tree	✔	✔		Guernsey (nursery), Spain (nursery)	CSL records, COMTF (undated)
	Arctostaphylos columbiana	Hairy manzanita	✔	✔		USA (outdoor)	COMTF (undated)
	Arctostaphylos manzanita[1]	Manzanita	✔	✔		USA (outdoor)	Garbelotto *et al.* (2003)
	Arctostaphylos uva-ursi	Kinnikinnik, bearberry	✔			USA (nursery)	COMTF (undated)
	Calluna vulgaris[1]	Heather		✔		Poland (nursery)	Orlikowski & Szkuta (2004)
	Gaultheria shallon[1]	Salal, Oregon wintergreen	✔			Canada (nursery), UK (nursery)	CFIA records, CSL records
	Kalmia sp.	Species not presently known				Canada (nursery)	CFIA records
	Kalmia angustifolia	Sheep laurel	✔	✔		UK (nursery)[2]	CSL records
	Kalmia latifolia[1]	Mountain laurel	✔	✔		UK (outdoor and nursery), Slovenia (nursery)	CSL records, RAPRA (undated)
	Leucothoe axillaris	Fetter-bush, dog hobble	✔			Canada (nursery)	COMTF (undated)
	Leucothoe fontanesiana[1]	Drooping leucothoe	✔			UK (nursery), France (nursery)	CSL records, Husson (personal communication)
	Pieris sp.	Species not presently known	✔			Canada (nursery)	CFIA records
	Pieris floribunda x *japonica*[1]	Mountain andromeda	✔	✔		USA (nursery)	Parke *et al*. (2004)
	Pieris formosa[1]	Himalaya andromeda	✔	✔		UK (outdoor and nursery)	Inman *et al.* (2003)
	Quercus ilex[1]	Holm oak	✔	✔		UK (outdoor)	Denman *et al*. (2005)

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[†]Also includes situation: nursery and/or out door
[1] Koch’s postulates have been successfully completed for this host.
NB Koch’s postulates for *Gaultheria shallon* could only be completed on wounded leaves on the whole plant.
[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

Family	Latin name	Common name	Damage type[*]			Location(s)[†]	References
			F	D	C		
Ericaceae (continued)	*Pieris japonica*[1]	Japanese pieris	✔	✔		UK (nursery and outdoor), France (nursery), Germany (nursery and outdoor), Poland (nursery), USA (nursery)	CSL records, RAPRA (undated), Husson (personal communication), Orlikowski & Szkuta (2004), Parke *et al*. (2004)
	Pieris japonica x *formosa*[1]	Ornamental pieris	✔	✔		UK (nursery), USA (nursery)	CSL records, Parke *et al*. (2004)
	Rhododendron spp. [1]	Rhododendron	✔	✔		UK (nursery and outdoor), Belgium (nursery), Finland (nursery), France (nursery and outdoor), Germany (nursery and outdoor), Ireland (nursery), Italy (nursery), the Netherlands (nursery and outdoor), Norway (outdoor), Poland (nursery), Slovenia (nursery), Spain (nursery), Sweden (nursery), Switzerland (nursery), Canada, (nursery), USA (nursery and outdoor)	CSL records, De Merlier *et al*. (2003), RAPRA (undated), Husson (personal communication), Cahalane (2004), Gullino *et al*. (2003), de Gruyter & Steeghs (2006), Orlikowski & Szkuta (2002), Žerjav *et al*. (2004), Morajelo & Werres (2002), Goheen *et al*. (2002a), Anon. (2006a), COMTF (undated), Garbelotto *et al.* (2003)
	Vaccinium ovatum[1]	Californian huckleberry	✔	✔		USA (outdoor)	Garbelotto *et al.* (2003), Goheen *et al*. (2002a)
	Vaccinium vitis-idaea	Cowberry	✔			UK (nursery)	CSL records
Fabaceae	*Cercis chinensis*	Redbud	✔			Canada (nursery) Nov 2007	CFIA March 2008
Fagaceae	*Castanea sativa*[1]	Sweet chestnut	✔	✔	✔	UK (outdoor)	Denman *et al*. (2005)
	Castanopsis orthacantha	-	✔	✔		UK (outdoor)	Forest Research records
	Fagus sylvatica[1]	Beech			✔	UK (outdoor), Netherlands (outdoor)	Forest Research records, RAPRA (undated)
	Lithocarpus densiflorus[1]	Tanoak	✔	✔	✔	USA (outdoor)	Garbelotto *et al.* (2003)
	Nothofagus obliqua	Roble beech			✔	UK (outdoor)	Forest Research records
	Quercus acuta	Japanese evergreen oak			✔	UK (outdoor)	Forest Research records
	Quercus agrifolia[1]	Coast live oak			✔	USA (outdoor)	Garbelotto *et al.* (2003)
	Quercus chrysolepis[1]	Canyon live oak		✔	✔	USA (outdoor)	Murphy & Rizzo (2003)
	Quercus cerris[1]	Turkey oak	✔		✔	UK (outdoor)	Forest Research records
	Quercus falcata[1]	Southern red oak			✔	UK (outdoor)	Brasier *et al*. (2004a)

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[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

Family	Latin name	Common name	Damage type*			Location(s)†	References
			F	D	C		
Fagaceae (continued)	*Quercus kelloggii*[1]	Californian black oak			✔	USA (outdoor)	Garbelotto *et al.* (2003)
	Quercus parvula var. *shrevei* [1]	Shreve oak			✔	USA (outdoor)	Garbelotto *et al.* (2003)
	Quercus petraea	Sessile oak			✔	UK (outdoor)	Forest Research records
	Quercus rubra	Northern red oak			✔	Netherlands (outdoor)	RAPRA (undated)
Garryaceae	*Garrya elliptica*	Silk tassel bush	✔			UK (nursery)	CSL records
Grossulariaceae	*Ribes laurifolium*		✔			UK (nursery)	CSL records Feb 2008
Hamamelidaceae	*Corylopsis spicata*	Spike winter hazel	✔			Canada (nursery)	CFIA records
	Distylium myricoides	Myrtle-leafed distylium	✔			Canada (nursery)	CFIA records
	Hamamelis mollis	Chinese witch hazel	✔	✔		UK (nursery)	CSL records
	Hamamelis virginiana[1]	Virginian witch hazel	✔	✔		UK (nursery and outdoor)	Giltrap *et al.* (2004)
	Hamamelis x *intermedia* (*H. mollis* x *H. japonica*)	Hybrid witch hazel	✔			Canada (nursery)	Anon. (2006a)
	Loropetalum chinense	Loropetalum	✔			Canada (nursery); USA (nursery),	APHIS records; COMTF (undated)
	Parrotia persica[1]	Ironwood	✔	✔		UK (outdoor), Canada (nursery)	Hughes *et al.* (2006b), CFIA records
Hippocastanaceae	*Aesculus californica*[1]	Californian buckeye	✔	✔		USA (outdoor)	Garbelotto *et al.* (2003)
	Aesculus hippocastanum[1]	Horse chestnut			✔	UK (outdoor)	Forest Research records
Lauraceae	*Cinnamomum* sp. [4]	-				Canada (nursery)	CFIA records
	Cinnamomum camphora	Camphor tree		✔	✔	UK (outdoor)	Forest Research records
	Laurus nobilis[1]	Bay laurel	✔			UK (nursery)	CSL records
	Umbellularia californica[1]	Californian bay laurel	✔			UK (outdoor), USA (outdoor)	CSL records, Garbelotto *et al.* (2003)
Liliaceae	*Clintonia andrewsiana*	Andrew's clintonia bead lily	✔			USA (outdoor)	COMTF (undated)
	Maianthemum racemosum [syn. *Smilacina racemosa*]	False Solomon's seal	✔			USA (outdoor)	COMTF (undated)
Magnoliaceae	*Magnolia denudata*	Lily Tree	✔			Canada (nursery); UK (outdoor)	CFIA records; FR records
	Magnolia figo (Michelia figo	Banana magnolia (Banana shrub)	?			USA (nursery)	APHIS May 2008

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[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

Family	Latin name	Common name	Damage type[*]			Location(s)[†]	References
			F	D	C		
Magnoliaceae (continued)	*Magnolia grandiflora*[1]	Magnolia	✔			UK (nursery and outdoor), USA (nursery), Canada (nursery)	CSL records, COMTF (undated)
	Magnolia kobus	Kobus magnolia	✔			Canada (nursery)	CFIA records
	Magnolia stellata[1]	Star magnolia	✔	✔		UK (nursery and outdoor)	Giltrap *et al.* (2006)
	Magnolia x *loebneri*[1] (*M. kobus* & *M. stellata*)	Loebner magnolia	✔	✔		UK (nursery and outdoor)	Giltrap *et al.* (2006)
	Magnolia salicifolia	Anise magnolia	✔			UK (outdoor)	Forest Research records
	Magnolia x *soulangeana* (*M. liliiflora* x *M. denudate*)	Saucer magnolia	✔	✔		UK (nursery)	CSL records
	Magnolia denudata x *salicifolia*	Magnolia hybrid	✔			UK (outdoor)	Forest Research records
	Michelia cavalieri	Michelia	✔			Canada (nursery)	CFIA records
	Michelia doltsopa[1]	Michelia	✔			UK (outdoor)	Forest Research records
	Michelia foveolata	Michelia	✔			Canada (nursery)	CFIA records
	Michelia maudiae[1]	Michelia	✔			UK (outdoor), Canada (nursery)	CSL records, APHIS records
	Michelia wilsonii	Michelia	✔			Canada (nursery)	APHIS records
	Manglietia insignis	Red lotus tree	✔			Canada (nursery)	APHIS records
	Parakmeria lotungensis	Eastern joy lotus tree	✔			Canada (nursery)	APHIS records
Myrtaceae	*Eucalyptus haemastoma*	Scribbly gum	✔			UK (outdoor)	Forest Research records
Mysinaceae	*Ardisia japonica*	Japanese ardisia, Maleberry	✔			Canada (nursery)	COMTF (undated)
Oleaceae	*Fraxinus excelsior*[1]	Ash	✔			UK (outdoor)	Forest Research records
	Fraxinus latifolia	Oregon ash	✔			USA (outdoor)	COMTF (undated)
	Osmanthus heterophyllus[1]	Holly osmanthus	✔			UK (nursery), USA (nursery)	CSL records, COMTF (undated)
	Osmanthus decorus	Osmanthus	✔			Canada (nursery)	RAPRA (undated)
	Rosa spp. (several different cultivars)	Rose	✔			Canada (nursery)	APHIS records
	Osmanthus delavayi	Delavay osmanthus	✔			USA (nursery), UK (outdoor)	COMTF (undated); Forest Research records
	Osmanthus fragrans	Sweet olive	✔	✔		USA (nursery), Canada (nursery)	COMTF (undated), CFIA records

