Phytophthora ramorum: a biosecurity threat to the Australian nursery industry

Background

Phytophthora ramorum is a recently discovered invasive plant pathogen causing serious and widespread damage in nurseries and natural woodland ecosystems of Europe and North America (Fig. 1). Spread of this pathogen has been linked to international nursery trade. Should it gain entry into Australia it could cause devastating losses of susceptible hosts, including a significant number of potentially susceptible Australian native species. *Phytophthora ramorum* is currently listed as a category 1 emergency plant pest in Australia because of its potentially devastating effects not only to affected plant industries, such as nurseries, but also to native ecosystems.

Fig. 1. Tree death symptoms – (a) Tanoak (*Lithocarpus densiflorus*) mortality in North Eastern California and (b) Grand fir (*Pseudotsuga menziesii*) dieback symptoms (lower limbs) in the UK.

Biology

Phytophthora ramorum is primarily an aerial pathogen, impacting on stems, trunks and leaves. In this way it differs from some of the other important *Phytophthora* pathogens such as *P. cinnamomi*, which commonly infect via roots and cause root rot symptoms. The life cycle of *P. ramorum* is complex, with several different spore stages. The pathogen produces asexual sporangia and zoospores, as well as thick-walled chlamydospores. Sporangia of *P. ramorum*, which are produced on the surfaces of infected leaves and twigs, can be dispersed by water splash to neighbouring hosts, or spread longer distances by wind and rain [7]. The pathogen can also be carried downstream of infested areas in rivers and streams, or spread via infested soil. Under suitable environmental conditions on a susceptible host, sporangia germinate to produce zoospores that infect host tissue. In many hosts, infected leaf tissue produces chlamydospores, which can survive in soil for long periods. The soilborne phase of the disease cycle is not well understood.

Host range

Phythophthora ramorum has a wide and diverse host range, with many plant families known to be susceptible. Susceptible hosts include trees (both hardwood and conifer species), shrubs, herbaceous plants and ferns. Many varieties of commonly grown nursery plants such as *Camellia*, *Kalmia, Pieris*, *Rhododendron*, *Magnolia* and *Virburnum* species are considered to be highly susceptible.

In California and Oregon, tree mortality in tanoak and several oak tree species has been extensive (Fig 1a). Similar local scales of mortality have occurred recently in Japanese larch plantations in the UK. In Australia, the concern is that a number of native species would be severely affected in the event of an incursion, given that overseas field observations and pathogenicity tests have shown that a number of Australian species are highly susceptible. In a recent study of 69 species of Australian native plants, six species (*Eucalyptus regnans*, *Isopogon cuneatus*, *I. formosus*, *Leptospermum scoparium*, *L. lanigerum* and *Melaleuca squamea*) were found to be highly susceptible to *P. ramorum* [4, 5] (Table 1). Other Australian species which are potentially highly susceptible include *Eucalyptus gunnii* [1], *E. dalrympleana* [8] and *Pittosporum undulatum* [3].

Symptoms

Three different diseases can be caused by *P. ramorum*: stem or bole canker (sudden oak death), leaf blight (ramorum leaf blight) and twig blight/dieback (ramorum shoot dieback). Individual plant species can display more than one disease type (e.g. leaf blight, shoot dieback and stem cankers on tanoak) [2]. Leaf blight and twig blight/dieback symptoms are typically visible within five to fourteen days following infection, while bleeding cankers and whole plant dieback may not be visible for some time (i.e. months or years) following an infection event. Infections typically develop rapidly under moist, temperate conditions, similar to those prevalent in the nursery environment.

Sudden oak death is characterised by bleeding bark cankers, usually on the lower trunk, which cause red-brown to black discolouration of tissue below the bark (Fig. 2). These cankers can lead to death of entire tree crowns due to necrotic girdling of trunk tissue.

