The impact of *Phytophthora cinnamomi* on ecosystem function and health of Mediterranean forests, woodlands and heathlands in Western Australia

Bernard Dell,[1] Giles Hardy,[1,3] Emer O'Gara,[1] and Bryan Shearer[2]

[1] Centre for Phytophthora Science & Management, Murdoch University, Western Australia
[2] Department of Environment and Conservation, Western Australia
[3] Contact should be made to G.Hardy, email g.hardy@murdoch.edu.au, (08) 9360 6272

Keywords
Phytophthora dieback, Biological Bulldozer

Introduction

In Australia, the introduced soil-borne plant pathogen *Phytophthora cinnamomi* is listed by the Commonwealth's Environmental Protection and Biodiversity Conservation Act 1999 as a 'Key Threatening Process to Australia's Biodiversity'. It causes major epiphytotics in the Mediterranean areas of the continent receiving more than 600 mm of rainfall. In the Southwest Botanical Province of Western Australia over 2,285 native plant species of the 5,710 described are susceptible to *P. cinnamomi* (Shearer et al. 2004). The indirect effects of *P. cinnamomi* in terms of botanical impact through the loss of vertebrate and invertebrate pollinators, and loss of canopy and litter cover have yet to been determined. Recent studies indicate that the pathogen is impacting on native fauna due to loss of litter, understorey and overstorey canopy cover, food resources and refugia (Garkaklis et al. 2004). The pathogen also impacts on stream flow, water quality, and can increase salinity. Hygiene and quarantine management controls impact on mining, timber harvesting, road building, and the activities of utilities and general use of parks and reserves by the public. The plant communities impacted on in south-western Australia include the jarrah (*Eucalyptus marginata*) forest, the banksia woodlands and heathlands. The area of impact includes the only global biodiversity 'hotspot' in Australia (Mittermeier et al. 2004).

Many susceptible species belong to the families Proteaceae, Epacridaceae, Dilleniaceae, Xanthorrhoeaceae and Fabaceae (Dell and Malajczuk 1989), which together make up a large component of the flora of the region. The death of susceptible understorey and overstorey species results in an irreversible decline in the diversity of vegetation on infested sites, and this in turn impacts on ecosystems and their overall health and function. Consequently, the impact of the pathogen has been likened to a 'biological bulldozer' (Carter 2004). This review gives a brief overview of knowledge on the biology, ecology, and pathology of this pathogen in these ecosystems; how Phytophthora dieback changes the structural complexity and floristic composition of these ecosystems and how in turn these changes impact on other aspects of the biotic and abiotic components of these ecosystems; and lastly discusses the methods used to reduce the spread and impact of the pathogen.

Discussion

There is still much to be understood about the disease dynamics of *P. cinnamomi* in the different plant communities in which it impacts. However, it has become apparent that it is an extremely 'plastic' organism and its biology and pathology can vary between ecosystems. In addition to warm and moist conditions, sporangium production by *P. cinnamomi* also requires stimulatory factors, which are influenced by soil type and associated soil flora, to be present. In all soil types, the capacity to stimulate sporangia formation changes with season and tends to be greatest in summer and least in winter. Sporangia production also tends to be greater under susceptible plant species than under resistant plant species. Whether these differences are due to the presence of particular microflora, the composition of root exudates or combinations of both is still to be full ascertained, and still remains one of the least known aspects affecting sporulation in the jarrah forest. Little is also known of how *P. cinnamomi* sporulates from different hosts, although, the highly susceptible *Banksia grandis* contributes to the build up of inoculum in the soil.

There are only three clonal lineages of *P. cinnamomi* in Western Australia (Dobrowolski 1998), but there is considerable variation in the pathogenicity of isolates between regions, as shown for jarrah forest isolates (Huberli et al. 2002a, b). This indicates that strict hygiene and quarantine measures should be continued to ensure pathogenic isolates are not spread to areas with less pathogenic isolates. Little is known about the role of the resting spores, chlamydospores, in survival of the pathogen over the long dry summers and in the absence of susceptible hosts; there is still debate about their role in the jarrah forest (McCarren et al. 2005) where research has been undertaken for over 40 years. *P. cinnamomi* requires two mating types (A1 and A2) in order to undergo sexual reproduction to produce long-lived oospores. In the majority of plant communities, only the A2 mating type is present. However, in the Fitzgerald River National Park, on the south coast, the A1 mating type is dominant and the A2 mating type is rarely isolated. Recent work has shown that under *Acacia pulchella*, a resistant host, oospores are produced by selfing (Jayasekera et al. 2007). This observation raises many interesting questions about the possible role of the long-term survival of the pathogen, especially as it has been shown to be a poor saprophyte in jarrah forest soils (McCarren et al. 2005). More work is required to determine how many isolates are able to self and produce oospores, how widespread this occurs and what floristic components may be triggering the process. Oospores have the ability to survive many years in the absence of hosts and optimal environmental conditions.