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[†]Also includes situation: nursery and/or out door
[1] Koch's postulates have been successfully completed for this host.
NB Koch's postulates for *Gaultheria shallon* could only be completed on wounded leaves on the whole plant.
[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

Family	Latin name	Common name	Damage type*			Location(s)†	References
			F	D	C		
Oleaceae (continued)	*Syringa* sp.	Not identified to species level				Canada (nursery) France (nursery)	CFIA records, Husson (personal communication)
	Syringa vulgaris[1]	Lilac	✔	✔		UK (outdoor and nursery)	Beales *et al*. (2004a)
Pinaceae	*Abies concolor*	White fir	✔			USA (outdoor)	COMTF (undated)
	Abies grandis	Grand fir	✔	✔		USA (outdoor)	COMTF (undated)
	Abies magnifica	Red fir	✔	✔		USA (outdoor)	COMTF (undated)
	Pseudotsuga menziesii[1]	Douglas fir	✔	✔		USA (outdoor)	Davidson *et al.* (2002)
Pittosporaceae	*Pittosporum undulatum*	Victorian box	✔			USA (outdoor)	Hüberli *et al*. (2006)
Polypoidiaceae	*Adiantum aleuticum*[1] [syn. *Adiantum pedatum*]	Western maidenhair fern	✔			USA (outdoor)	Vettraino *et al.* (2006)
	Adiantum jordanii[1]	California maidenhair fern	✔			USA (outdoor)	COMTF (undated)
Primulaceae	*Trientalis latifolia*[1]	Western star flower	✔			USA (outdoor)	Hüberli *et al*. (2003)
Rhamnaceae	*Ceanothus thyrsiflorus*	Blue blossom, Californian lilac	✔	✔		USA (outdoor)	COMTF (undated)
	Frangula californica[1] [syn. *Rhamnus californica*]	Californian coffeeberry, California buckthorn	✔	✔		USA (outdoor)	Garbelotto *et al.* (2003)
	Frangula purshiana[1] [syn. *Rhamnus purshiana*]	Cascara	✔			USA (outdoor)	Vettraino *et al*. (2006), Goheen *et al*. (2002b)
Rosaceae	*Heteromeles arbutifolia*[1]	Toyon	✔	✔		USA (outdoor)	Garbelotto *et al.* (2003)
	Photinia x *fraseri*[1] (*P. glabra* x *P. serrulata*)	Fraser photinia	✔			Poland (outdoor)	Orlikowski & Szkuta (2004)
	Physocarpus	Ninebark	?			Canada (nursery)	CFIA 2007
	Pyracantha koidzumii	Formosa firethorn	✔			Canada (nursery)	Briere *et al.* (2005)
	Prunus laurocerasus 'Nana'	Dwarf English Laurel	✔			USA (nursery)	COMTF (undated)
	Prunus lusitanica	Portuguese laurel cherry	✔			Canada (nursery)	COMTF (undated)
	Rosa gymnocarpa[1]	Californian wood rose	✔			USA (outdoor)	Hüberli *et al.* (2004)
	Rosa rugosa	Rugosa rose	✔			Canada (nursery)	APHIS records
	Rubus spectabilis	Salmonberry	✔			USA (outdoor)	Goheen *et al.* (2002b)
Rutaceae	*Choisya ternata* *"Aztec Pearl"*	Mexican orange	✔			UK	CSL Records (2008)

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†Also includes situation: nursery and/or out door
[1] Koch's postulates have been successfully completed for this host.
NB Koch's postulates for *Gaultheria shallon* could only be completed on wounded leaves on the whole plant.
[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

Family	Latin name	Common name	Damage type*			Location(s)†	References
			F	D	C		
Salicaceae	*Salix caprea*[1]	Goat willow/sallow	✔	✔		UK (nursery) [2]	CSL records
Taxaceae	*Taxus* sp.		✔			Canada (nursery), France (nursery)	CFIA records, Husson (personal communication)
	Taxus baccata[1]	Yew	✔	✔		UK (nursery)	Lane *et al.* (2004)
	Taxus brevifolia	Pacific yew	✔	✔	✔	USA (outdoor)	COMTF (undated)
	Taxus x *media* (*T. baccata* x *T. cuspidata*)	Anglojap yew			✔	Netherlands (nursery)	de Gruyter & Steeghs (2006)
	Torreya californica	California nutmeg	✔	✔		USA (outdoor)	COMTF (undated)
Taxodiaceae	*Sequoia sempervirens*[1]	Coast redwood	✔			USA (outdoor) UK (outdoor)	Maloney *et al.* (2002) CSL records
Theacae	*Camellia* spp.[1]	Camellia	✔	✔		UK (nursery and outdoor), France (nursery), Spain (nursery), USA (nursery and outdoor), Canada (nursery)	Beales *et al*. (2004b), Husson (personal communication), Pintos Varela *et al*. (2003), COMTF (undated), CFIA records
	Schima argentea	-			✔	UK (outdoor)	Forest Research records
	Schima wallichii	Chinese guger tree	✔			UK (outdoor)	CSL records
Winteraceae	*Drimys winteri*	Winter's bark	✔	✔		UK (outdoor)	CSL records

*F = Ramorum leaf blight (including petiole), D = Ramorum dieback, C = Ramorum canker
†Also includes situation: nursery and/or out door
[1] Koch's postulates have been successfully completed for this host.
NB Koch's postulates for *Gaultheria shallon* could only be completed on wounded leaves on the whole plant.
[2] These records refer to interceptions on nursery stock. The country given is where the infected plant was found but the plants were originally grown in another country that is not named here.
[4] Symptoms not known

APPENDIX III. Species susceptibilities to *P. ramorum* as determined by experimental tests.

Compiled from the RAPRA Database of potential hosts (as of 9 August 2006) http://rapra.csl.gov.uk plus input from RAPRA partners – 9 October 2008

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[15]	Reference
Abies concolor	White fir	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Abies grandis	Grand fir	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Abies grandis	Grand fir	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Abies grandis	Grand fir	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Abies grandis	Grand fir	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ms	Hansen *et al*., 2005
Abies magnifica	Red fir	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Abies magnifica	Red fir	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Abies procera	Noble Fir	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ms	Denman *et al*., *Personal Communication*
Abies procera	Noble fir	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Needles showing necrosis	Hs	Denman *et al*., 2005
Abies procera	Noble fir	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Abies procera	Noble fir	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Abies procera	Noble fir	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Abies procera	Noble fir	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Acer campestre	Field maple	Aceraceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Hs	Vannini, *Personal Communication*
Acer campestre	Field maple	Aceraceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Acer campestre	Field maple	Aceraceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Acer campestre	Field maple	Aceraceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Acer circinatum	Vine maple	Aceraceae	Details not supplied	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Acer circinatum	Vine maple	Aceraceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Acer circinatum	Vine maple	Aceraceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls - R	Hansen *et al*., 2005
Acer macrophyllum	Bigleaf maple	Aceraceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Acer macrophyllum	Bigleaf maple	Aceraceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ms	Garbelotto *et al*., 2003

[15] R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[16]	Reference
Acer macrophyllum	Bigleaf maple	Aceraceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Acer macrophyllum	Bigleaf maple	Aceraceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls	Hansen *et al*., 2005
Acer macrophyllum	Bigleaf maple	Aceraceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Acer monspessulanum	Montpellier maple	Aceraceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Acer monspessulanum	Montpellier maple	Aceraceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Acer monspessulanum	Montpellier maple	Aceraceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Acer monspessulanum	Montpellier maple	Aceraceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Acer palmatum	Japanese maple	Aceraceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Acer platanoides	Norway maple	Aceraceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Acer platanoides	Norway maple	Aceraceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ms	Vannini, *Personal Communication*
Acer pseudoplatanus	Sycamore	Aceraceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with necrosis, high level of back isolation	Ls	Denman *et al*., 2005
Acer pseudoplatanus	Sycamore	Aceraceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Acer pseudoplatanus	Sycamore	Aceraceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion extension slight	Ls	Defra, PH0193S
Acer pseudoplatanus	Sycamore	Aceraceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Acer pseudoplatanus	Sycamore	Aceraceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., 2002
Acer sp.	Maple	Aceraceae	Details not supplied	Details not supplied	Details not supplied	Details not supplied	Ls	Inman *et al*., 2002
Aesculus californica	California buckeye	Hippocastanaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ms	Garbelotto *et al*., 2003
Aesculus hippocastanum	Horse chestnut	Hippocastanaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with necrosis, high level of back isolation	Hs - Ms	Denman *et al*., 2005
Aesculus hippocastanum	Horse chestnut	Hippocastanaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., 2002
Alnus glutinosa	Alder	Betulaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Alnus glutinosa	Alder	Betulaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Alnus glutinosa	European alder, black alder	Betulaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[17]	Reference
Alnus glutinosa	European alder, black alder	Betulaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Alnus glutinosa	European alder, black alder	Betulaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with necrosis, low level of back isolation	Ls	Denman *et al*., 2005
Alnus incana	Gray alder	Betulaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Alnus rhombifolia	White alder	Betulaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Alnus rhombifolia	White alder	Betulaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Alnus rhombifolia	White alder	Betulaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ls	Hansen *et al*., 2005
Alnus rubra	Red alder	Betulaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Alnus rubra	Red alder	Betulaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Alnus rubra	Red alder	Betulaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Alnus rubra	Red alder	Betulaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls - Ms	Hansen *et al*., 2005
Alnus sp.	Alder	Betulaceae	Leaf inoculation	Details not supplied	Leaf	Details not supplied	R	Inman *et al*., 2002
Andromeda polifolia	Bog rosemary	Ericaceae	Details not supplied	Details not supplied	Leaves and stems	Stem lesions	Ls	Orlikowski & Szkuta, 2003
Andromeda polifolia	Bog rosemary	Ericaceae	Details not supplied	Details not supplied	Leaves and stems	Leaf necrosis	R	Orlikowski & Szkuta, 2003
Arbutus canariensis	Canary madrone	Ericaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Arbutus menziesii	Madrone	Ericaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Hs	Garbelotto *et al*., 2003
Arbutus unedo	Strawberry Tree	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ms	Vannini, *Personal Communication*
Arbutus unedo	Strawberry tree	Ericaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo et al., *Personal Communication*
Arbutus unedo	Strawberry tree	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Necrotic lesions followed by extensive blight.	Ms - Hs	Moralejo & Hernandez, 2002
Arbutus unedo	Strawberry tree	Ericaceae	Mycelial plug on twig	Yes	Twig cutting	Blight	Ms	Moralejo *et al*., *Personal Communication*
Arbutus unedo	Strawberry tree	Ericaceae	Log inoculation	Yes	Inner bark	inner bark necrosis	Ms	Moralejo *et al*., *Personal Communication*
Arbutus xalapensis	Madrone	Ericaceae	Whole plant dip in zoospore suspension	No	Whole plant	Dieback	Hs	Hansen *et al*., 2005
Arbutus xalapensis	Madrone	Ericaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls - R	Hansen *et al*., 2005
Arbutus xalapensis	Madrone	Ericaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[18]**	**Reference**
Arbutus xalapensis	Madrone	Ericaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Girdled	Hs	Hansen *et al*., 2005
Arctostaphylos manzanita	Manzanita	Ericaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ms	Garbelotto *et al*., 2003
Arctostaphylos uva-ursi	Bearberry	Ericaceae	Heathland species also tested by zoospore suspension dipping	No	Leaf	Lesion well developed	Ms	Defra, PH0193S
Arctostaphylos uva-ursi	Bearberry	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Arctostaphylos uva-ursi	Bearberry	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Ms	Tooley & Englander, 2002
Aucuba japonica	Japanese laurel	Aucubaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Betula pendula	European white birch, Silver birch	Betulaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	Ls	Denman *et al*., 2005
Betula pendula	European white birch, Silver birch	Betulaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Buddleja davidii	Butterfly bush, Summer lilac	Loganiaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Buddleja davidii	Butterfly bush, Summer lilac	Loganiaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Buxus microphylla	Japanese box	Buxaceae	Detached leaf dip in zoospore suspension	Yes and No	Leaf	None developed	R	Kaminski & Wagner, 2008
Buxus semperviresns var. *aborescens*	Common or European box	Buxaceae	Detached leaf dip in zoospore suspension	Yes and No	Leaf	None developed	R	Kaminski & Wagner, 2008
Calluna vulgaris 'Allegro', Amethyst', 'Long White', 'Marleen'	Heather	Ericaceae	Detached twigs dipped in zoospore suspension	No	Shoots with leaves	Shoot necrosis	Hs (Allegro, Amethyst, Long White) Ls (Marleen)	Wagner *et al*., 2005 Kaminski & Wagner, 2008
Calluna vulgaris	Heather	Ericaceae	Details not supplied	Details not supplied	Stems	Stem lesions	Ms	Orlikowski & Szkuta, 2003
Calluna vulgaris	Heather	Ericaceae	Mycelial discs on wounded petioles, stem bases or shoots	Yes	Petioles, stem bases, shoots	Details not supplied	Not given	Orlikowski & Szkuta, 2002
Calluna vulgaris	Heather	Ericaceae	Mycelial plugs	Details not supplied	Apical tip of shoots	Necrosis	Ms	Orlikowski & Szkuta, 2004
Calluna vulgaris	Heather	Ericaceae	Unwounded and wounded; zoospore suspension dipping	Yes and No	Leaves and stems	Leaf necrosis	Hs	Defra, PH0193S
Calluna vulgaris 'Winter chocolate'	Heather	Ericaceae	Unwounded and wounded; zoospore suspension dipping	Yes and No	Leaves and stems	Leaf necrosis	Hs	Defra, PH0193S
Calocedrus decurrens	Incense cedar	Cupressaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Calocedrus decurrens	Incense cedar	Cupressaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Camellia japonica	Common camellia	Ericaceae	Detached foliage dipped into a suspension of mycelial fragments and sporangia	No	Leaf	Leaf necrosis, petiole lesions	Ms	Orlikowski & Szkuta, 2003

