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Pest Risk Analysis for *Phytophthora ramorum*

THIS DOCUMENT PRE-DATES THE FIRST TREE FINDINGS IN THE UK AND THE NETHERLANDS. A FULL REVISION OF THIS PRA IS IN PROGRESS.

1. Name of Pest:

Phytophthora ramorum (Werres *et al*., 2001), the cause of sudden death of oaks in the USA through stem cankering and of shoot and foliage diseases of other woody plants in North America and Europe. It has been suggested that the different types of disease caused by *P. ramorum* be distinguished by referring to them as sudden oak death, ramorum shoot dieback and ramorum leaf blight respectively (Hansen *et al*., 2002).

2. Does it occur in the UK/EU/EPPO or arrive regularly as a natural migrant?

Phytophthora ramorum was first identified in the UK in 2002 (Lane *et al*., 2003). In official surveys and from other samples it has been found to be of widespread occurrence, but at low incidence, on a range of hosts propagated in the UK (including the Channel Islands) as well as on hosts introduced from Europe (C. Lane and P. Beales, CSL, UK, 2003; personal communications). It was found in the Republic of Ireland in 2003 (P. Walsh, Republic of Ireland, 2003, personal communication).

In addition to the UK and the Republic of Ireland, within the EU, the pathogen has been detected in Belgium (De Merlier *et al*., 2003), Denmark (L. Hendrikson, Denmark, 2003, personal communication), France (Delatour *et al*., 2002), Germany (Werres, 2001), the Netherlands (van Opstal, the Netherlands, 2001, personal communication), Spain (Moralejo and Werres, 2002; E. Moralejo, Spain, 2002, personal communication) and Sweden (M. Gråberg, Sweden, 2003, personal communication).

In addition to the above countries, within the EPPO region, the pathogen has also been isolated in Poland from imported hosts (Anon., 2002; Orlikowski and Szkuta, 2002; L. Orlikowski, Poland, 2002, personal communication) and in Slovenia (M. Zerjav, Slovenia, 2003, personal communication).

Separate European and American subpopulations/clades have been identified. Until recently, only the A1 mating type of *P. ramorum* had been identified in the European subpopulation (Werres *et al*., 2001; Brasier, 2003). However, a single A2 mating type has now been isolated from *Viburnum bodnantense* in a Belgian nursery (Werres and De Merlier, 2003). This is also of the European subpopulation.

All isolates of the North American subpopulation examined to date have been of the A2 mating type (Werres and Zielke, 2003; Brasier, 2003). However, A1 mating types of the European subpopulation have also been found recently in a different region of North America (Hansen *et al*., 2003).

How *P. ramorum* originally entered Europe or the USA is currently unknown, but the mating type and population/clade distribution suggests that separate

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introductions into the EU/EPPO region and to North America may have occurred, from an unknown third location.

3. EC Directive status?

Under the EC Plant Health Directive (Anon., 2000), emergency legislation that came into force on 1 November 2002 (2002/757/EC) controls the introduction of susceptible hosts into the European Community and also the movement of *Rhododendron* and *Viburnum* (main hosts of *P. ramorum* in Europe) within the Community. This legislation is to be reviewed by 31 December 2003.

4. EPPO status?

The pathogen is on the EPPO Alert List pending the outcome of the review of the EC emergency legislation

5. What are its host plants?

Natural hosts in North America:

In addition to the USA whose host list is shown below in Table 1, one rhododendron plant has been found affected by *P. ramorum* in a nursery in British Columbia, Canada. This is the only recorded outbreak in Canada. (The plant has been destroyed (Anon., 2003b)).

Table 1. Natural hosts of *Phytophthora ramorum* in the USA giving details of symptoms and location (Anon., 2003a; Rizzo, 2003; Davidson *et al*., 2003; D. Rizzo, USA, 2003, personal communication)

Scientific Name (Family)	Common Name	Symptoms and other information	Location
Abies grandis (Pinaceae)	Grand fir	Branch-tip dieback; long-term impact on individual plants unknown	CA
Acer macrophyllum (Aceraceae)	Big leaf maple	Foliar lesions; long-term impact on individual plants unknown	CA
Aesculus californica (Hippocastanaceae)	California buckeye	Foliar lesions; long-term impact on individual plants unknown	CA
Arbutus menziesii (Ericaceae)	Madrone	Branch cankers; foliar lesions; death of regeneration and possibly large trees	CA
Arctostaphylos manzanita (Ericaceae)	Manzanita	Stem and branch cankers; foliar lesions; dieback of branches; long-term impact on individual plants not known	CA
Camellia japonica[1] (Theaceae)	Common camellia	Foliar lesions; found in nurseries	CA, WA
Camellia sasanqua[1] (Theaceae)	Sasanqua	Foliar lesions; found in nurseries	CA
Corylus cornuta (Betulaceae)	California hazelnut	Foliar lesions; long-term impact on individual plants unknown; see also Murphy and Rizzo (2002)	CA
Heteromeles arbutifolia (Rosaceae)	Toyon	Branch cankers; branch dieback; foliar lesions; long-term impact on individual plants not known; see also Murphy and Rizzo (2002)	CA
Lithocarpus densiflorus[2] (Fagaceae)	Tanoak	Stem and branch cankers; foliar lesions; death of large trees, saplings and regeneration; see also Murphy and Rizzo (2002) and Goheen *et al*. (2002c)	CA, OR
Lonicera hispidula (Caprifoliaceae)	California honeysuckle	Foliar lesions; long-term impact on individual plants unknown	CA