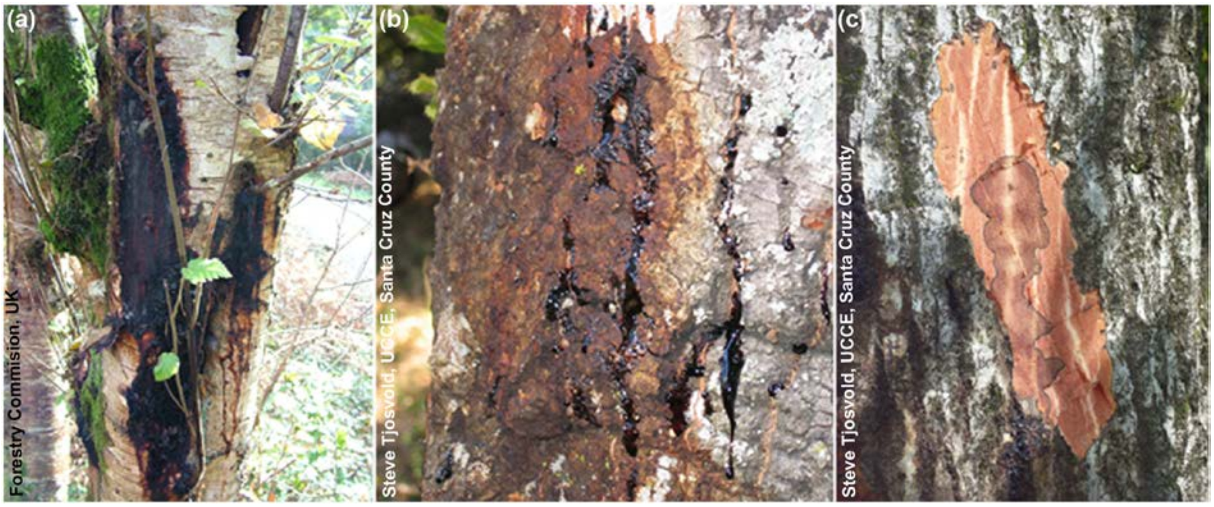

Fig. 2. Trunk symptoms – (a) Birch (*Betula* sp.) - discolouration and bleeding of outer bark; (b) Coast live oak (*Quercus agrifolia*) - infected tree exhibiting sap bleeding; (c) Coast live oak - bark removed from bleeding lesion showing diseased lesion compared with healthy tissue.

Ramorum leaf blight symptoms appear as diffuse brown to dark-brown spots or blotches with fuzzy margins, often but not always at the leaf tip where moisture can accumulate (Fig. 3). In advanced stages of infection, entire leaves can turn brown to black and fall prematurely. Shoot dieback symptoms include blackened shoots, with or without foliage attached (Fig. 4).