[18] R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[19]	Reference
Camellia japonica	Common camellia	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Camellia japonica	Common camellia	Ericaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesions very extensive	Hs	Defra, PH0193S
Camellia japonica	Common camellia	Ericaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesions very extensive	Hs	Defra, PH0193S
Camellia japonica	Common camellia	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	R	Linderman *et al*., 2002
Camellia japonica	Common camellia	Ericaceae	Detached foliage dipped in zoospore suspension	No	Leaf	Leaf and petiole necrosis	Ms	Pintos Varela *et al*., 2003
Camellia sasanqua	Sasanqua Camellia	Theaceae	Mycelial plugs	Yes	Leaf	Foliage with necrosis, bud and stem death, necrotic lesions, leaf abscission	Ms	Parke *et al*., 2004
Camellia sp.	Camellia	Ericaceae	Leaf inoculation	Details not supplied	Leaf	Details not supplied	Hs	Inman *et al*., 2002
Camellia sp.	Camellia	Ericaceae	Not reported	Details not supplied	Detached leaf	Leaf necrosis (blight)	Not rated, just given as susceptible	Beales *et al*., 2004a
Carpinus betulus	Hornbeam	Betulaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Carpinus betulus	Hornbeam	Betulaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, high level of back isolation	Ls	Denman *et al*., 2005
Castanea sativa	Sweet chestnut	Fagaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Castanea sativa	Sweet chestnut	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	More susceptible	Brasier *et al*., *Personal Communication*
Castanea sativa	Sweet chestnut	Fagaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Castanea sativa	Sweet chestnut	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Ms	Denman *et al*., 2005
Castanopsis chryophylla	Giant chinquapin, Giant chinkapin, Golden chinkapin	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark necrosis	Ls - Hs	Hansen *et al*., 2005
Ceanothus impressus	Californian lilac, Santa Barbara	Rhamnaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Celtis australis	Nettle tree	Ulmaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ms - Hs	Moralejo *et al*., *Personal Communication*
Celtis australis	Netlte tree	Ulmaceae	Log inoculations	Yes	Inner bark	Inner bark necrosis	R	Moralejo *et al*., *Personal Communication*
Ceratonia siliqua	Carob, St. John's Bread	Leguminosae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[20]	Reference
Ceratonia siliqua	Carob, St. John's Bread	Leguminosae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Ceratonia siliqua	Carob, St. John's Bread	Leguminosae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Ceratonia siliqua	Carob, St. John's Bread	Leguminosae	Detached leaf dip in zoospore suspension	No	Leaf	Necrotic lesions followed by extensive blight.	Hs	Moralejo & Hernandez, 2002
Ceratonia siliqua	Carob, St. John's Bread	Leguminosae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Cercis siliquastrum	Judas tree	Leguminosae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Vannini, *Personal Communication*
Cercis siliquastrum	Judas tree	Leguminosae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Chaenomeles speciosa	Flowering quince	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	R	Parke *et al*., 2002a
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	More susceptible	Brasier *et al*., *Personal Communication*
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Ms	Zanzot *et al*., 2002
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Needles generally unaffected	R	Denman *et al*., 2005
Chamaecyparis lawsoniana	Lawsons cypress	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ms	Hansen *et al*., 2005
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark necrosis	Ls - Ms	Hansen *et al*., 2005
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Chamaecyparis lawsoniana	Port-Orford cedar, Lawson's cypress	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	R	Hansen *et al*., 2005
Choisya ternata	Mexican orange blossom	Rutaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Chrysolepis chrysophlla	Golden chinquapin	Fagaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Hs	Hansen *et al*., 2005
Chrysolepis chrysophlla	Golden chinquapin	Fagaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Cistus salviifolius	Rock rose	Cistaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Moralejo & Hernandez, 2002
Cistus salviifolius	Rock rose	Cistaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[21]**	**Reference**
Citrus deliciosa	Tangerine	Rutaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Citrus limon	Lemon tree	Rutaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Citrus sinensis	Orange tree	Rutaceae	Zoospore point inoculation	No	Detached leaf	Details not supplied	R	Moralejo *et al*., *Personal Communication*
Clematis flammula	Fragrant virgin's bower	Ranunculaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Moralejo & Hernandez, 2002
Clematis montana	Anenome clematis	Ranunculaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Clematis montana	Anenome clematis	Ranunculaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Cornus alba	Tatarian dogwood	Cornaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Cornus florida	Flowering dogwood	Cornaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	Not given	Parke *et al*., 2002a
Cornus mas	Cornelian cherry	Cornaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ms	Vannini, *Personal Communication*
Cornus mas	Cornelian cherry	Cornaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Cornus nuttalii	Pacific dogwood	Cornaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Cornus nuttalii	Pacific dogwood	Cornaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ms	Hansen *et al*., 2005
Cornus nuttalii	Pacific dogwood	Cornaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Cornus sanguinea	Dogwood	Cornaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Corylus	Hazel	Betulaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Corylus americana	Hazel	Betulaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Corylus avellana	Hazel	Betulaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Corylus avellana	Hazel	Corylaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	R	Denman *et al*., 2005
Corylus avellana	Hazel	Betulaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Corylus avellana	Hazel	Corylaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Corylus avellana	Hazel	Corylaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Corylus avellana	Hazel	Corylaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ls	Hansen *et al*., 2005
Corylus sp.	Hazel	Corylaceae	Leaf inoculation	Details not supplied	Leaf	Details not supplied	R	Inman *et al*., 2002

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility**[22]	**Reference**
Cotoneaster multiflorus	Cotoneaster	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	Not given	Parke *et al*., 2002a
Crataegus monogyna	Hawthorn	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Crataegus monogyna	Hawthorn	Rosaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Crataegus monogyna	Hawthorn	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Cupressus sempervirens	Italian cypress	Cupressaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	R	Moralejo *et al*., *Personal Communication*
Daphne gnidium	Spurge flax	Thymelaeaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Empetrum nigrum	Heather	Ericaceae	Unwounded and wounded; zoospore suspension dipping	Yes and No	Leaves and stems	No necrosis	R	Defra, PH0193S
Erica arborea	Tree heath	Ericaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Erica carnea 'Snowstorm'	Heather	Ericaceae	Unwounded and wounded; zoospore suspension dipping	Yes and No	Leaves and stems	Leaf necrosis	Ls	Defra, PH0193S
Erica carnea 'Rubin Feuer', ‚Schneekuppe''	Heather	Ericaceae	Dipped in zoospore suspension	Yes and No	Twigs with leaves	Twig and leaf necrosis	Ms (Rubin Feuer) Hs (Schneekuppe)	Wagner *et al*., 2005 Kaminski, Wagner, 2008
Erica cinerea 'Glen Cairn'	Heather	Ericaceae	Unwounded and wounded; zoospore suspension dipping	Yes and No	Leaves and stems	Stem and flower necrosis	Ms	Defra, PH0193S
Erica cinerea 'Roter Kobold', ‚Alba Major'	Heather	Ericaceae	Dipped in zoospore suspension	Yes and No	Twigs with leaves	Twig and leaf necrosis	Ms	Wagner *et al*., 2005 Kaminski, Wagner, 2008
Erica x darleyensis 'Cramers Rote', White Perfection'	Heather	Ericaceae	Dipped in zoospore suspension	Yes and No	Twigs with leaves	Twig and leaf necrosis	Ls	Wagner *et al*., 2005 Kaminski, Wagner, 2008
Erica gracilis 'Glasers Rote', 'Weißes Schloss'	Heather	Ericaceae	Dipped in zoospore suspension	No	Shoots with leaves	Shoot necrosis	Hs	Wagner *et al*., 2005 Kaminski, Wagner, 2008
Erica multiflora	Heather	Ericaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Erica tetralix	Heather	Ericaceae	Unwounded and wounded; zoospore dipping	Yes and No	Leaves and stems	No necrosis	R	Defra, PH0193S
Erica vagans 'Valerie Proudley'	Heather	Ericaceae	Unwounded and wounded; zoospore dipping	Yes and No	Leaves and stems	Leaf necrosis	Ls	Defra, PH0193S
Eucalyptus dalrympleana	White mountain gum	Myrtaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ms	Moralejo *et al*., *Personal Communication*
Eucalyptus gunii	Cider gum tree	Myrtaceae	Detached leaves dipped in zoospore suspensions	Non-wound	Leaf	High proportion with necrosis, high level of back isolation	Ms	Denman *et al*., 2005