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Pieris japonica[1] (Ericaceae)	Andromeda	No details of symptoms; found outdoors under diseased bay laurel and in a nursery	CA, OR
Pieris japonica x *P. formosa*[1] (Ericaceae)	Ornamental pieris	No details of symptoms; found in a nursery	OR
Pittosporum undulatum[1] (Pittosporaceae)	Victorian box	No details of symptoms; detected by PCR; unconfirmed	CA
Pseudotsuga menziesii var. *menziesii* (Pinaceae)	Douglas fir	Branch cankers; foliar lesions; death of new shoots and small branches; long-term impact on saplings and trees unknown; see also Davidson *et al*. (2002)	CA
Quercus agrifolia (Fagaceae)	Coast live oak	Stem cankers; death of large trees; see also Murphy and Rizzo (2002)	CA
Quercus chrysolepis (Fagaceae)	Canyon live oak	Stem and branch cankers; possible death of large trees; see also Murphy and Rizzo (2002)	CA
Quercus kelloggii (Fagaceae)	California black oak	Stem cankers, death of large trees	CA
Quercus parvula var. *shrevei* (Fagaceae)	Shreve oak	Stem cankers, death of large trees; see also Murphy and Rizzo (2002)	CA
Rhamnus californica (Rhamnaceae)	California coffeeberry	Foliar lesions; long-term impact on individual plants unknown	CA
Rhamnus purshiana (Rhamnaceae)	Cascara	Foliar lesions; long-term impact on individual plants unknown; see also Goheen *et al*. (2002c)	OR
Rhododendron macrophyllum[2] (Ericaceae)	West coast rhododendron	Stem and branch cankers; foliar lesions; dieback and death of plants; see also Goheen *et al*. (2002c)	CA
Rhododendron species/ hybrids[1] (Ericaceae)	Ornamental rhododendron	Stem and branch cankers; foliar lesions; dieback and death of plants; found diseased in nurseries	CA, OR, WA
Rubus spectabilis (Rosaceae)	Salmonberry	Foliar lesions; long-term impact on individual plants unknown; see also Goheen *et al*. (2002c)	OR
Sequoia sempervirens (Taxodiaceae)	Coast redwood	Branch cankers; foliar lesions; death of sprouts; long-term impact on saplings and trees unknown; see also Maloney *et al*. (2002)	CA
Toxicodendron diversilobum (syn. *Rhus diversiloba*) (Anacardiaceae)	Poison oak	Limited stem cankers; long-term impact on individual plants unknown; see also Goheen *et al*. (2002c)	CA, OR
Trientalis latifolia (Primulaceae)	Western star flower	Foliar lesions; long-term impact on herbaceous plant unknown	CA
Umbellularia californica[2] (Lauraceae)	California bay laurel	Foliar lesions; long-term impact on individual plants unknown; see also Murphy and Rizzo (2002)	CA, OR
Vaccinium ovatum (Ericaceae)	Huckleberry	Stem and branch cankers; foliar lesions; dieback of canes and possible death of plants; see also Murphy and Rizzo (2002) and Goheen *et al*. (2002c)	CA, OR
Viburnum species/hybrids[1] e.g.. *V.* x *bodnantense, V. fragrans, V. plicatum, V. tinus* (Caprifoliaceae)	Ornamental viburnum	Stem cankers; found in nurseries	CA, OR, WA

Key: [1]not native to USA; [2]major source of inoculum in Californian woodlands; CA California; OR Oregon, WA Washington

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Natural hosts in Europe

Natural hosts reported in the UK (including the Channel Islands) plus the Republic of Ireland are listed in Table 2. The pathogen has been found mainly on species/hybrids of *Rhododendron* and *Viburnum*. Findings on other hosts have been far less common.

Table 2. Hosts of *Phytophthora ramorum* in the UK/Republic of Ireland (A. Inman, C. Lane, P. Beales, CSL, UK, personal communications; P. Walsh, Republic of Ireland, 2003, personal communication).

Species /hybrid (Family)	Common name
Camellia japonica (Theaceae)	Common camellia
Camellia reticulata (Theaceae)	-
Camellia x *williamsii* = *Camellia saluenensis* x *C. japonica* (Theaceae)	-
Hamamelis virginiana	Virginian witch hazel
Kalmia latifolia (Ericaceae)	Mountain laurel
Leucothoe fontanesiana (Ericaceae)	Drooping leucothoe
Pieris formosa var. *forrestii* (Ericaceae)	Andromeda forresttii
Pieris formosa var. *forrestii x Pieris japonica* (Ericaceae)	Pieris 'Forest Flame'
Pieris japonica (Ericaceae)	Lily-of-the-valley bush
Rhododendron augustinii (Ericaceae)	-
Rhododendron balfourianum (Ericaceae)	-
Rhododendron brachycarpum (Ericaceae)	Fujiyama rhododendron
Rhododendron ferrugineum (Ericaceae)	Alpine rose rhododendron
Rhododendron ponticum (Ericaceae)	-
Rhododendron hybrids – over 80 found infected. They were breed from crosses involving *R. arboreum*, *R. campylocarpum*, *R. catawbiense*, *R. campylocapum*, *R. caucasicum*, *R. dichroanthum*, *R. facetum*, *R. forrestii*, *R. fortunei*, *R. galactinum R. geraldii*, *R. grande*, *R. griffithianum*, *R. griersonianum*, *R. maximum*, *R. ponticum*, *R. smirnowii*, *R. strigillosum*, *R. viscidifolium, R. wardii*, *R. yakushimanum* and possibly other species (Ericaceae)	Rhododendron varieties including 'Alice', 'Cheer', 'Baden-Baden', 'Belle Heller', 'Bengal', Blue Peter', 'Boule de Neige', 'Cunningham white', 'Dopey', 'Everestianum', 'Kalinka', 'Nova Zembla', 'Sappho', 'Unique', 'Viscy', etc.
Syringa vulgaris (Oleaceae)	Lilac
Taxus baccata (Taxaceae)	Yew
Viburnum davidii (Caprifoliaceae)	-
Viburnum farreri (syn. *V. fragrans*); (Caprifoliaceae)	-
Viburnum lantana (Caprifoliaceae)	Twistwood
Viburnum opulus (Caprifoliaceae)	Guelder rose
Viburnum plicatum (Caprifoliaceae)	Mariesii
Viburnum tinus (Caprifoliaceae) (see also Lane *et al*., 2003)	Laurustinus
Viburnum x *bodnantense* = *V. farrerii* x *V. grandiflorum;* (Caprifoliaceae)	Bodnantense
Viburnum x *burkwoodii* = *V. carlesii* x *V. utile*) (Caprifoliaceae)	Burkwoodii
Viburnum x *carlcephalum* x *V.. utile* = *V. carlesii x V. macrocephalum x V. utile* (Caprifoliaceae)	-
Viburnum x *pragnense* = *V. rhytidophyllum* x *V. utile* (Caprifoliaceae)	-

Most infected hosts found in the UK, Channel Islands and the Republic of Ireland have been grown in containers located at nurseries/retail garden centres.

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However, some affected plants have been growing outdoors in the ground in managed gardens and one find on wild *Rhododendron ponticum* in the south-west of the Republic of Ireland was reported in September 2003 (P. Walsh, Republic of Ireland, 2003, personal communication).

In Belgium, France, Germany, the Netherlands, Poland (interceptions), Slovenia, Spain and Sweden, the pathogen has been isolated from either *Rhododendron* or *Viburnum* or both. These records are mainly from nurseries/retail garden centres, but also on ornamental *Rhododendron* growing in parks in the Netherlands. In Poland, imported *Vaccinium vitis-idaea* has been reported as a natural host (L. Orlikowski, Poland, 2002, personal communication). *Arbutus unedo* (strawberry tree) is recorded as an additional host in Spain (E. Moralejo, Spain, 2002, personal communication). In Denmark, *Rhododendron caucasicum* and *R. repens* (syn. *R. forrestii* var. *repens*) are new host records (L. Hendrikson, Denmark, 2003, personal communication).