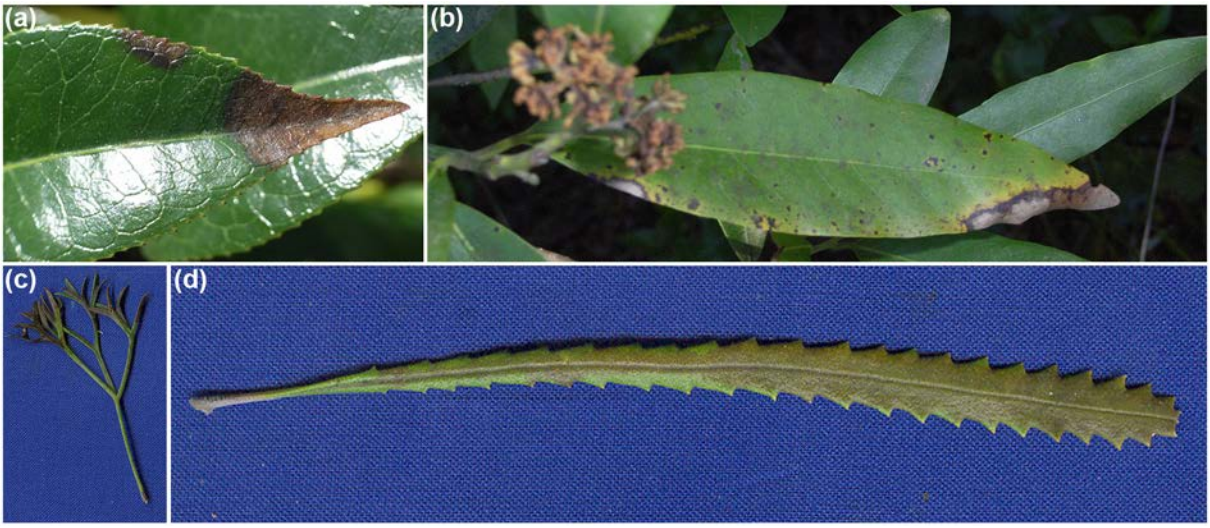

Fig. 3: Leaf symptoms – Natural infection symptoms of (a) *Camellia* sp. and (b) California bay laurel (*Umbellularia californica*); and laboratory inoculation symptoms for Australian native species (c) *Isopogon formosus*; (d) *Banksia attenuata* (images: Kylie Ireland, CRC for National Plant Biosecurity).

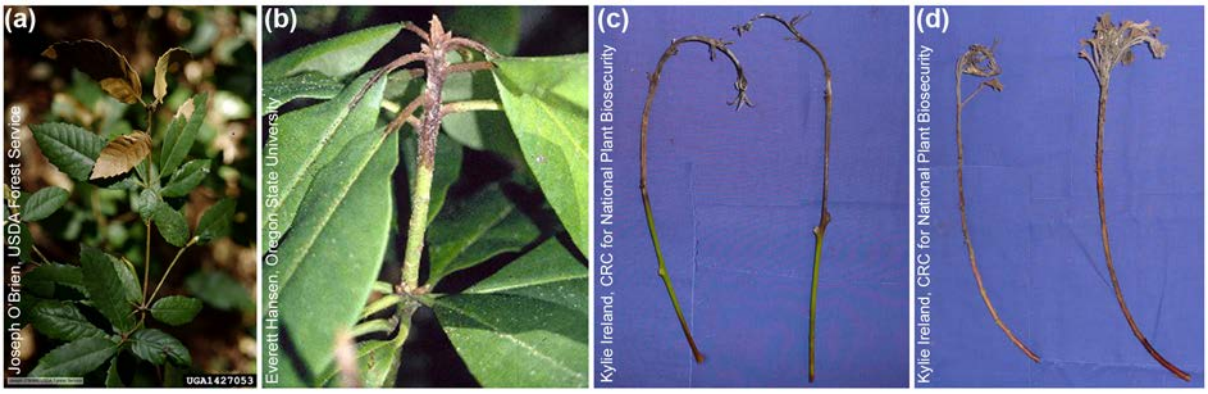

Fig. 4. Branch symptoms – Natural infection symptoms of (a) Tanoak (*Lithocarpus densiflorus*) and (b) *Rhododendron* sp.; and laboratory inoculation symptoms for Australian native species (c) *Eucalyptus leucoxylon* subspecies megasperma and (d) *Isopogon formosus*.

Symptoms of diseases caused by *P. ramorum* are variable and are often not distinct from those resulting from other plant pathogens. For example, bleeding bark cankers caused by *Botryosphaeria* and other *Phytophthora* species can occur on the trunks of many plant species, and can be similar in appearance to those associated with sudden oak death. Foliar symptoms caused by other *Phytophthora* species (e.g. *P. nicotianae, P. citrophthora* and *P. heveae*) can also be similar to those caused by *P. ramorum.* For this reason, confirming the presence of *P. ramorum* requires culturing and/or molecular diagnostic testing.

Current global distribution and potential Australian distribution

It is thought that *P. ramorum* has been separately introduced into North America and Europe from a third area, or areas, which are currently not known [6]. In the United States, the pathogen has been recorded in nurseries, residential plantings from those nurseries, and in Californian and Oregon woodlands. In Canada, the pathogen has only been recorded in a few nurseries in British Columbia and was eradicated from the nursery and on any trace forwards/backs following any detections. *Phytophthora ramorum* has also been recorded in several European countries (nurseries and limited outbreaks in parks and gardens/woodlands) [7].