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[23]	Reference
Eucalyptus sp.	Eucalyptus, Gum tree	Myrtaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Eucalyptus sp.	Eucalyptus, Gum tree	Myrtaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Euonymus japonicus	Japanese euonymus	Celastraceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Fagus sylvatica	Beech	Fagaceae	Mycelial plug on wounded stem	Yes	Stem	Severe twig dieback	Ms	de Gruyter *et al*., 2002
Fagus sylvatica	Beech	Fagaceae	Details not supplied	Details not supplied	Stems	Stem lesions	Ms	Orlikowski & Szkuta, 2003
Fagus sylvatica	Beech	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with necrosis, low level of back isolation	R	Denman *et al*., 2005
Fagus sylvatica	Beech	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Fagus sylvatica	Beech	Fagaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Fagus sylvatica	Beech	Fagaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Forsythia sp.	Golden bells	Oleaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Fraxinus angustifolia	Narrow leaved ash	Oleaceae	Log inoculation	Yes	Inner bark	Details not supplied	R	Moralejo *et al*. *Personal Communication*
Fraxinus angustifolia	Narrow leaved ash	Oleaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*. *Personal Communication*
Fraxinus excelsior	Ash	Oleaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Fraxinus excelsior	Common ash, European ash	Oleaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Fraxinus excelsior	Common ash, European ash	Oleaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with necrosis, high level of back isolation	Hs	Denman *et al*., 2005
Fraxinus excelsior	Common ash, European ash	Oleaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Fraxinus excelsior	Common ash, European ash	Oleaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion well developed	Ms	Defra, PH0193S
Fraxinus excelsior	Common ash, European ash	Oleaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion well developed	Ms	Defra, PH0193S
Fraxinus latifolia	Oregon ash	Oleaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Fraxinus latifolia	Oregon ash	Oleaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ms - Ls	Hansen *et al*., 2005
Fraxinus latifolia	Oregon ash	Oleaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Fraxinus ornus	Flowering ash	Oleaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[24]	Reference
Fuchsia sp.	Fuschia	Onagraceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Gaultheria shallon	Salal	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	R	Linderman *et al*., 2002
Gaultheria sp.	Wintergreen	Ericaceae	Details not supplied	Details not supplied		Details not supplied	Ls	Inman *et al*., 2002
Gaultheria x *wisleyensis*	Wisley Pearl	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Gleditsia triacanthos	Honeylocust	Fabaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Hamamelis vernali	Vernal witch hazel	Styracaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Hamamelis virginiana	Virginian witch hazel	Hamamelidaceae	Mycelial plugs placed on detached wounded leaves	Yes	Leaf	Leaf and twig necrosis	Hs	Giltrap *et al*., 2004
Hebe imbricata	Hebe	Plantaginaceae	Mycelial discs on wounded petioles, stem bases or shoots	Yes	Petioles, stem bases, shoots	Details not supplied	Not given	Orlikowski & Szkuta, 2002
Heberdenia excelsa	Aderno, Sacatero	Lauraceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Hedera helix	Ivy	Araliaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Hedera helix	Ivy	Araliaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Hedera helix	Ivy	Araliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Hedera helix	Ivy	Araliaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	R	Linderman *et al*., 2002
Heteromeles arbutifolia	Toyon	Rosaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ls	Garbelotto *et al*., 2003
Humulus lupulus	Golden hop	Cannabidaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Hypericum 'Hidcote'	St. John's Wort	Hypericaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	Not given	Parke *et al*., 2002a
Ilex aquifolium	Holly	Aquifoliacea	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ms	Moralejo *et al*., *Personal Communication*
Hedera helix	Ivy	Araliaceae	Dipped in zoospore suspension	Yes and No	Leaves	No symptoms	R	Kaminski & Wagner, 2008
Ilex aquifolium	Holly	Aquifoliacea	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Ilex aquifolium	Holly	Aquifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Ilex aquifolium	Holly	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	R - Ls	Denman *et al*., 2005
Ilex aquifolium	Holly	Aquifoliaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Ilex aquifolium	Holly	Aquifoliaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	R	Linderman *et al*., 2002

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility**[25]	**Reference**
Ilex canariensis	Small leaved holly	Aquifoliaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Ilex perado	Madeiran holly	Aquifoliaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Ilex sp.	Holly	Aquifoliaceae	Leaf inoculation	Details not supplied	Leaf	Details not supplied	R	Inman *et al*., 2002
Kalmia angustifolia	Sheep laurel	Ericaceae	Mycelial discs on wounded petioles, stem bases or shoots	Yes	Petioles, stem bases, shoots	Leaf necrosis, stem blight	Not given	Orlikowski & Szkuta, 2002
Kalmia latifolia	Mountain laurel	Ericaceae	Details not supplied	Details not supplied	Details not supplied	Details not supplied	Not given	Orlikowski & Szkuta, 2002
Kalmia latifolia 'Madeline'	Mountain laurel	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Not given	Tooley & Englander, 2002
Laburnum anagyroides	Golden chain tree	Leguminosae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Laburnum anagyroides	Golden chain tree	Leguminosae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Hs	Vannini, *Personal Communication*
Lantana camara	Shrub verbena	Verbenaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ms - Hs	Moralejo *et al*., *Personal Communication*
Larix occidentalis	Western larch	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls - R	Hansen *et al*., 2005
Larix occidentalis	Western larch	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Hs	Hansen *et al*., 2005
Larix occidentalis	Western larch	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Laurus nobilis	Bay laurel	Lauraceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Laurus nobilis	Bay laurel	Lauraceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Laurus nobilis	Bay laurel	Lauraceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Lavatera sp.	Tree mallow	Malvaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Ledum palustre	Marsh tea, wild rosemary	Ericaceae	Details not supplied	Details not supplied	Leaves and stems	Leaf necrosis	Ls	Orlikowski & Szkuta, 2003
Ledum palustre	Marsh tea, wild rosemary	Ericaceae	Details not supplied	Details not supplied	Leaves and stems	Stem lesions	Ls	Orlikowski & Szkuta, 2003
Leucothoe fontanesiana	Girard's Rainbow dog hobble	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Leucothoe walteri	Drooping laurel	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf necrosis	Ls	Orlikowski & Szkuta, 2003
Leucothoe walteri	Drooping laurel	Ericaceae	Details not supplied	Details not supplied	Stems	Stem lesions	Ls	Orlikowski & Szkuta, 2003
Ligustrum sp.	Privet	Oleaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[26]**	**Reference**
Ligustrum vulgare	Common privet	Oleaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Linnaea borealis	Twinflower	Caprifoliaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Ls	Zanzot *et al*., 2002
Liriodendron tulipifera	Tulip tree	Magnoliaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Lithocarpus densiflorus	Tanoak	Fagaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Hs	Garbelotto *et al*., 2003
Lithocarpus densiflorus	Tanoak	Fagaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Lithocarpus densiflorus	Tanoak	Fagaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Girdled	Hs	Hansen *et al*., 2005
Lithocarpus densiflorus	Tanoak	Fagaceae	Whole plant dip in zoospore suspension	No	Whole plant	Dieback	Hs	Hansen *et al*., 2005
Lithocarpus densiflorus	Tanoak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Large cankers	Hs	Hansen *et al*., 2005
Lithocarpus densiflorus	Tanoak	Fagaceae	Mycelial plugs	Yes	Tree trunk (mature tree)	Stem lesions bleeding	Hs	Rizzo *et al*., 2002
Lithocarpus densiflorus	Tanoak	Fagaceae	Mycelial plugs	Yes	Stems (seedlings)	Stem lesions some discolouration in xylem, wilting, stem girdling, lesion extension into petioles, seedling death	Hs	Rizzo *et al*., 2002
Lonicera implexa	Honeysuckle	Caprifoliaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Lonicera implexa	Honeysuckle	Caprifoliaceae	Detached leaf dip in zoospore suspension	No	Leaf	Necrotic lesions followed by extensive blight	Hs	Moralejo & Hernandez, 2002
Lonicera periclymenum	Common honeysuckle	Caprifoliaceae	Young plants inoculated through stem or leaf	Not specified	Stem/Leaf	No symptoms	Not given	de Gruyter *et al*., 2002
Lonicera periclymenum	Common honeysuckle	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Lonicera periclymenum	Common honeysuckle	Caprifoliaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion extension slight	Ls	Defra, PH0193S
Lonicera periclymenum	Common honeysuckle	Caprifoliaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Malus sp.	Apple	Rosaceae	Details not supplied	Details not supplied		Details not supplied	Ls	Inman *et al*., 2002
Malus sylvestris	Crab apple	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Morus sp.	Mulberry	Moraceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Myoporum pictum	Popwood, Sandalwood	Myoporaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Myrica faya	Fire tree	Myricaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Myrtus communis	Myrtle	Myrtaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	R - Ls	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[27]	Reference
Myrtus communis	Myrtle	Myrtaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	R	Moralejo *et al*., *Personal Communication*
Nerium oleander	Oleander	Apocynaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Nerium oleander	Oleander	Apocynaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Nerium oleander	Oleander	Apocynaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Details not supplied	R	Moralejo *et al*., *Personal Communication*
Nothofagus dombeyi	False beech	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Nothofagus obliqua	Roble beech	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Nothofagus procera	Rauli	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Ocothea foetens	Greenheart	Lauraceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Olea europaea	Olive	Oleaceae	Detached leaf dip in zoospore suspension	No	Leaf	Necrotic lesions followed by extensive blight	Hs	Moralejo & Hernandez, 2002
Olea europaea	Olive	Oleaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	R	Moralejo *et al*., *Personal Communication*
Olea europaea	Olive	Oleaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	R	Moralejo *et al*., *Personal Communication*
Oxydendrum arboreum	Sourwood	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Pachysandra terminalis	Japanese pachysandra	Buxaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Not given	Linderman *et al*., 2002
Persea indica	Lauraceous tree	Lauraceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Philadelphus coronarius	Mock orange	Saxifragaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	Not given	Parke *et al*., 2002a
Photinia fraseri 'Red Robin'	Photinia	Rosaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls - Ms	Vannini, *Personal Communication*
Photinia fraseri 'Red Robin'	Photinia	Rosaceae	Mycelial plugs	Details not supplied	Leaf base	Necrosis	Ms - Ls	Orlikowski & Szkuta, 2004
Photinia serrulata	Chinese photinia	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	Not given	Parke *et al*., 2002a
Photinia sp.	Christmas berry	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Phyllirea latifolia	European holly	Oleaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Phyllirea latifolia	European holly	Oleaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	R	Moralejo *et al*., *Personal Communication*
Picconia excelsa	Southern olive	Oleaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[28]	Reference
Picea abies	Norway spruce	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Picea abies	Norway spruce	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	Ls	Denman *et al*., 2005
Picea abies	Norway spruce	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Picea sitchensis	Sitka spruce	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Picea sitchensis	Sitka spruce	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Picea sitchensis	Sitka spruce	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	Ls	Denman *et al*., 2005
Picea sitchensis	Sitka spruce	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls - Hs	Hansen *et al*., 2005
Picea sitchensis	Sitka spruce	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Picea sitchensis	Sitka spruce	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Picea sitchensis	Sitka spruce	Pinaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ms	Hansen *et al*., 2005
Pieris 'Brouwer's Beauty'	Mountain and Japanese pieris	Ericaceae	*In planta* foliage inoculations leaves still attached to potted plants either dipped into zoospore suspensions or inoculum sprayed onto leaves	No	Leaf, shoots and terminal buds	Leaf and stem necrosis, defoliation	Ms	Parke *et al*., 2004
Pieris floribunda	Fetterbush	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Not given	Tooley & Englander, 2002
Pieris formosa var. *forrestii*	Chinese pieris, Himalaya pieris	Ericaceae	Mycelial plugs inoculated onto wounded detached leaves	Yes	Leaf	Leaf lesions	Ms	Inman *et al*., 2003
Pieris japonica	Japanese pieris, Lily-of-the-valley bush	Ericaceae	Mycelial discs on wounded petioles, stem bases or shoots	Yes	Petioles (leaf), stem bases, shoots	Leaf necrosis, stem blight	Not given	Orlikowski & Szkuta, 2002
Pieris japonica	Japanese pieris, Lily-of-the-valley bush	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Pieris japonica 'Flaming Silver'	Japanese pieris, Lily-of-the-valley bush	Ericaceae	*In planta* foliage inoculations leaves still attached to potted plants either dipped into zoospore suspensions or inoculum sprayed onto leaves	No	Leaf, shoots and terminal buds	Leaf and stem necrosis, defoliation	Ms	Parke *et al*., 2004
Pieris japonica 'Prelude'	Pieris	Ericaceae	Mycelial plugs	Details not supplied	Leaf base	Necrosis	Ms	Orlikowski & Szkuta, 2004