There are no records of *P. ramorum* causing stem cankers or killing mature (non-nursery) trees in Europe.

Experimental hosts:
Much research has been undertaken on assessing plants for their potential as hosts of *P. ramorum*. Natural host species, which have been included in some experiments as controls, are marked below with an asterisk.

The origin as well as the number of different isolates used in tests in the following countries is not always clear from the literature, but has been specified where possible.
USA
In seedling inoculation tests in California, two representative eastern hardwood oak species, northern red oak (*Quercus rubra*) and pin oak (*Quercus palustris*) have been found to be susceptible to *P. ramorum* (Anon., 2001c).

Log inoculation tests with *P. ramorum* have revealed that necrotic areas were greatest on tanoak (*Lithocarpus densiflorus**) and Port Orford cedar (*Chamaecyparis lawsoniana*). Smaller lesions developed on Californian black oak (*Quercus kelloggii**), Oregon white oak (*Quercus garryana*), chinquapin (*Quercus muhlenbergei*) and canyon live oak (*Quercus chrysolepsis**) (Hansen and Sutton, 2002).

To evaluate susceptibility of eastern US oak species to *P. ramorum*, stems of 2- to 3-year-old seedlings of white oak (*Quercus alba*), Northern red oak (*Q. rubra*), chestnut oak (*Q. prinus*), cherrybark oak (*Q. falcata* var *pagodifolia*), and coast live oak (*Q. agrifolia*) were wound-inoculated with agar plugs of *P. ramorum* (Tooley and Kyde, 2003). All five oak species developed lesions below the bark. White and chestnut oak sustained the largest lesions, followed by Northern red oak, cherrybark oak, and coast live oak. The results suggested that, following wound-inoculation, *P. ramorum* can infect seedlings of eastern oak species under greenhouse conditions.

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In detached leaf assays in Oregon, lingonberry (*Vaccinium vitis-idaea**) and some cultivars of commercial blueberry (*Vaccinium* spp.) have been shown to be susceptible.
Cranberry (*V. macrocarpon*) was found to be resistant (Parke *et al*., 2002b).

Further work with nursery plants showed that Japanese maple (*Acer palmatum*), laurustinus (*Viburnum tinus**), currant (*Ribes sanguineum*), honey locust (*Gleditsia tricanthos*), summer lilac (*Buddleia davidii*), clematis (*Clematis montana*), Santa Barbara (*Ceanothus impressus*), witch hazel (*Hamamelis vemalis*) and *Rhododendron** 'Exbury hybrids' were very susceptible (Parke *et al*., 2002c).

Vine maple (*Acer circinatum*) and salal (*Gaultheria shallon*) have also been reported as hosts (Parke *et al*., 2002a). Western azalea (*Rhododendron occidentale*) is another susceptible native host (D. Rizzo, USA, 2003, personal communication).

No symptoms were observed on inoculated St. John's wort (*Hypericum* 'Hidcote'), Japanese quince (*Chaenomeles speciosa*), cotoneaster (*Cotoneaster multiflorus*), mock orange (*Philadelphus coronarius*)*, Cornus florida, Photinia serrulata* or *Rhaphiolepsis umbellata* (Parke *et al*., 2002c).

In other leaf tests with species in the Ericaceae, common bearberry (*Arctostaphylos uva-ursi*), mountain laurel (*Kalmia latifolia**), fetterbush (*Pieris floribunda*) and *Zenobia pulverulenta*, as well as rhododendron and azalea controls, were susceptible (Tooley and Englander, 2002). In addition, leaves of the understorey plants common prince's pine (*Chimaphila umbellata*), red huckleberry (*Vaccinium parvifolium*) and twinflower (*Linnaea borealis*), have been found to be susceptible (Zanzot *et al*., 2002). Zanzot *et al.,* (2002) note that these species have not been exposed to *P. ramorum* in nature.

Deciduous azaleas (*Rhododendron* spp.) were found to be generally more susceptible than evergreen azaleas (*Rhododendron* spp.) in detached leaf tests (Tjosvold *et al*., 2002a)

<u>UK</u>

Mature tree stems
Wound inoculation tests on inner bark of fresh cut logs of 23 UK/EU forest and plantation tree species have been conducted using a range of isolates of *P. ramorum* from both North America and Europe, by the Forest Research Agency, (FRA) (Brasier *et al*., 2002).

Mediterranean holly oak (*Quercus ilex*), American red oak (*Q. rubra*), Turkey oak (*Q. cerris*), European beech (*Fagus sylvatica*), sweet chestnut (*Castanea sativa*), Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii**), Lawson's cypress (*Chamaecyparis lawsoniana*) and rhododendron (*Rhododendron ponticum**) were placed in a 'more susceptible' category.

In a 'less susceptible' category was bark of English oak (*Quercus robur*), cork oak (*Q. suber*), European birch (*Betula pubescens*), horse chestnut (*Aesculus*

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hippocastanum), cherry laurel (*Prunus laurocerasus*), sycamore (*Acer pseudoplatanus*), European alder (*Alnus glutinosa*), coast redwood (*Sequoia sempervirens**) and yew (*Taxus baccata**).

Placed in a 'resistant category' were small-leaved lime (*Tilia cordata*), hornbeam (*Carpinus betula*), poplar (*Populus* sp.), elm (*Ulmus procera*) and ash (*Fraxinus excelsior*).

In some tests, extensive 'bleeding' from cankers was observed in logs of *Fagus* and *Castanea* after 3 weeks (C.M. Brasier, Forest Research 2002, personal communication).

No difference in the host ranges of North American and European isolates was observed in these tests, but a difference in aggressiveness (pathogenicity) was revealed. A sample of 15 European isolates was on average significantly more (ca. 50%) aggressive than a sample of 15 North American isolates on both *Q. robur* and *Q. rubra,* although the ranges of the two groups overlapped. Turkey oak (*Quercus cerris*) was in the 'less susceptible', (rather than the usual 'more susceptible') category in two experiments with North American isolates (Brasier *et al*., 2002).

A method for containing zoospore inoculum on bark was developed and used in unwounded log tests. Under these conditions bark of beech (*Fagus sylvatica*) and sweet chestnut (*Castanea sativa*) was penetrated and bark lesions developed. Bark of English oak (*Q. robur*) was penetrated but no lesions resulted. Bark of American red oak *(Q. rubra)* was occasionally penetrated with a few lesions resulting. (C.M. Brasier, Forest Research, 2003, personal communication).