As cool, moist conditions favour survival, infection and spread of *P. ramorum*, the pathogen would be particularly suited to establishment in coastal areas of south-eastern and south-western mainland Australia, as well as Tasmania, should it be introduced into this country. As such, *P. ramorum* would be a major threat to southern Australia forest and woodland systems, as well as to amenity trees, horticultural crops (including ornamental species) and home gardens.

Potential impact on Australian nursery production

Phytophthora ramorum is most likely to enter Australia through infected plant material as part of international nursery trade. Aside from the ornamental species currently known to be susceptible to *P. ramorum* (such as *Camellia* and *Rhododendron* species), there are a significant number of native Australian species likely to be affected (Table 1).

Protecting your nursery from *P. ramorum*

Should *P. ramorum* gain entry into Australia, early detection will be crucial for eradication to be feasible. For this reason, regular disease monitoring is very important in production nurseries. Developing familiarity with common diseases of nursery plants is helpful as it will make it easier to know if unusual symptoms are present. Inspection of all incoming plant material into production nurseries for the presence of disease symptoms is essential.

Adopting best management practice in your nursery will help to minimise biosecurity risks such as *P. ramorum*, as well as improve overall pest and disease management. In particular, ensure nursery workers are familiar with important biosecurity threats such as *P. ramorum*, always practice strict nursery hygiene, and regularly monitor crops for pests and diseases.

PLEASE NOTE: The use of fungicides against *Phytophthora* spp. in nurseries should be avoided as these will only mask the presence of these pathogens rather than eradicate them. Once the effects of these chemicals have worn off, pathogen activity resumes. While symptom development is slowed, pathogen death does not occur. This can result in apparently healthy plants being moved and traded, hampering management and containment efforts.

If you see anything unusual, call the Exotic Plant Pest Hotline on 1800 084 881. More detailed information on the biology and management of diseases caused by *Phytophthora ramorum* is available in the Sudden Oak Death Contingency Plan, produced by Plant Health Australia and the Nursery and Garden Industry Australia (NGIA) as part of the Nursery Industry Biosecurity Plan. A copy of this plan can be obtained from the NGIA website. Additional information, including links to the most current nursery-associated research and best management practices to reduce the impact of *Phytophthora ramorum* in USA in nurseries, can be found at the websites listed below. Interestingly, solarisation and steam treatment of soils and soil amendment with *Trichoderma* species have shown some promise in recent studies, the details of which are available at the first website and would have applicability to the control of other *Phytophthora* species and soil-borne pests.

Websites

1. California Oak Mortality Task Force (COMTF) website: http://www.suddenoakdeath.org/
2. Risk Analysis for *Phytophthora ramorum* (RAPRA) website: http://rapra.csl.gov.uk/
3. Canadian Food inspection Agency website: http://www.inspection.gc.ca/plants/plant-protection/diseases/sudden-oak-death/eng/1327587864375/1327587972647

This document was prepared by Kylie Ireland, Andrew Manners, Lindy Coates, Tony Cooke and Leif Forsberg (Department of Agriculture, Fisheries and Forestry, Queensland - DAFFQ) as part of HAL Project NY11001 “Plant health, biosecurity, risk management and capacity building for the nursery industry”. Thanks go to Ken Pegg (DAFFQ), John McDonald (NGIQ) and Anthony Kachenko (NGIA) for their help in the preparation of the document.