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[29]	Reference
Pieris japonica 'Variegata'	Variegated Japanese pieris	Ericaceae	*In planta* foliage inoculations leaves still attached to potted plants either dipped into zoospore suspensions or inoculum sprayed onto leaves	No	Leaf, shoots and terminal buds	Leaf and stem necrosis, defoliation	Ms	Parke *et al*., 2004
Pieris japonica x *formosa* 'Forest Flame'	Chinese pieris, Himalaya pieris	Ericaceae	*In planta* foliage inoculations leaves still attached to potted plants either dipped into zoospore suspensions or inoculum sprayed onto leaves	No	Leaf, shoots and terminal buds	Leaf and stem necrosis, defoliation	Ms	Parke *et al*., 2004
Pieris sp.	Pieris	Ericaceae	Details not supplied	Details not supplied		Details not supplied	Hs	Inman *et al*., 2002
Pinus contorta	Lodgepole pine	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	R	Denman *et al*., 2005
Pinus contorta	Lodgepole pine	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Pinus contorta	Lodgepole pine	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Pinus contorta	Lodgepole pine	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	R	Hansen *et al*., 2005
Pinus contorta	Lodgepole pine	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Pinus contorta	Lodgepole pine	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Pinus contorta	Lodgepole pine	Pinaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls	Hansen *et al*., 2005
Pinus halepensis	Aleppo pine	Pinaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Pinus halepensis	Aleppo pine	Pinaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Pinus halepensis	Aleppo pine	Pinaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Hs	Moralejo *et al*., *Personal Communication*
Pinus lambertiana	Sugar pine	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Pinus lambertiana	Sugar pine	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls - R	Hansen *et al*., 2005
Pinus lambertiana	Sugar pine	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Pinus nigra	Black pine	Pinaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Pinus nigra var. *maritima*	Corsican pine	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Pinus nigra var. *maritima*	Corsican pine	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	R	Denman *et al*., 2005
Pinus nigra var. *maritima*	Corsican pine	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Pinus pinaster	Maritime pine	Pinaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ls	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[30]	Reference
Pinus pinea	Stone pine	Pinaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Hs	Moralejo *et al*., *Personal Communication*
Pinus ponderosa	Ponderosa pine	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	R	Hansen *et al*., 2005
Pinus ponderosa	Ponderosa pine	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Pinus ponderosa	Ponderosa pine	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Pinus strobus	Western white pine	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Pinus strobus	Western white pine	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Pinus strobus	Western white pine	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Hs	Hansen *et al*., 2005
Pinus sylvestris	Scots pine	Pinaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Pinus sylvestris	Scots pine	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Pinus sylvestris	Scots pine	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	R	Denman *et al*., 2005
Pinus sylvestris	Scots pine	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Pistacia atlantica	Mastic tree	Anacardiaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Pistacia lentiscus	Evergreen pistache mastic tree	Anacardiaceae	Detached leaf dip in zoospore suspension	No	Leaf	Necrotic lesions followed by extensive blight.	Hs	Moralejo & Hernandez, 2002
Pistacia lentiscus	Evergreen pistache mastic tree	Anacardiaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Pistacia lentiscus	Evergreen pistache mastic tree	Anacardiaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ms	Moralejo *et al*., *Personal Communication*
Pistacia terebinthus	Turpentine tree	Anacardiaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Pittosporum tobira	Mock orange	Pittosporaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Populus sp.	Hybrid poplar	Salicaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Populus tremula	Aspen	Salicaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Populus tremula	Aspen	Salicaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Medium proportion with leaf necrosis, low level of back isolation	R	Denman *et al*., 2005
Populus tremuloides	Quaking aspen	Salicaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Populus tremuloides	Quaking aspen	Salicaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Populus tremuloides	Quaking aspen	Salicaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[31]	Reference
Populus trichocarpa	Black cottonwood	Salicaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Populus trichocarpa	Black cottonwood	Salicaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Populus trichocarpa	Black cottonwood	Salicaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Prunus avium	Sweet cherry, wild cherry	Rosaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	R - Ls	Denman *et al*., 2005
Prunus avium	Sweet cherry, wild cherry	Rosaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Prunus emarginata	Bitter cherry	Rosaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ls	Hansen *et al*., 2005
Prunus emarginata	Bitter cherry	Rosaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Hs	Hansen *et al*., 2005
Prunus emarginata	Bitter cherry	Rosaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Prunus emarginata	Bitter cherry	Rosaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls	Hansen *et al*., 2005
Prunus laurocerasus	Cherry laurel	Rosaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Prunus laurocerasus	Cherry laurel	Rosaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Prunus laurocerasus	Cherry laurel	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Prunus lusitanica	Portuguese laurel	Rosaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Prunus lusitanica	Portuguese laurel	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Prunus persica	Nectarine	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Prunus sp.	Ornamental cherry, stonefruits	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Pseudotsuga menziesii	Douglas fir	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Pseudotsuga menziesii	Douglas fir	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	Hs	Denman *et al*., 2005
Pseudotsuga menziesii	Douglas Fir	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Pseudotsuga menziesii	Douglas fir	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Pseudotsuga menziesii	Douglas fir	Pinaceae	Mycelial plugs places in stem wounds	Yes	Stems	Dieback	Hs	Davidson *et al*., 2002
Pseudotsuga menziesii	Douglas fir	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ms	Hansen *et al*., 2005
Pseudotsuga menziesii	Douglas fir	Pinaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ms	Hansen *et al*., 2005
Pseudotsuga menziesii	Douglas fir	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Girdled	Ms	Hansen *et al*., 2005
Pseudotsuga menziesii	Douglas fir	Pinaceae	Mycelial plugs pinned onto misted leaves	Yes	Leaves/needles	Needle necrosis and shoot/sprout dieback	Hs	Davidson *et al*., 2002
Quercus agrifolia	Coast live oak	Fagaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ls	Garbelotto *et al*., 2003