Saplings

Tests on the susceptibility of containerised conifer saplings during summer have been conducted by FRA, using wound-inoculation of stems and side branches with mycelial plugs of both US and European isolates of *P. ramorum* (S. Denman, Forest Research, 2003, *personal communication*; Denman *et al*., 2002). Western hemlock (*Tsuga heterophylla*) died. Sitka spruce (*Picea sitchensis*) either developed large (near girdling) lesions, or wilted and stems were girdled. Lesions on Douglas fir (*Pseudotsuga menziesii**) almost girdled the stems. Norway spruce (*Picea abies*) and noble fir (*Abies procera*) developed smaller stem lesions, but inoculated side branches developed severe wilt, leaf desiccation and died. Yews (*Taxus baccata**) only developed small lesions on stems, but inoculated side branches wilted. Small lesions developed slowly on stems of Lawson's cypress (*Chamaecyparis lawsoniana*) and lodge pole pines (*Pinus contorta*) but only one inoculated side branch of a lodge pole pine died. No infection developed on Scots pine (*Pinus sylvestris*) or Corsican pine (*Pinus nigra* subsp. *salzmannii*). Additional preliminary work at the Central Science Laboratory (CSL) (A. Inman and P. Jennings, CSL, UK, 2003, personal communication) wound-inoculating saplings of broad leaf trees and conifers showed that symptoms developed on red oak (*Quercus rubra*), sweet chestnut (*Castanea sativa*), beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), some saplings of English oak (*Quercus robur*), Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii**) and wild cherry (*Prunus avium*). No symptoms developed on ash (*Fraxinus excelsior*),

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horse chestnut (*Aesculus hippocastanum*), sycamore (*Acer pseudoplatanus*) or small-leaved lime (*Tilia cordata*).

Detached stems
Detached stems of various species were tested at CSL for susceptibility by wound inoculation using mycelial plugs. Rhododendron (*Rhododendron ponticum**) was very susceptible and field maple (*Acer campestre*) was moderately susceptible. Disease development was minimal on honeysuckle (*Lonicera periclymenum*), common elder (*Sambucus nigra*), dog rose (*Rosa canina*), sycamore (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*), wych elm (*Ulmus glabra*), and camellia (*Camellia japonica*)*. Disease did not develop on stems of lilac (*Syringa vulgaris**) despite wounded leaves being highly susceptible (A. Inman. CSL, UK, 2003, personal communication).

Foliage: trees
Tests have been carried out by FRA on detached, wounded and non-wounded, summer and winter foliage of broad leafed and conifer trees using a zoospore leaf dipping technique with both European and North American isolates (S. Denman, Forest Research, 2003, *personal communication*). Provisional results indicate that the foliage of broad-leafed trees is more susceptible to infection and necrosis than conifer leaves, and similarly wounded leaves are more susceptible than non-wounded leaves. In the non-wounded tests the most susceptible hosts were ash (*Fraxinus excelsior*), elm (*Ulmus procera*), holly oak (*Quercus ilex*) and horse chestnut (*Aesculus hippocastanum*). Less susceptible were aspen (*Populus tremuloides*), Californian bay laurel (*Umbellularia californica**), cherry (*Prunus avium*), sessile oak (*Quercus petraea*) and Turkey oak (*Quercus cerris*). Least susceptible were alder (*Alnus glutinosa*), beech (*Fagus sylvatica*), holly (*Ilex aquifolium*), common oak (*Quercus robur*), cork oak (*Quercus suber*) and the red oak (*Quercus rubra*). Results for gum (*Eucalyptus gunnii*) and small-leaved lime (*Tilia cordata*) were unclear.

Foliage: shrubs and understorey plants
Inoculation studies have been undertaken at CSL, using mycelial plugs of both North American and European isolates of *P. ramorum* on detached leaves of UK ornamental, hedgerow and woodland understorey plants. (Inman *et al*., 2002).

This work has shown that ornamental red-berried elder (*Sambucus racemosa*), common elder (*S. nigra*), common camellia (*Camellia japonica**), lily-of–the-valley bush (*Pieris japonica**), lilac (*Syringa* vulgaris*), fetterbush (*Leucothoe* sp.), wild UK rhododendron (*Rhododendron ponticum**) and gum (*Eucalyptus* sp.) have the potential to be highly susceptible.

Leaves of the following have the potential to be moderately susceptible: wych elm (*Ulmus glabra*), ornamental yellow-leaved Scots elm (*Ulmus* sp.), lime (*Tilia* sp.), ash (*Fraxinus excelsior*), laurustinus (*Viburnum tinus**), snowberry (*Symphoricarpus albus*), common bearberry (*Arctostaphylos uva-ursi*), fuchsia (*Fuchsia* sp.) and Christmas berry (*Photinia* sp.).

Sycamore (*Acer pseudoplatanus*), viburnum (*Viburnum davidii**), gaultheria (*Gaultheria* x *wisleyensis*), crab apple (*Malus sylvestris*), Portugal laurel (*Prunus lusitanica*), cherry laurel (*P. laurocerasus*), nectarine (*P. persicae*) an azalea

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(*Rhododendron* sp.), ivy (*Hedera helix*) and dog rose (*Rosa canina*) were slightly susceptible in the tests.

Those considered to be resistant were hazel (*Corylus avellana*), field or hedge maple (*Acer campestre*), holly (*Ilex aquifolium*), alder (*Alnus glutinosa*) honeysuckle (*Lonicera periclymenum*), guelder rose (*Viburnum opulus*), azalea (*Rhododendron japonicum*), Sim's azalea (*Rhododendron simsii*), blueberry (*Vaccinium corymbosum*), hedge privet (*Ligustrum* sp.), clematis (*Clematis montana*), tartarian (*Cornus alba*) and hawthorn (*Crataegus monogyna*).

Rated as virtually immune were golden hop (*Humulus lupulus*), Japanese weigela (*Weigela japonica*), Japanese laurel (*Aucuba japonica*), Japanese skimmia (*Skimmia japonica*), Japanese spiraea (*Spiraea japonica*), English bay laurel (*Laurus nobilis*), tree mallow (*Lavatera* sp.), golden bells (*Forsythia* sp.), heath (*Calluna* sp.), summer lilac (*Buddleia davidii*), Mexican orange blossom (*Choisya ternata*), bramble (*Rubus fructicosus* agg.), grapevine (*Vitis vinifera*), mulberry (*Morus* sp.) and an azalea (*Rhododendron* sp.). No differences in the host ranges and virulences of European and North American isolates was recognised in these tests, although some North American isolates appeared slightly less aggressive (A. Inman, CSL, UK, 2003, personal communication).