References

1. Denman, S., S.A. Kirk, C.M. Brasier, and J.F. Webber, 2005. In vitro leaf inoculation studies as an indication of tree foliage susceptibility to *Phytophthora ramorum* in the UK. *Plant Pathology* **54**: 512-521.
2. Hansen, E.M., J.L. Parke, and W. Sutton, 2005. Susceptibility of Oregon forest trees and shrubs to *Phytophthora ramorum*: A comparison of artificial inoculation and natural infection. *Plant Disease* **89**: 63-70.
3. Huberli, D., C. Wilkinson, M.A. Smith, M. Meshriy, T.Y. Harnik, and M. Garbelotto, 2006. *Pittosporum undulatum* is a potential Australian host of *Phytophthora ramorum*. *Australasian Plant Disease Notes* **1**: 19-21.
4. Ireland, K.B., D. Hueberli, B. Dell, I.W. Smith, D.M. Rizzo, and G.E.S.J. Hardy, 2012. Potential susceptibility of Australian flora to a NA2 isolate of *Phytophthora ramorum* and pathogen sporulation potential. *Forest Pathology* **42**: 305-320.
5. Ireland, K.B., D. Hueberli, B. Dell, I.W. Smith, D.M. Rizzo, and G.E.S.J. Hardy, 2012. Potential susceptibility of Australian native plant species to branch dieback and bole canker diseases caused by *Phytophthora ramorum*. *Plant Pathology* **61**: 234-246.
6. Ivors, K., M. Garbelotto, I.D.E. Vries, C. Ruyter-Spira, B.T. Hekkert, N. Rosenzweig, and P. Bonants, 2006. Microsatellite markers identify three lineages of *Phytophthora ramorum* in US nurseries, yet single lineages in US forest and European nursery populations. *Molecular Ecology* **15**: 1493-1505.
7. Kliejunas, J.T., 2010. Sudden oak death and *Phytophthora ramorum*: a summary of the literature. *General Technical Report - Pacific Southwest Research Station, USDA Forest Service*: 181 pp.-181 pp.
8. Moralejo, E., J.A. Garcia-Munoz, and E. Descals, 2009. Susceptibility of Iberian trees to *Phytophthora ramorum* and *P. cinnamomi*. *Plant Pathology* **58**: 271-283.

Table 1. Potential susceptibility of 73 native Australian plant species and three positive control species (not native to Australia) to foliar, branch and bole canker diseases caused by *Phytophthora ramorum* and sporulation potential on foliage[a]. Species were tested by Kylie Ireland[4,5], unless otherwise indicated by surrounding hash symbols (#) or additional notes.

Species [b]	Susceptibility			Sporulation potential [γ]
	Foliar [α]	Branch [β]	Bole canker [β]	
Positive control hosts				
Notholithocarpus densiflorus	# High #	# High #	High	# High #
Rhododendron cv. Colonel Coen	Moderate	High	…	High
Umbellularia californica	Moderate	High	…	High
Australian hosts				
Acacia dealbata (Tas)	Low	Low	Low	Moderate
Acacia melanoxylon (Tas)	Low	Low	…	Unlikely
Acmena smithii	Low	Low	…	Marginal
Adenanthos obovatus (WA)	Moderate	Tolerant	…	…
Agonis flexuosa (WA)	Low	Low	…	Marginal
Atherosperma moschatum (Tas)	Low	Low	…	Unlikely
Banksia attenuata (WA)	Moderate	Tolerant	…	Marginal
Banksia marginata (Tas)	Low	Tolerant	…	Marginal
Bauera rubioides (Tas)	Moderate	Low	…	…
Billardiera heterophylla (WA)	Low	Tolerant	…	…
Brachychiton populneus	Moderate	Low	…	…
Bursaria spinosa (Tas)	Low	Tolerant	…	…
Callitris rhomboidea (Tas)	Low	Low	…	…
Ceratopetalum apetalum	Low	Low	…	…
Correa alba	Low	Low	…	…
Correa backhousiana	Low	Low	…	…
Correa decumbens	Low	Low	…	…
Correa cv. Ivory Bells	Low	Low	…	…
Correa reflexa (Tas)	Moderate	Low	…	Marginal
Correa cv. Sister Dawn	High	Tolerant	…	…
Corymbia ficifolia (WA)	Moderate	Low	…	Moderate
Corymbia maculata	Low	Low	…	Marginal
Dicksonia antarctica (Tas)	Low	Low	…	Unlikely
Dodonea viscosa (Tas; WA)	Low	Low	…	Marginal
Eucalyptus camaldulensis	Low	Low	…	…
Eucalyptus cneorifolia	Low	Moderate	…	…
# *Eucalyptus dalrympleana* # [8]	…	…	# High #	…
Eucalyptus delegatensis (Tas)	Moderate	Low	…	Moderate
Eucalyptus denticulata	Moderate	High	Moderate	Moderate
Eucalyptus diversicolor (WA)	Low	Low	Tolerant	
Eucalyptus globulus (Tas)	Low	Low	Low	Marginal
# *Eucalyptus gunnii* # [1]	# High #	…	…	…
Eucalyptus haemastoma	Moderate	Tolerant	…	High
Eucalyptus leucoxylon	Low	Low	…	…