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[32]**	**Reference**
Quercus agrifolia	Coast live oak	Fagaceae	Mycelial plugs	Yes	Tree trunk (mature trees)	Stem lesions bleeding	Hs	Rizzo *et al*., 2002
Quercus agrifolia	Coast live oak	Fagaceae	Mycelial plugs	Yes	Stems (saplings)	Stem lesions	Hs	Rizzo *et al*., 2002
Quercus agrifolia	Coast live oak	Fagaceae	Mycelial plugs	Yes	Stems (seedlings)	Stem lesions some discolouration in xylem	Hs	Rizzo *et al*., 2002
Quercus canariensis	African oak	Fagaceae	Log inoculation	Yes	Inner bark	Bark necrosis	Hs	Moralejo *et al*., *Personal Communication*
Quercus canariensis	African oak	Fagaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls	Moralejo *et al*. *Personal Communication*
Quercus cerris	Turkey oak	Fagaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Quercus cerris	Turkey oak	Fagaceae	Details not supplied	Details not supplied	Inner bark	Details not supplied	Ms to two European isolates. Ls to North American isolates	Brasier *et al*., 2002
Quercus cerris	Turkey oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms to an European isolate	Brasier *et al*., *Personal Communication*
Quercus cerris	Turkey oak	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Ms	Denman *et al*., 2005
Quercus chrysolepis	Canyon live oak	Fagaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Quercus chrysolepis	Canyon live oak	Fagaceae	Whole plant dip in zoospore suspension	No	Whole plant	Dieback	Ms	Hansen *et al*., 2005
Quercus chrysolepis	Canyon live oak	Fagaceae	Not specified (probably mycelial plugs)	Yes	Stems	Stem lesions	Ms	Murphy & Rizzo, 2003
Quercus chrysolepis	Canyon live oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ms	Hansen *et al*., 2005
Quercus chrysolepis	Canyon live oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Small lesions	Not given	Hansen *et al*., 2005
Quercus chrysolepis	Canyon live oak	Fagaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Quercus coccinea	Scarlet oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Quercus dentata	Japanese Emperor oak	Fagaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Quercus douglasii	Blue oak	Fagaceae	Agar plug	Yes	Stem	Bark lesions	R	Rizzo *et al*., 2001
Quercus faginea	Portuguese oak	Fagaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Quercus faginea	Portuguese oak	Fagaceae	Log inoculation	Yes	Inner bark	Bark necrosis	Ms (winter)	Moralejo *et al*., *Personal Communication*
Quercus faginea	Portuguese oak	Fagaceae	Log inoculation	Yes	Inner bark	Bark necrosis	Hs (summer)	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[33]	Reference
Quercus falcata	Southern red oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Hs	Brasier *et al*., *Personal Communication*
Quercus garryana	Oregon white oak, Garry oak	Fagaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Quercus garryana	Oregon white oak, Garry oak	Fagaceae	Whole plant dip in zoospore suspension	Details not supplied	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Quercus garryana	Oregon white oak, Garry oak	Fagaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Quercus garryana	Oregon white oak, Garry oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ms	Hansen *et al*., 2005
Quercus garryana	Oregon white oak, Garry oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Small lesions	Not given	Hansen *et al*., 2005
Quercus humilis	Downy oak	Fagaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Quercus ilex	Holm oak, Holly oak	Fagaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Quercus ilex	Holm oak, Holly oak	Fagaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Quercus ilex	Holm oak, Holly oak	Fagaceae	Detached leaf dip in zoospore suspension	No	Leaf	Limited lesion development	Ls	Moralejo & Hernandez, 2002
Quercus ilex	Holm oak, Holly oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark necrosis	Ms	Moralejo *et al*., *Personal Communication*
Quercus ilex	Holm oak, Holly oak	Fagaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Quercus ilex	Holm oak, Holly oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Quercus ilex	Holm oak, Holly oak	Fagaceae	Details not supplied	Details not supplied	Details not supplied	Details not supplied	Ms	Brasier *et al*., 2002
Quercus ilex	Holm oak, Holly oak	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Hs	Denman *et al*., 2005
Quercus kelloggii	Californian black oak	Fagaceae	Whole plant dip in zoospore suspension	Details not supplied	Whole plant	Dieback	Ms	Hansen *et al*., 2005
Quercus kelloggii	Californian black oak	Fagaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ls	Garbelotto *et al*., 2003
Quercus kelloggii	Californian black oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls	Hansen *et al*., 2005
Quercus kelloggii	Californian black oak	Fagaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Quercus kelloggii	Californian black oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Small lesions	Not given	Hansen *et al*., 2005
Quercus kelloggii	Californian black oak	Fagaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility**[34]	**Reference**
Quercus lobata	Valley oak, California white oak	Fagaceae	Agar plug	Yes	Stem	None	R	Rizzo *et al*., 2001
Quercus macrolepis	Valonia oak	Fagaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Quercus macrolepis	Valonia oak	Fagaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Quercus palustris	Northern pin oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Quercus palustris	Northern pin oak	Fagaceae	Agar plug	Yes	Stem	Cambial and bark lesions	Hs	Rizzo *et al*., 2001
Quercus palustris	Northern pin oak	Fagaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls - R	Hansen *et al*., 2005
Quercus petraea	Sessile oak, Durmast oak	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Ms	Denman *et al*., 2005
Quercus petraea	Sessile oak, Durmast oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Quercus petraea	Sessile oak	Fagaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*
Quercus pubescens	Downy oak	Fagaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Quercus pubescens	Downy oak	Fagaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Hs	Moralejo *et al*., *Personal Communication*
Quercus pyrenaica	Pyrenean oak	Fagaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Quercus pyrenaica	Pyrenean oak	Fagaceae	Log inoculation	Yes	Inner bark	Inner bark necrosis	Hs	Moralejo *et al*., *Personal Communication*
Quercus pyrenaica	Pyrenean oak	Fagaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Spraying sporangia	Unspecified	Bark	All plants produced bark necrosis with occasional bleeding but necrosis on leaves was rare	Ms	Delatour *et al*., 2002
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Wounded bark inoculations	Yes	Bark	All plants produced bark necrosis with occasional bleeding but necrosis on leaves was rare	Ms	Delatour *et al*., 2002
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Mycelial plug on wounded stem	Yes	Stem	No symptoms	R	de Gruyter *et al*., 2002
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ls	Denman *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[35]	Reference
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	Ls	Denman *et al*., 2005
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Quercus robur	English oak, Pedunculate oak, Common oak	Fagaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Quercus rubra	Red oak	Fagaceae	Mycelial plug on wounded stem	Yes	Stem	Severe twig dieback	Ms	de Gruyter *et al*., 2002
Quercus rubra	Red oak	Fagaceae	Details not supplied	Details not supplied	Stems	Stem lesions	Ms	Orlikowski & Szkuta, 2003
Quercus rubra	Red oak	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	R	Denman *et al*., 2005
Quercus rubra	Red oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Quercus rubra	Red oak	Fagaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Quercus rubra	Red oak	Fagaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Quercus rubra	Red oak	Fagaceae	Agar plug	Yes	Stem	Cambial and bark lesions	Hs	Rizzo *et al*., 2001
Quercus suber	Cork oak	Fagaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Quercus suber	Cork oak	Fagaceae	Log inoculation	Yes	Inner bark	Bark necrosis and bleeding	Ls (winter)	Moralejo *et al*., *Personal Communication*
Quercus suber	Cork oak	Fagaceae	Log inoculation	Yes	Inner bark	Bark necrosis and bleeding	Hs (summer)	Moralejo *et al*., *Personal Communication*
Quercus suber	Cork oak	Fagaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Quercus suber	Cork oak	Fagaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, low level of back isolation	R	Denman *et al*., 2005
Quercus trojana	Macedonian oak	Fagaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Quercus trojana	Macedonian oak	Fagaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Rhamnus alaternus	Italian buckthorn evergreen	Rhamnaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Rhamnus alaternus	Italian buckthorn evergreen	Rhamnaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls - Ms	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[36]	Reference
Rhamnus alaternus	Italian buckthorn evergreen	Rhamnaceae	Detached leaf dip in zoospore suspension	No	Leaf	Conspicuous necrotic lesions followed by extensive blight	Hs	Moralejo & Hernandez, 2002
Rhamnus californica	Coffeeberry	Cascara	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ls	Garbelotto *et al*., 2003
Rhamnus purshiana	Cascara buckthorn	Rhamnaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	R	Hansen *et al*., 2005
Rhamnus purshiana	Cascara buckthorn	Rhamnaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Rhamnus purshiana	Cascara buckthorn	Rhamnaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Rhamnus purshiana	Cascara buckthorn	Rhamnaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Rhamnus purshiana	Cascara buckthorn	Rhamnaceae	Leaf dip in zoospore suspension	No	Leaf	Necrotic spots	Ms	Vettraino *et al*., 2006
Rhaphiolepis umbellata	Round-leaf hawthorn	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	No symptoms were observed	R	Parke *et al*., 2002a
Rhododendron	Rhododendron	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ms	Vannini, *Personal Communication*
Rhododendron	Rhododendron	Ericaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Rhododendron	Rhododendron	Ericaceae	Mycelial discs on wounded petioles, stem bases or shoots	Yes	Petioles (leaf), stem bases, shoots	Leaf necrosis, stem blight	Not given	Orlikowski & Szkuta, 2002
Rhododendron	Rhododendron	Ericaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Rhododendron	Girard's rose' azalea	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Leaf lesion	Not given	Tooley & Englander, 2002
Rhododendron	Azalea 'Northern Hilites'	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Hs	Tjosvold *et al*., 2002d
Rhododendron	Florist's azalea 'Inga'	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Not given	Tooley & Englander, 2002
Rhododendron	Rhododendron 'Cunningham's white'	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Leaf lesion	Not given	Tooley & Englander, 2002
Rhododendron	Rhododendron 'Cunningham's white'	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Hs	Tjosvold *et al*., 2002d
Rhododendron	Rhododendron 'Exbury' hybrids	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Rhododendron	Azaleas	Ericaceae	Detached leaf using a mycelial inoculum plug	Details not supplied	Leaf	Details not supplied	Ms	Tjosvold *et al*., 2002d
Rhododendron catawbiense	Rhododendron	Ericaceae	Not specified	Not specified	Stem cuttings	Lesions	Not given	De Merlier *et al*., 2003
Rhododendron catawbiense	Rhododendron	Ericaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesions very extensive	Hs	Defra, PH0193S
Rhododendron catawbiense	Rhododendron	Ericaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesions very extensive	Hs	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[37]	Reference
Rhododendron catawbiense	Rhododendron	Ericaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Hs	Denman *et al*., 2005
Rhododendron catawbiense	Rhododendron	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Rhododendron catawbiense 'Cunninghams White'	Rhododendron	Ericaceae	Mycelial plugs placed on abaxial surface of detached leaves	Yes	Leaves	Leaf necrosis	Not given	Žerjav *et al*., 2004
Rhododendron catawbiense 'Cunningham's White'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Grandiflorum'	Rhododendron	Ericaceae	Wounded shoot tip using colonised mycelial plugs	Yes	Shoot tip	Twig blight, shoot tip dieback, brown spots on leaves	Hs	Werres *et al*., 2001
Rhododendron catawbiense 'Grandiflorum'	Rhododendron	Ericaceae	Colonised agar plugs added to water	Yes	Base of stem cutting	Twig blight, shoot tip dieback, brown spots on leaves	Hs	Werres *et al*., 2001
Rhododendron catawbiense 'Grandiflorum'	Rhododendron	Ericaceae	Base of stem end exposed to mycelial discs floating on water	Yes	Base of stem	Stem necrosis	Not rated	Lane *et al*., 2003
Rhododendron catawbiense 'H. Charmant'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ls	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Haaga'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Helliki'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Lumina Jakushim'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ls	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Mikkeli'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Nova Zembla'	Rhododendron	Ericaceae	Mycelial plugs	Details not supplied	Leaf base	Necrosis	Ms - Hs	Orlikowski & Szkuta, 2004
Rhododendron catawbiense 'Nova Zembla'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Pohjola's Daughter'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Purple Splendour'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron catawbiense 'Tiger stedli'	Rhododendron	Ericaceae	Details not supplied	Details not supplied	Leaves	Leaf lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron 'Cosmopolitan'	Rhododendron	Ericaceae	Detached leaves, either prick wounded or not, dipped in zoospore suspensions, or inoculated with a mycelial plug	Not specified	Leaves, tip or petiole	Leaf lesion	Not given	Heungens *et al*., 2003
Rhododendron 'Germania'	Rhododendron	Ericaceae	*In planta* inoculations (attached) leaves sprayed with zoospore suspension	Not specified	Leaves, tip or petiole	Leaf lesion	Ms	Heungens *et al*., 2003