Wounded and unwounded leaves of some of the above species were also inoculated by dipping in high and low concentrations of zoospores. Both wounded and unwounded leaves of rhododendron (*Rhododendron ponticum**) and ash (*Fraxinus excelsior*) were susceptible at both high and low concentrations of inoculum. Lilac (*Syringa vulgaris**) and common elder (*Sambucus nigra*) were susceptible at low concentrations only when wounded, but susceptible at the higher concentration unwounded. Camellia (*Camellia japonica**) was only susceptible when wounded; ivy (*Hedera helix*) was not susceptible at all. In a subsequent experiment both wounded and unwounded leaves of *Rosa canina* and *Vaccinium myrtillus* were also naturally susceptible when zoospore dipped (A. Inman, CSL, UK, 2003, personal communication).

<u>The Netherlands</u>
In the Netherlands, young plants of various hosts were inoculated with *P. ramorum* from the US and the EU. The control *Rhododendron ponticum** was found to be very susceptible developing severe leaf and stem lesions after one week. European wild blueberry (*Vaccinium myrtillus*) died within four weeks. European beech (*Fagus sylvatica*) and American red oak (*Quercus rubra*) wound inoculated on stems showed a severe dieback of twigs after four weeks. English oak (*Quercus robur*) seemed free of damage (de Gruyter *et al*., 2002).

<u>Spain</u>
In Spain, detached leaves of holly oak (*Quercus ilex),* strawberry tree (*Arbutus unedo**), honeysuckle (*Lonicera implexa*), Italian buckthorn (*Rhamnus alaternus*), mastic tree (*Pistacia lentiscus*), carob (*Ceratonia siliqua*), greenbrier (*Smilax aspera*), olive (*Olea europea*), rock rose (*Cistus salvifolius*) and evergreen rose (*Rosa sempervirens*) were susceptible to differing degrees. Clematis (*Clematis flammula*) and evergreen thornless blackberry (*Rubus ulmifolius*) were resistant (Moralejo and Hernández, 2002).

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Poland

Reports emanating from Poland suggest that dwarf laurel (*Kalmia angustifolia*) and lily-of-the-valley bush (*Pieris japonica**) are susceptible following inoculation with an intercepted isolate (origin unknown) (Orlikowski and Szkuta, 2002; L. Orlikowski, Poland, 2002, personal communication).

France

Saplings of *Quercus robur* were wounded and inoculated with *P. ramorum*. All plants produced bark necrosis with occasional bleeding. Necrosis on inoculated leaves was rare. (Delatour *et al*., 2002).

The significance of the results of all the above experiments in relation to possible field susceptibility of species and cultivars tested is yet to be determined. However, it again indicates that the natural host range of *P. ramorum* may be extensive and cover many plant genera in several families. In studies, apart from *Quercus cerris*, no differences in the host ranges of US and EU isolates have been observed, where both were used in the same experiments. However, a significant difference in average aggressiveness between European and American isolates has been documented (Brasier *et al*., 2002; Pogoda and Werres, 2002).

5(a) Highlight the crop plants grown economically, including those of environmental or amenity value, in the UK (and EU/EPPO) (include figures for potential yield/quality losses):

It is not yet known if oaks and other tree species growing in the UK/EU/EPPO region will be naturally susceptible to *Phytophthora ramorum*, as there have been no findings to date. Across Europe as a whole, the genus *Quercus* is very diverse, with 25 –30 species, both deciduous and evergreen, occupying a wide range of climatic conditions. Oaks native to the UK are *Quercus robur* (common oak) and *Q. petraea* (sessile oak). Continental European oaks introduced and locally naturalised in the UK which are now common include *Q. cerris* (Turkey oak) and *Q. ilex* (holly oak). Oaks native to the EU/EPPO region and found in gardens in the UK include *Q. pyrenaica, Q. pubescens* and *Q. suber.* Oaks, such as *Q. rubra* and *Q. alba*, have been introduced from North America as ornamentals. *Q. rubra* is common in the UK and self-seeds. *Quercus suber* is commercially important as the cork oak of southern Europe. None of these species are recorded as natural hosts.

Oaks play an important role in European natural ecosystems, especially forest and savanna-woodland ecosystems; and also in parks and open countryside. It has been estimated that there are *ca.* 200 million oak trees in the UK (which has a relatively low level of forest cover; National Inventory of Woodland and Trees, Forestry Commission). Their loss from specific areas could have a major impact on soil erosion, hydrology, sedimentation in rivers, loss of dependent or associated organisms and communities (biodiversity), tourism, cultural history and on local woodland economies (Brasier 2000a, unpublished).

Oak is an important source of wood for structural timber and for fine furniture in Europe. Also for cork *(Q. suber*) – a major industry in Portugal. In some areas such as south- west France, *Q. rubra* is planted extensively for oak barrel production.

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Inoculation experiments have indicated that *Q. cerris*, *Q. ilex* and *Q. rubra* have the potential to be very susceptible if the pathogen can gain entry to the bark. In addition, *Q. robur* and *Q. suber* have the potential to be moderately susceptible in the field. Many other oak species found naturally in Europe have not been tested.

Experimentally susceptible native European beech (*Fagus sylvatica*) and sweet chestnut (*Castanea sativa*) are also important high forest and plantation trees in Europe. Beech occurs in pure stands in some hilly or mountainous areas and is widely used for furniture (especially since the recent loss of the elms). Chestnut is common across southern UK and southern Europe and is used for coppice, fencing and in Europe also for commercial nut production (a large industry).

North American Sitka spruce (*Picea sitchensis*) and Douglas fir (*Pseudotsuga menzeisii*) (a known natural host in the USA) are major plantation species for pulp and timber in the UK (Sitka comprises ca. 38% of UK forest cover) and some other countries in the EU/EPPO region. North American Port Orford cedar/Lawson's cypress (*Chamaecyparis lawsoniana*) is abundant across the UK and the EU/EPPO region as an ornamental tree in parks and gardens. Tests indicate these species may have the potential to be rather susceptible. Birch (*Betula pubescens*), sycamore (*Acer pseudoplatanus*), alder (*Alnus glutinosa*) and yew (*Taxus baccata*) are major boreal forest, heath, high forest or riparian forest trees in the UK/EU/EPPO region All are indicated to be potentially susceptible (to a lesser degree) and yew is a known natural host. Horse chestnut (*Aesculus hippocastanum*), a common urban amenity tree, is also potentially at risk.