Table 1. (Continued)

Species [b]	Susceptibility			Sporulation potential γ
	Foliar α	Branch β	Bole canker β	
Eucalyptus pauciflora (Tas)	Moderate	Low	…	Marginal
Eucalyptus regnans (Tas)	High	Tolerant	High	Unlikely
Eucalyptus saligna	Low	Low	…	…
Eucalyptus sideroxylon	Moderate	Moderate	…	…
Eucalyptus viminalis (Tas)	Low	Moderate	Tolerant	High
Eucryphia lucida (Tas)	Low	Low	…	…
Grevillea synaphea (WA)	Moderate	Low	…	…
Hakea rostrata	Low	Low	…	…
Hardenbergia violaceae	Low	Moderate	…	Unlikely
Hedycarya angustifolia	Resistant	Low	…	…
Isopogon cuneatus (WA)	High	Low	…	…
Isopogon formosus (WA)	High	High	…	High
Lagarostrobos franklinii (Tas)	Low	Low	…	…
Leptospermum grandiflorum (Tas)	Low	Low	…	…
Leptospermum lanigerum (Tas)	High	Low	…	…
Leptospermum scoparium (Tas)	High	Tolerant	…	Marginal
Lomandra longifolia (Tas)	Low	…	…	…
Lomatia myricoides	Low	Tolerant	…	…
Macadamia tetraphylla	Low	Tolerant	…	…
Melaleuca squamea (Tas)	High	Low	…	…
Nothofagus cunninghamii (Tas)	Low	Moderate	…	High
Nothofagus moorei	Low	Low	…	Marginal
Olearia argophylla (Tas)	Resistant	Low	…	…
Phyllocladus aspleniifolius (Tas)	Resistant	Low	…	…
Pittosporum undulatum ^	Resistant^	Tolerant	…	Unlikely
Podocarpus lawrencei (Tas)	Resistant	Low	…	…
Polyscias sambucifolia	Moderate	Low	…	…
Pomaderris apetala (Tas)	Resistant	Low	…	Marginal
Prostanthera lasianthos (Tas)	Low	Low	…	Marginal
Senecio linearifolius	Low	Low	…	…
Stylidium graminifolium	Low	Tolerant	…	…
Tasmannia lanceolata	Low	Low	…	…
Taxandria marginata (WA)	High	Low	…	…
Tristaniopsis laurina	Low	Low	…	…
Viola hederaceae	Low	…	…	…
*Xanthorrhoea australis**	Low	…	…	…
Xanthorrhoea preisii (WA)	Low	…	…	…

[a] Calculations for susceptibility based upon measures of severity and infection potential, as outlined in Chapter 2 for foliar (α) studies and Chapter 3 for branch and bole canker (β) studies. Descriptions of sporulation potential (γ) are described in Chapter 2. Colours indicate the degree of host susceptibility/sporulation potential, where blue indicates tolerant or resistant species or those unlikely to produce sporangia, followed by low susceptibility or marginal likelihood in yellow, moderate in orange and high in red.

[b] Positive control species are known to be naturally infected in California. Species tested for foliar susceptibility using only agar plug inoculations (*). Species native to Tasmania (Tas) and Western Australia (WA). *Pittosporum undulatum* has been indicated as being a naturally infected and a potentially highly susceptible foliar host in another experiment [3] (^).