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[38]**	**Reference**
Rhododendron 'Gomer Waterer'	Rhododendron	Ericaceae	Detached leaves, either prick wounded or not, dipped in zoospore suspensions, or inoculated with a mycelial plug	Not specified	Leaves, tip or petiole	Leaf lesion	Ms	Heungens *et al*., 2003
Rhododendron japonica	Azalea	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Rhododendron japonica	Azalea	Ericaceae	Details not supplied	Details not supplied	Leaves and stems	Stem lesions	Ms	Orlikowski & Szkuta, 2003
Rhododendron 'Lachsgold'	Rhododendron	Ericaceae	Infested soil	Details not supplied	Details not supplied	Shoot necrosis plant death	Not given	Orlikowski & Szkuta, 2002
Rhododendron macrophyllum	Pacific rhododendron	Ericaceae	Whole plant dip in zoospore suspension	No	Whole plant	Dieback	Hs	Hansen *et al*., 2005
Rhododendron macrophyllum	Pacific rhododendron	Ericaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Rhododendron 'Marcel Menard'	Rhododendron	Ericaceae	Detached leaves, either prick wounded or not, dipped in zoospore suspensions, or inoculated with a mycelial plug	Not specified	Leaves, tip or petiole	Leaf lesion	Ms	Heungens *et al*., 2003
Rhododendron maximum	Rhododendron	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Leaf lesion	Not given	Tooley & Englander, 2002
Rhododendron 'Nova Zembla'	Rhododendron	Ericaceae	*In planta* foliage inoculations leaves still attached to potted plants either dipped into zoospore suspensions or inoculum sprayed onto leaves	No	Leaf, shoots and terminal buds	Foliage with necrosis, bud and stem death, necrotic lesions, leaf abscission	Hs	Parke *et al*., 2004
Rhododendron occidentale	Western azalea	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Tjosvold *et al*., 2002d
Rhododendron ponticum	Rhododendron	Ericaceae	Seedlings inoculated with either EU or NA isolates	Not specified	Stem/Leaf	Severe stem/leaf lesions	Hs	de Gruyter *et al*., 2002
Rhododendron ponticum	Wild species	Ericaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesions very extensive	Hs	Defra, PH0193S
Rhododendron ponticum	Rhododendron	Ericaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ms	Brasier *et al*., *Personal Communication*
Rhododendron ponticum	Wild species	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Rhododendron ponticum	Wild species	Ericaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesions very extensive	Hs	Defra, PH0193S
Rhododendron ponticum 'Variegatum'	Rhododendron	Ericaceae	Detached leaves, either prick wounded or not, dipped in zoospore suspensions, or inoculated with a mycelial plug	Not specified	Leaves, tip or petiole	Leaf lesion	Ms	Heungens *et al*., 2003
Rhododendron simsii	Sim's azalea	Ericaceae	Dipped in zoospore suspension	Yes and No	Leaves	Leaf necrosis	Ls	Wagner *et al*., 2005 Kaminski & Wagner, 2008
Rhododendron simsii	Sim's azalea	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Rhododendron sp.	Azalea (I)	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Rhododendron sp.	Azalea (II)	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[39]	Reference
Rhododendron yakushimanum 'Kalinka'	Rhododendron	Ericaceae	Detached leaves, either prick wounded or not, dipped in zoospore suspensions, or inoculated with a mycelial plug	Not specified	Leaves, tip or petiole	Leaf lesion	Ms	Heungens *et al*., 2003
Ribes sanguineum	Flowering currant, winter currant	Grossulariaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Robinia pseudacacia	Robinia	Leguminosae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ms	Vannini, *Personal Communication*
Robinia pseudacacia	Robinia	Leguminosae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Rosa californica	California rose	Rosaceae	Detached foliage dipped into a zoospore suspension	Yes	Leaf	Leaf and petiole necrosis	Not rated, just given as susceptible	Hüberli *et al*., 2003
Rosa canina	Dog rose	Rosaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Rosa canina	Dog rose	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Rosa canina	Dog rose	Rosaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion extension slight	Ls	Defra, PH0193S
Rosa gymnocarpa	Wood rose	Rosaceae	Detached foliage dipped into a zoospore suspension	Yes	Leaves	Leaf and petiole necrosis	Not rated, just given as susceptible	Hüberli *et al*., 2003
Rosa sempervirens	Evergreen rose	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Moralejo & Hernandez, 2002
Rosa sempervirens	Evergreen rose	Rosaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ms	Moralejo *et al*., *Personal Communication*
Rosa sp.	Rose	Rosaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Rubus fructicosus	Bramble	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Rubus fructicosus	Bramble	Rosaceae	Zoospore suspension dipping	No	Stem/Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Rubus spectabilis	Salmonberry	Rosaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ls	Hansen *et al*., 2005
Rubus ulmifolius	Blackberry	Rosaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	R	Moralejo *et al*., *Personal Communication*
Rubus ulmifolius	Blackberry	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	R	Moralejo & Hernandez, 2002
Salix alba	White willow	Salicaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Vannini, *Personal Communication*
Salix alba	White willow	Salicaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Salix canariensis	Cascade willow	Salicaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Salix caprea	Goat willow	Salicaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[40]**	**Reference**
Salix hookeriana	Hooker's willow	Salicaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Salix hookeriana	Hooker's willow	Salicaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls - R	Hansen *et al*., 2005
Salix hookeriana	Hooker's willow	Salicaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Salix lasiandra	Pacific willow	Salicaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	R	Hansen *et al*., 2005
Salix lasiandra	Pacific willow	Salicaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Salix lasiandra	Pacific willow	Salicaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Salix sp.	Willow	Salicaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Sambucus nigra	Common elder	Caprifoliaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesions very extensive	Hs	Defra, PH0193S
Sambucus nigra	Common elder	Caprifoliaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesions very extensive	Hs	Defra, PH0193S
Sambucus nigra	Common elder	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Sambucus palmensis	Elderberry	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Sambucus racemosa	Red-berried elder	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Sambucus sp.	Elderberry	Caprifoliaceae	Details not supplied	Details not supplied	Details not supplied	Details not supplied	Hs	Inman *et al*., 2002
Sequoia sempervirens	Coast redwood	Taxodiaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	Ms	Denman *et al*., 2005
Sequoia sempervirens	Coast redwood	Taxodiaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Sequoia sempervirens	Coast redwood	Taxodiaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms - Hs	Hansen *et al*., 2005
Sequoia sempervirens	Coast redwood	Taxodiaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ms	Hansen *et al*., 2005
Sequoia sempervirens	Coast redwood	Taxodiaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Sequoia sempervirens	Coast redwood	Taxodiaceae	Mycelial plugs pinned onto misted leaves	Yes	Leaf/needles	Needle necrosis and shoot/sprout dieback	Ms	Maloney & Rizzo, 2002
Sequoia sempervirens	Coast redwood	Taxodiaceae	Mycelial plugs placed in stem wounds	Yes	Stems	Dieback	Ms	Maloney & Rizzo, 2002
Sequoia sempervirens	Coast redwood	Taxodiaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls - R	Hansen *et al*., 2005
Sequoiadendron giganteum	Giant sequoia	Taxodiaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	R	Hansen *et al*., 2005
Skimmia japonica	Japanese skimmia	Rutaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Smilax aspera	Greenbrier	Liliaceae	Detached leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Moralejo & Hernandez, 2002
Smilax aspera	Greenbrier	Liliaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[41]**	**Reference**
Sorbus aucuparia	Mountain ash	Rosaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls	Vannini, *Personal Communication*
Sorbus aucuparia	Mountain ash	Rosaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Spiraea japonica	Japanese spirea	Rosaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Symphoricarpus albus	Snowberry	Caprifoliaceae	Leaf inoculation	Yes	Leaf	Details not supplied	Ms	Inman *et al*., 2002
Symphoricarpus albus	Snowberry	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Syringa vulgaris	Common lilac	Oleaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesions very extensive	Hs	Defra, PH0193S
Syringa vulgaris	Common lilac	Oleaceae	Mycelial plugs	No	Detached leaf	Leaf necrosis	Not rated, just given as susceptible	Beales *et al*., 2004b
Syringa vulgaris	Common lilac	Oleaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesions very extensive	Hs	Defra, PH0193S
Syringa vulgaris	Common lilac	Oleaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesions very extensive	Hs	Defra, PH0193S
Tamus communis	Black bryony	Dioscoraceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	R	Moralejo *et al*., *Personal Communication*
Taxus baccata	English yew	Taxodiaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Taxus baccata	English yew	Taxodiaceae	Mycelial plug inoculations	Yes	Needles on detached stem	Needle necrosis and stem die back	Not rated, just given as susceptible	Lane *et al*., 2004
Taxus baccata	English yew	Taxodiaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Ms	Denman *et al*., *Personal Communication*
Taxus baccata	English yew	Taxodiaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Needles showing necrosis	Ms - Ls	Denman *et al*., 2005
Taxus brevifolia	Pacific yew	Taxodiaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Taxus brevifolia	Pacific yew	Taxodiaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Ms	Hansen *et al*., 2005
Taxus brevifolia	Pacific yew	Taxodiaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et al*., 2005
Thuja plicata	Western red cedar	Cupressaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Thuja plicata	Western red cedar	Cupressaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Thuja plicata	Western red cedar	Cupressaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	R	Hansen *et al*., 2005
Thuja plicata	Western red cedar	Cupressaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls - R	Hansen *et al*., 2005
Tilia cordata	Small-leaved lime, Small-leaved linden	Tiliaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Tilia cordata	Small-leaved lime, Small-leaved linden	Tiliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	**Common name**	**Host family**	**Test method**	**Wounded?**	**Plant part tested**	**Symptom**	**Susceptibility[42]**	**Reference**
Tilia cordata	Small-leaved lime, Small-leaved linden	Tiliaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Low proportion with leaf necrosis, high level of back isolation	Ls	Denman *et al*., 2005
Toxicodendron diversilobum	Poison oak	Taxodiaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ms	Hansen *et a*l., 2005
Toxicodendron diversilobum	Poison oak	Taxodiaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Trientalis latifolia	Starflower	Primulaceae	Leaves dipped in zoospore suspensions (leaves still attached to plants)	No	Leaf	Leaf necrosis	Hs	Hüberli *et al*., 2003
Tsuga heterophylla	Western hemlock	Pinaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	Ls	Brasier *et al*., *Personal Communication*
Tsuga heterophylla	Western hemlock	Pinaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	Details not supplied	Ms - Ls	Denman *et al*., 2005
Tsuga heterophylla	Western hemlock	Pinaceae	Sapling stem inoculation	Yes	Stem	Stem lesion	Hs	Denman *et al*., *Personal Communication*
Tsuga heterophylla	Western hemlock	Pinaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Hs	Hansen *et al*., 2005
Tsuga heterophylla	Western hemlock	Pinaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ms	Hansen *et al*., 2005
Tsuga heterophylla	Western hemlock	Pinaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Tsuga heterophylla	Western hemlock	Pinaceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	Ls	Hansen *et al*., 2005
Ulmus campestre	English elm	Ulmaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ms	Vannini, *Personal Communication*
Ulmus glabra	Wych elm	Ulmaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion well developed	Ms	Defra, PH0193S
Ulmus glabra	Wych elm	Ulmaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Ulmus glabra	Wych elm	Ulmaceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion well developed	Ms	Defra, PH0193S
Ulmus minor	Small-leaved elm	Ulmaceae	Wounded stem tests using mycelial plugs	Yes	Stem	Bark necrosis	Ls - Ms	Vannini, *Personal Communication*
Ulmus minor	Small-leaved elm	Ulmaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Ulmus minor	Small-leaved elm	Ulmaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Ls	Moralejo *et al*., *Personal Communication*
Ulmus minor	Small-leaved elm	Ulmaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Ls	Moralejo *et al*., *Personal Communication*
Ulmus minor	Small-leaved elm	Ulmaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Ms - Hs	Moralejo *et al*., *Personal Communication*
Ulmus procera	English elm	Ulmaceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Hs - Ms	Denman *et al*., 2005
Ulmus procera	English elm	Ulmaceae	Log inoculations	Yes	Inner bark	Inner bark death and bleeding cankers	R	Brasier *et al*., *Personal Communication*
Ulmus sp.	Ornamental Scots elm	Ulmaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[43]	Reference
Umbellularia californica	Californian bay laurel, Oregon myrtle	Lauraceae	Detached leaves dipped in zoospore suspensions	No	Leaf	High proportion with leaf necrosis, high level of back isolation	Hs - Ms	Denman *et al*., 2005
Umbellularia californica	Californian bay laurel, Oregon myrtle	Lauraceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S
Umbellularia californica	Californian bay laurel, Oregon myrtle	Lauraceae	Zoospore suspension dipping	No	Stem/Leaf	Lesion extension slight	Ls	Defra, PH0193S
Umbellularia californica	Oregon myrtlewood	Lauraceae	Log inoculations	Details not supplied	Inner bark	Details not supplied	R	Hansen *et al*., 2005
Umbellularia californica	Oregon myrtlewood	Lauraceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Ls	Hansen *et al*., 2005
Umbellularia californica	Oregon myrtlewood	Lauraceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Details not supplied	Ls	Hansen *et al*., 2005
Umbellularia californica	Oregon myrtlewood	Lauraceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ls	Garbelotto *et al*., 2003
Umbellularia californica	Oregon myrtlewood	Lauraceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	R	Hansen *et al*., 2005
Vaccinium corymbosum	High-bush blueberry	Ericaceae	Leaf dip in zoospore suspension	Yes and No	Detached leaves	No symptoms	R	Kaminski & Wagner, 2008
Vaccinium membranaceum	Big huckleberry	Ericaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Vaccinium macrocarpon	Cranberry	Ericaceae	Leaf dip in zoospore suspension	Yes and No	Detached leaves	No symptoms	R	Kaminski & Wagner, 2008
Vaccinium myrtillus	European wild blueberry	Ericaceae	Young plants inoculated through stem or leaf tissue	Not specified	Stem/Leaf	Plant death	Hs	de Gruyter *et al*., 2002
Vaccinium myrtillus	European wild blueberry	Ericaceae	Leaf dip in zoospore suspension	Yes and No	Detached leaves	Leaf necrosis	Hs	Kaminski & Wagner, 2008
Vaccinium ovatum	Evergreen huckleberry	Ericaceae	Leaf inoculation by pinning a mycelial plug to the upper surface of leaves	Yes	Leaf	Leaf lesions	Ms	Garbelotto *et al*., 2003
Vaccinium ovatum	Evergreen huckleberry	Ericaceae	Whole plant dip in zoospore suspension	No	Whole plant	Details not supplied	Hs	Hansen *et al*., 2005
Vaccinium ovatum	Evergreen huckleberry	Ericaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Vaccinium parvifolium	Red huckleberry	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Details not supplied	Details not supplied	Not given	Zanzot *et al*., 2002
Vaccinium parvifolium	Red huckleberry	Ericaceae	Leaf dip in zoospore suspension	No	Leaf	Details not supplied	Hs	Hansen *et al*., 2005
Vaccinium sp.	Blueberry	Ericaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
3.45. *Vaccinium vitis-idaea*	Mountain cranberry	Ericaceae	Details not supplied	Details not supplied	Leaves and stems	Stem lesions	Ms	Orlikowski & Szkuta, 2003
Vaccinium vitis-idaea	Lingonberry	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis and dieback	Not given	Parke *et al*., 2002b
Viburnum davidii	Viburnum	Caprifoliaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion extension slight	Ls	Defra, PH0193S
Viburnum davidii	Viburnum	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion extension slight	Ls	Defra, PH0193S