P. ramorum appears to be fundamentally an aerial pathogen which affects leaves, shoots and woody stems. It should be noted that *Q. suber, Q. ilex, Alnus, Fagus, Castanea* and *Taxus* are already considered particularly susceptible to certain invasive *Phytophthora* root and collar pathogens in Europe (Brasier, 1999, 2000b; Brasier and Jung 2003).

The record on imported *Vaccinium vitis-idaea* in Poland may have significance for commercial blueberry (*Vaccinium* spp.), which is grown on a small scale in the UK. Environmentally important UK/EU/EPPO *Vaccinium* heath and moorland species such as cowberry, bilberry and cranberry might also be potential hosts if climate is not limiting (P. Reed, CSL, UK, 2003, personal communication).

Many ecologically and environmentally important woody evergreen heath species, such as coastal Mediterranean heath species or coastal tree laurel species still remain to be tested for susceptibility, as do many European forest tree species.

Rhododendron, *Viburnum, Camellia* and *Pieris* species and hybrids, which are some of the known natural hosts, are highly valued ornamentals and are grown extensively in many countries. The natural host *R. ferrugineum* is native to the mountains of central Europe. The natural hosts *Arbutus unedo*, *Hamamelis virginiana*, *Leucothoe fontanesiana*, *Syringa vulgaris* and *Kalmia latifolia* are grown as specimen plants. Many other ornamentals have the potential to be natural hosts and could perhaps serve as reservoirs of inoculum should the pathogen become established.

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5(b) Are any of the potential host plants of Forestry importance ? Yes. See above

6. What is its present geographical distribution ?

Asia: No record
Africa: No record
North America: USA and Canada

In woodland in the USA, symptoms of sudden oak death associated with *P. ramorum* (American sub population/clade) have been observed in habitats in Alameda, Contra Costa, Humboldt, Marin, Mendocino, Monterey, Napa, Santa Clara, Santa Cruz, San Mateo, Solano and Sonoma counties in California (Anon., 2003a). The disease has also been observed on native vegetation near Brookings in Curry County in southwest Oregon (Anon., 2001b; Goheen *et al*., 2002a).

Eradication is being attempted in Oregon (Goheen *et al*., 2002b) but not in California where the pathogen is endemic.

In early 2001, about 8000 trees along a 350-mile stretch of coastal oak woodland in California were believed to be diseased with symptoms. The percentage of infection was 8-15% of trees in the northern part of the affected area, 30-40% in the San Francisco Bay area and higher in some other locations (Anon., 2001a). Recently, *P. ramorum* has been detected by PCR test on big leaf maple in Placer County in the foothills of the Sierras in California. The significance of this inland record has not yet been determined as no symptoms were observed and the pathogen could not be isolated. As a consequence, Placer County has not been classified as a regulated county by the USDA for *P. ramorum* purposes.

In May 2003, *P. ramorum* (American sub population/clade) was detected in ornamental hosts in four nurseries in Alameda, Marin, Santa Cruz and Stanislaus Counties in California. The nursery in Stanislaus County is approximately 100 miles east of the closest known naturally infested area. *Camellia sasanqua* sold by this nursery are being traced (Anon., 2003a).

Phytophthora ramorum has also been detected at a nursery in Clackamas County in northern Oregon on *Rhododendron*, *Viburnum plicatum* var. *tomentosum*, *V. bodnantense*, *P. japonica* and a *Pieris* x (Anon 2003c, N. Osterbauer, USA, 2003, personal communication, Hansen *et al*., 2003); and on *Rhododendron* hybrids, *Viburnum plicatum* and *Camellia japonica* plants at a nursery in Kings County, Washington State (Anon., 2003a, c; A. Wagner, USA, 2003, personal communication). In Canada there has been one finding on one rhododendron at a nursery in Greater Vancouver, British Colombia (Anon., 2003b).

These outbreaks on *Rhododendron*/*Camellia* on the one nursery in Clackamas County, northern Oregon, *Rhododendron/ /Camellia* in Washington and on *Rhododendron* in the one nursery affected in British Colombia are all reported to be of the A1 mating type from the European subpopulation. All plants infected

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with the A1 mating type have been destroyed (Anon., 2003a,b,c; Hansen *et al*., 2003; A. Wagner, USA, 2003, personal communication).

Central America and the Caribbean: No record
South America: No record
Oceania: No record

EPPO region: *Phytophthora ramorum* has been detected in Belgium, Denmark, France, Germany, the Netherlands, Poland (interceptions), Republic of Ireland, Slovenia, Spain, Sweden and the UK. Most isolates have been of the A1 mating type, but an A2 mating type has recently been identified from a host in Belgium. All isolates are from the European population/clade.
EU: see above

7. Does it appear capable of becoming established in the UK/EU/EPPO ?
(a) outdoors. Yes. It has been found outdoors in the UK/EU/EPPO region. European countries where *Rhododendron* is affected have cool-to-warm summers and cool-to-cold winters with rain throughout the year. The pathogen, therefore, may be capable of establishment in other northern areas or some southern coastal Atlantic/Mediterranean areas of the EU/EPPO region. However the present distribution on rhododendron might also reflect the main pattern of dispersal of infected stock.

Reports from the USA suggest that the pathogen has an optimum growth temperature of 20°C. The fungus grows slightly less at 15°C and 25°C, but there is no mycelial growth at 30°C. Sporangia form best below 20°C (D.M. Rizzo, USA, 2001, personal communication). Similar results have been obtained with isolates from *Rhododendron* and *Viburnum* in Europe. In this work, a minimum growth temperature of 2°C was recorded (Werres *et al*., 2001). This does not indicate however that 2°C is lethal. Equally, periodic temperatures of 30°C may not be limiting if the pathogen can infect host tissues successfully during a cooler rainy period.

The oaks under attack in the central coastal counties of California mainly grow at an elevation of 200-250 m. However, the present concentration of the pathogen in western California might in part reflect its recent introduction into the San Francisco Bay area. The climate in this part of California has cool, wet winters and hot, dry summers. Although the Californian climate is similar to that found in central and southern Europe, fog commonly moderates coastal temperatures in this part of California in the summer. This climate may not be the optimum for the pathogen. From growth experiments (see above), it is likely that cooler, wetter weather, such as is found in temperate areas of northern Europe, could be optimal.

As different mating types and populations/clades of *P. ramorum* appear to be associated with the original disease outbreaks in North America and Europe, and as both populations/clades also show evidence of adaptive differences (Brasier, 2003), it is likely that the pathogen is not native to either of these locations. One possibility is that *P. ramorum* evolved in an Asian Mediterranean or maritime ecosystem containing mixtures of *Chamaecyparis* species, *Lithocarpus* species and other Fagaceae; or similar evergreen or sclerophyllous tree hosts. An

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alternative hypothesis is that *P. ramorum* might have evolved as a pathogen of rhododendron. Rhododendrons are native across much of Europe, Asia and northwest America. The centre of origin of *Rhododendron* is the Himalayas and southeast Asia. *Viburnum* is also found in this region. Equally however, because of the common susceptibility of nursery rhododendrons to *Phytophthora* species, the rhododendron alternative could be a 'red herring', rhododendrons acting only as a carrier of the pathogen via the trade.

(b) on protected crops. Oaks and other potential host trees are not usually grown under protection. Known hosts in the genera *Camellia*, *Kalmia*, *Hamamelis, Leucothoe, Pieris*, *Rhododendron, Syringa, Vaccinium*, *Viburnum* and *Taxus* may be propagated and grown in nursery glasshouses or polytunnels. The glasshouse environment may be particularly suitable for the pathogen, especially if there is ample overhead or mist irrigation.

8. What is its potential likely to be as a pest or as a vector of viruses in the UK/EU/EPPO?

At the moment, the pathogen is mainly a pest of species of *Rhododendron* and *Viburnum* in the UK/EU/EPPO region. The potential for *Phytophthora ramorum* to cause serious disease of forest trees (and other plant species) or to undermine woodland and heathland ecosystems in the region depends on a number of factors, many of which are unknown at present.

A critical factor is whether trees such as European oaks, beech and chestnut are susceptible hosts in nature. This issue includes whether the pathogen's inoculum can penetrate the bark of woody species. Other factors relate to disease development and spread, in particular whether leaves of trees, understorey plants, hedgerow plants and ornamentals could serve as sources of inoculum and whether the climate is suitable for dissemination and survival. In California for example, the canopy tree Californian bay laurel (*Umbellularia californica*) is highly significant in the epidemiology of the disease. It supports rapid and abundant sporulation, and is considered to support epidemics on susceptible species of *Quercus* and *Lithocarpus* in California, though not in southwest Oregon. The pathogen also appears to survive as infection on evergreen Californian bay laurel leaves over the summer. Leaves of *Lithocarpus densiflorus* are another potential source of inoculum (A. Inman, CSL, UK, 2003, personal communication). In the US, streamwater, as well as soil attached to hiker's boots, car tyres and to the feet of animals have been implicated in the dissemination of the pathogen (Tjosvold *et al*., 2002). Whether local insects might disseminate the fungus from tree to tree is unknown, but in the US this is presently considered unlikely (D. M. Rizzo, USA, 2002, personal communication). Factors such as drought and secondary attacks by bark beetles and latent fungal pathogens could also hasten the decline of affected trees, as with some other *Phytophthora* tree diseases (cf. *P. cinnamomi* and cork oak mortality in Europe; Brasier 1999).

Climatic conditions in the UK and EU/EPPO region seem to favour disease development on *Rhododendron* and *Viburnum*. However, little is known at the moment about the epidemiology of the pathogen and the amount of damage that it may cause in nature. It is likely to be lethal to young *Rhododendron* and *Viburnum* plants. If death does not occur as a direct result of *P. ramorum,* invasions by secondary organisms may lead to death. The widespread

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commercial use of fungicides specific in their action against oomycetes has been suggested as a possible factor that allows the distribution of *Phytophthora* in infected, but symptomless, ornamental plants or in associated soil (Brasier and Jung, 2003).

Isolates of *P. ramorum* so far detected in Europe are all from a similar population/clade, which is molecularly and adaptively distinct from the established North American subpopulation. Most European isolates are of the A1 mating type, although one isolate of the A2 mating type has been found. Isolates from the North American population/clade are of the A2 mating type. If isolates of the North American A2 mating type were to establish in Europe, genetic recombination through sexual outcrossing of the European A1 and American A2 mating types might become possible. Although sexual reproduction has not been observed in nature, in view of other possible differences between the North American and European populations, such as differences in aggressiveness, the potential for exchange of genetic material might lead to an increase in the pathogens general fitness, its host range and/or its general capability to cause disease should this occur (Brasier, 2003). It may also increase its ability to overcome control by the use of fungicides. The formation of sexual resting spores could further increase the long-term survival potential of *P. ramorum.*

Another key factor in determining the success of the pathogen as an invader of UK/EU/EPPO region woodland, heathland and other environments is the potential for local hosts to produce inoculum to perpetuate epidemics. The risk of spread is greatly reduced if the pathogen in diseased plants produces few or no spores. Work is underway in the UK to determine the sporulation potential of various host species.

9. What are the prospects for continued exclusion ?

Until more is known about the distribution, etiology and host range of *P. ramorum* and its potential to adapt ecologically or to hybridise with other species of *Phytophthora* pathogens (Brasier 2000a,b) it would be prudent to reduce the chances of introduction of the organism into the UK and other countries in the EU/EPPO region. The prospects of excluding US isolates of *P. ramorum* are good. Quarantine regulations have been in force in the UK since 13 May 2002. EU legislation was introduced on 1 November 2002. This will control the introduction of susceptible plants and plant products from the USA. The movement of *Rhododendron* and *Viburnum* within and between countries in the EU is also being controlled by plant passport.

10. What are the prospects for eradication ?

If European oaks or other trees in forests were naturally susceptible to *P. ramorum* and climatic conditions and other factors favoured rapid rather than slow spread, should the pathogen be discovered on trees, the chances of eradication might be limited. By the time the problem was diagnosed, especially in a remote forest situation, attempts at eradication might only be practicable if the disease were confined to discrete pockets of less than (e.g.) two hectares. The practicalities are also likely to depend on factors, such as land use, land ownership and proximity to urban situations. Attempted eradication of *P. ramorum* is currently being undertaken in affected Oregon forests, mainly via felling and

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total burning as 'clearcuts' (Goheen *et al.*, 2002b). It is uncertain as yet, whether this will be successful.

On *Rhododendron* and *Viburnum*, as well as other ornamentals found to be natural hosts, such as *Camellia*, *Kalmia* and *Pieris,* eradication may be possible if the disease is confined to a small number of plants in nursery/retail garden centre/managed park situations. However, if the pathogen becomes locally established on wild *Rhododendron* or other wild plants that allow abundant sporulation*,* attempts at eradication will become much more difficult.

To date, *P. ramorum* has been confirmed at a total of over 300 sites in the UK (including the Channel Islands) and a few sites in the Republic of Ireland. Most of these detections have been on *Rhododendron* and *Viburnum* plants in nurseries/retail garden centres. However, the pathogen has also been found on hosts in several, intensively managed, garden environments and on one wild *Rhododendron ponticum* in the Republic of Ireland. Although eradication is being attempted at locations where the pathogen is found, it is unclear as yet whether this is going to be successful. It is highly likely that plants affected by *P. ramorum* remain undetected in the UK/Republic of Ireland. Plants may also still be being imported into the UK/Republic of Ireland with latent infections despite plant passporting requirements for *Rhododendron* and *Viburnum*.