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

Host name	Common name	Host family	Test method	Wounded?	Plant part tested	Symptom	Susceptibility[44]	Reference
Viburnum davidii	Viburnum	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Not given	Linderman *et al*., 2002
Viburnum lucidum	Northern arrow wood	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Viburnum opulus	Guelder rose	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion not extending much beyond wound	R	Defra, PH0193S
Viburnum plicatum var. *tomonentosum*	Viburnum	Ericaceae	Detached leaf dip in zoospore suspension	Details not supplied	Leaf	Details not supplied	Not given	Linderman *et al*., 2002
Viburnum plicatum var. *tormentosum* 'Mariesii'	Viburnum	Ericaceae	*In planta* foliage inoculations leaves still attached to potted plants either dipped into zoospore suspensions or inoculum sprayed onto leaves	No	Leaves, shoots, terminal buds	Leaf necrosis and defoliation	Ms	Parke *et al*., 2004
Viburnum tinus	Laurustinus	Caprifoliaceae	Spraying sporangia	No	Leaf	Foliar necrosis which could be limited or large	Not given	Delatour *et al*., 2002
Viburnum tinus	Viburnum	Caprifoliaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Ls	Vannini, *Personal Communication*
Viburnum tinus	Laurustinus	Caprifoliaceae	Mycelial plug on twig	Yes	Twig cutting	Bark necrosis	Hs	Moralejo *et al*., *Personal Communication*
Viburnum tinus	Laurustinus	Caprifoliaceae	Zoospore point inoculation	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Viburnum tinus	Viburnum	Caprifoliaceae	Stem susceptibility by wound inoculation with mycelial plugs	Yes	Stem	Lesion well developed	Ms	Defra, PH0193S
Viburnum tinus	Viburnum	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	Lesion well developed	Ms	Defra, PH0193S
Viburnum tinus	Viburnum	Caprifoliaceae	Detached leaf dip in zoospore suspension	No	Leaf	Foliar necrosis	Hs	Parke *et al*., 2002a
Viburnum tinus subsp. *rigidum*	Guelder Rose	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	Hs	Moralejo *et al*., *Personal Communication*
Viburnum x *bodnantense*	Viburnum	Ericaceae	Young plants inoculated through stem or leaf tissue	Not specified	Stem/leaf	Free of damage	R	de Gruyter *et al*., 2002
Visnea mocanera	Mocan	Lauraceae	Mycelial plug inoculum on leaf	Yes	Detached leaf	Leaf necrosis	R	Moralejo *et al*., *Personal Communication*
Vitis vinifera	Grapevine	Vitaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Weigela sp.	Weigela	Caprifoliaceae	Mycelial plug inoculum on leaf	Yes	Leaf	No necrosis or necrosis only in damaged tissue	Virtually immune	Defra, PH0193S
Zenobia pulverulenta	Dusty zenobia	Ericaceae	Detached leaf dip in zoospore suspension	No	Leaf	Leaf lesion	Not given	Tooley & Englander, 2002

R, resistance; Ls, low susceptibility; Ms, Moderate susceptibility; Hs, High susceptibility.
Note that susceptibilities are from many different experiments and care should be applied with regard to direct comparisons between different pieces of work.

APPENDIX IV: Countries for which *P. ramorum* is either on their regulated pests lists or mentioned in their legislation.

Countries for which *Phytophthora ramorum* is a regulated pest, and those whose RPPO includes *P. ramorum* on their regulated pest lists are shown in the Table below. The information in this Table is taken from the International Phytosanitary Portal (www.ippc.int), from CSL documents and from EPPO PQR. In theory, all contracting parties to the IPPC are required to provide copies of their regulated pests lists for inclusion on the website, however in practise this does not always happen. Consequently the table should not be considered a definitive list of countries for which *P. ramorum* is a regulated pest *P. ramorum*. However, it is as complete as possible given the information which is available. Websites (where available) for each RPPO have been scrutinised try and obtain copies of their pest lists; but this has been largely unsuccessful. Contact details for the RPPOs are available on the International Phytosanitary Portal.

References:

EPPO (2005) Plant Quarantine Data Retrieval System v4.3, EPPO, Paris.

IPPC 1 (2007) Phytosanitary restrictions, requirements and prohibitions (Art. VII.2b). Available on-line at www.ippc.int last accessed 09/02/07

IPPC 2 (2007) List of regulated pests (Art. VII.2i). Available on-line at www.ippc.int last accessed 09/02/07.

Country	Source	Country	Source
Albania	IPPC 2	Mali	IPPC 1 and 2
Antigua and Barbuda	IPPC 1 and 2	Malta	IPPC 2
Armenia	IPPC 1	Mauritania	IPPC 1 and 2
Australia	IPPC 1 and 2	Mauritius	IPPC 1 and 2
Austria	IPPC 1 and 2	Mexico	EPPO PQR
Barbados	IPPC 1	Micronesia, Federated States of	IPPC 1
Belarus	IPPC 1 and 2	NAPPO members	EPPO PQR
Belgium	IPPC 1 and 2	Netherlands	IPPC 1 and 2
Benin	IPPC 1	New Zealand	IPPC 1 and 2
Bulgaria	IPPC 1 and 2	Nigeria	IPPC 1
Burundi	IPPC 1 and 2	Norway	CSL
Cambodia	IPPC 1 and 2	Papua New Guinea	IPPC 2
Cameroon	IPPC 1	Paraguay	IPPC 1 and 2
Canada	EPPO PQR	Peru	IPPC 1 and 2
Chile	IPPC 1 and CSL	Philippines	IPPC 1
Cook Islands	IPPC 2	Poland	IPPC 1 and 2
Costa Rica	IPPC 2	Sabah, East Malaysia	IPPC 1
Croatia	IPPC 1 and 2	Saint Kitts and Nevis	IPPC 1 and 2
Czech Republic	IPPC 1 and 2	Saint Lucia	IPPC 2
Denmark	IPPC 1	Saint Vincent and the Grenadines	IPPC 1
EPPO members	EPPO PQR	Samoa	IPPC 1
Ethiopia	IPPC 1	Senegal	IPPC 1
EU members states	2000/29/EC	Serbia	IPPC 1 and 2
Finland	IPPC 1 and 2	Slovenia	IPPC 1 and 2
French Polynesia	IPPC 1 and 2	South Africa	IPPC1 and CSL
Germany	IPPC 1	Sweden	IPPC 1
Greece	IPPC 1 and 2	FYR Macedonia	IPPC 1 and 2
Grenada	IPPC 1 and 2	Turkey	IPPC 1 and 2
Guinea	IPPC 1	Ukraine	IPPC 1 and 2
India	IPPC 1	United Kingdom	IPPC 1 and 2
Indonesia	IPPC 1	USA	EPPO PQR
Korea, Republic of	IPPC 2	Vietnam	IPPC 1 and 2
Lebanon	IPPC 1	Yemen	IPPC 1 and 2
Madagascar	IPPC 1 and 2		
Malaysia	IPPC 1		

Those EU member states and EPPO countries which are referenced on the International Phytosanitary Portal have been given individual entries in the table. All other EU member states and EPPO countries are covered by the general entries for ‘EPPO members’ and ‘EU members states’.

Appendix IV prepared by S. Bishop, Central Science Laboratory,UK

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