The same situation probably occurs in other countries in the EU/EPPO region. EU legislation that came into force on 1 November 2002 calls for Member States of the Community to undertake surveys for *P. ramorum* and disseminate the results. This requirement is shedding further light on the overall disease situation in the EU.

11. How would eradication be achieved?

Eradication is being attempted under UK/EU legislation in the UK/EU by destroying all infected plants within a 2 m radius of a diseased plant and holding all susceptible plants within a 10 m radius plus any remaining plants from the same consignment as the diseased plants for further assessment. Release of these plants will be allowed following two negative visual inspections during three months of active growth. Other susceptible plants on the premises will be released after an intensive inspection confirms disease freedom (D. Slawson, PHSI, UK, 2002, personal communication). Hygiene and biosecurity measures will be required to prevent spread of inoculum.

Although containerised yew saplings in a retail garden centre in the UK have been found infected with *P*. *ramorum* and one shrub/tree of *Hamamelis virginiana* in a managed garden, no trees in natural environments in the UK/EU/EPPO region have been found affected*.* In the UK, 12 forest sites affected by classic oak decline (which in some respects resembles sudden oak death, cf. Brasier 1999), were surveyed by the UK Forestry Commission during June-October 2001 with no evidence of *P. ramorum*. Potential host trees adjacent to nurseries where the pathogen had been found were surveyed in 2002. To date, no *P. ramorum* has been found on these trees. No affected trees have been found so far in similar surveys in the Netherlands in 2002 (de Gruyter, Netherlands, 2002, personal communication).

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If trees affected by *P. ramorum* are found in the future, and an assessment of the various factors lead to a conclusion that eradication is a viable option in that situation, then the diseased trees and surrounding susceptible trees would need to be destroyed. A localised cordon sanitaire would need to be established. Precautions to prevent contamination and spread would need to be taken including burning or deep burial of the affected trees. Intensive monitoring of the site would be required (cf. Kanaskie *et al.,* 2002). Eventual replanting in areas cleared of diseased hosts should be with non-susceptible species.

Contingency plans for activation should *P. ramorum* spread to woodland, heathland and/or other habitats in the UK are being formulated by Plant Health Division of Defra.

12. Conclusion

Phytophthora ramorum has been found in both Europe and North America. However, different populations/clades of the pathogen have been found in the two regions. Most isolates analysed in Europe belong to the A1 mating type while most in North America belong to the A2 mating type. Apart from the difference in mating type distribution there are also differences in adaptation between European and North American populations, such as variations in average aggressiveness. Current evidence, therefore suggests the original European and North American outbreaks are not directly related.

In the USA, the North American population/clade of *P. ramorum* causes a lethal disease of several forest oak species native to California and southwest Oregon. It also causes severe to moderate diseases of other native tree canopy genera and understorey plants. The oak species are affected by stem cankers after infection and commonly die in 1-2 seasons. Leaves, young shoots and small stems or branches are commonly affected on other hosts. The pathogen has recently been detected on ornamental hosts, such as *Rhododendron*, *Viburnum, Camellia* and *Pieris*, in a number of nurseries/retail garden centres in the states of California, Oregon and Washington. Attempts are being made in the USA to eradicate the pathogen outside the counties in California where it is endemic.

Isolates belonging to the A1 mating type from the European population/clade have recently been detected in a nursery in northern Oregon, one in Washington and one in British Colombia, Canada.

In the UK/EU/EPPO region, *P. ramorum* mainly affects species/hybrids of *Rhododendron* and *Viburnum*. It has also been found on some species in the genera *Arbutus*, *Camellia*, *Hamamelis*, *Leucothoe*, *Kalmia*, *Pieris, Syringa*, *Taxus*, and *Vaccinium.* To date, *P. ramorum* has been identified on one or more of these hosts in Belgium, Denmark, France, Germany, the Netherlands, Poland (interceptions), Republic of Ireland, Slovenia, Spain, Sweden and the UK (including the Channel Islands), but it probably also occurs elsewhere.

The susceptibility of European oak and most other tree species to both North American and European isolates of the pathogen in nature is not yet known. Containerised yews in a retail garden centre in the UK have been found with *P. ramorum*, but only foliage was affected. One mature shrub/tree of Virginian witch-hazel/witch hazel has been found with die-back and foliage symptoms in a

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managed garden in Wales. No trees have been found with stem cankers and no deaths of trees have been reported.

An A2 mating type has recently been identified from a host in Belgium. However, this isolate is again of the European, not the North American subpopulation/clade.

Inoculation experiments have shown that a range of important native forest trees in the EU/EPPO region, including species of oak, beech and sweet chestnut have the potential to become bark hosts of *P. ramorum.* In addition, some trees grown widely in plantations as a source of pulpwood and timber and others grown in large numbers ornamentally may also be naturally susceptible. Ash and other trees have been shown to be experimentally susceptible foliar hosts and could act as inoculum sources for epidemics. A wide range of other native and ornamental plants has been infected in tests.

The pathogen can spread long distances on infected hosts such as rhododendron as well as on plant products from these hosts. The pathogen may be being suppressed in plants in nurseries by the widespread commercial use of fungicides specific in their action against oomycetes. This may be allowing the pathogen to spread in trade in symptomless material.

Research that will further help define the host ranges of North American and European isolates of *P. ramorum* on European forest trees and on ornamental, hedgerow and woodland understorey as well as heathland plants is underway. Relating the results of inoculation experiments to what may happen naturally is a problem, but may be partially overcome by the use of suitable experimental controls, and by further experimentation, e.g. on the pathogens ability to enter bark of woody species. Investigations aimed at defining the capability of *P. ramorum* to produce sporangia and chlamydospores on known UK/EU/EPPO hosts and survival potential of propagules should further help to determine risks. So also should investigations of the differences between the North American and European populations/clades and their potential to sexually recombine.

Until more information is known, quarantine measures are seen as appropriate to control the entry of North American isolates of *P. ramorum* into the EU region and also the further movement of European isolates on *Rhododendron* and *Viburnum* hosts within the EU region. These measures are intended to (1) prevent the introduction of exotic US A2 genotypes, which may lead to sexual recombination and the formation of more aggressive strains; (2) prevent the further dissemination of European isolates; and (3) aid eradication of the pathogen from sites where the disease has been found.

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