Management of *P. cinnamomi* remains a daunting task as we have few tools available to reduce the extension, spread and impact of the pathogen and the diseases it causes. Additionally, management is underpinned by our current understanding of the pathogen's biology, ecology and epidemiology. Management strategies must include components of prevention, treatment, restoration and conservation. Monitoring is a major tool for successful management. Initial activities involve the use of 230 mm-format large scale, aerial photography (nominally 1:4,500 scale) to identify areas of dying vegetation. Trained dieback 'interpreters' validate aerial photography interpretation by ground survey. The interpreters map areas that are (a) infested with the pathogen, (b) are free of *P. cinnamomi*, (c) cannot be interpreted, as the presence or absence of the pathogen cannot be ascertained, (d) unprotectable – areas which are infested and those areas where it is judged that autonomous spread of the pathogen will occur within 50 years, and (e) protectable – free of the pathogen and likely to remain so. Field data are transferred to a base map and subsequently into Geographical Information Systems (GIS). This information is then the basis for compiling disease location maps, determining management strategies and deploying risk mitigation tactics, including hygiene and quarantine management to control the disease (Dell et al. 2005). Management of the pathogen places great emphasis on intensive pre-operation planning of any activities involving earth moving or the potential to move soil. These include mining, road building or maintenance, timber harvesting, vehicle movement along gravel roads, and construction of gas and powerlines. This is followed by a monitoring and auditing process, to assist in assessing the effectiveness of the plans.

More recently, the low cost and low toxicity chemical phosphite (neutralised phosphorous acid) has been used very effectively, applied as a trunk injection or low or high volume foliar spray, to reduce the rate of spread and impact of *P. cinnamomi* (Hardy et al. 2001). Phosphite induces a host defence response in many susceptible plant species. The protective effect can last between six months and six to eight years. The mechanisms behind phosphite's mode of action remain to be determined. However, it does provide a very strategic tool to manage rare or threatened plant species and or plant communities as well as preserve iconic trees, until we find more effective and persistent methods to control the pathogen.

In summary, *P. cinnamomi* is a major threat to many different ecosystems in south-western Australia. It has considerable direct impacts on many plant species causing loss of structural assemblages and its indirect impacts on resistant flora, fauna and ecosystem function remain largely unexplored or understood. Considerable work is being undertaken on (a) developing eradication methods, (b) improving the efficacy of phosphite, (c) understanding at a molecular and biochemical level the mechanisms of action of phosphite, (d) how host physiology (e.g. after fire, drought, waterlogging, phenological changes) at time of phosphite application affects phosphite's ability to contain the pathogen, (e) the use of Digital Multispectral imagery to map disease caused by *P. cinnamomi,* (f) developing effective rehabilitation strategies, (g) selection of resistant plant genotypes for rehabilitation purposes and (h) impacts on keystone animal species. Without continued integration of targeted research with strategic and operational management options, *P. cinnamomi* will continue to have a major impact on ecosystem health and function in Australia, particularly in areas of Mediterranean climate.

References

Carter R. 2004. Arresting Phytophthora dieback: the Biological Bulldozer. WWF-Australia, Sydney.

Dell B and Malajczuk N. 1989. Jarrah dieback – a disease caused by *Phytophthora cinnamomi.* Pages 67-87 in B Dell, J Havel and N Malajczuk editors. The Jarrah Forest. A Complex Mediterranean Ecosystem. Kluwer Academic Publishers, Dordrecht.

Dell B, Hardy G and Vear K. 2005. History of *Phytophthora cinnamomi* management in Western Australia. Pages 391-406 in MC Calver, H Bigler-Cole, G Bolton, J Dargavel, A Gaynor, P Horwitz, J Mills and G Wardell-Johnson editors. A forest conscienceness: Proceedings of the 6th National Conference of the Australian Forest History Society. Millpress Science Publishers, Rotterdam.

Dobrowolski M, Tommerup I and O'Brien P. 1998. Microsatellites in the mitochondrial genome of *Phytophthora cinnamomi* failed to provide highly polymorphic markers for population genetics. FEMS Microbiology Letters 163:243-248.

McCarren K, McComb J, Shearer B and Hardy G. 2005. The role of chlamydospores of *Phytophthora cinnamomi*- a review. Australasian Plant Pathology 34:333-338.

Garkaklis M, Calver M, Wilson B and Hardy G. 2004. Habitat alteration caused by introduced plant disease: a significant threat to the conservation of Australian forest fauna. Pages 899-913 in D Lunney, Editor. Conservation of Australia's forest fauna Royal Zoological Society of NSW, Mosman, NSW.

Hardy G, Barrett S and Shearer B. 2001. The future of phosphite as a fungicide to control the soil-borne plant pathogen *Phytophthora cinnamomi* in natural ecosystems. Australasian Plant Pathology 30:133-139.

Huberli D, Tommerup I, Calver M, Colquhoun I and Hardy G. 2002. Temperature and inoculation method influence disease phenotypes and mortality of *Eucalyptus marginata* clonal lines inoculated with *Phytophthora cinnamomi*. Australasian Plant Pathology 31:107-118.

Huberli D, Tommerup I, Colquhoun I and Hardy G. 2002. Evaluation of resistance to *Phytophthora cinnamomi* in seed-grown trees and clonal lines of *Eucalyptus marginata* inoculated in lateral branches and roots. Plant Pathology 51:435-442.

Jayasekera A, McComb J, Shearer B and Hardy G. 2007. *In planta* selfing and oospore production of *Phytophthora cinnamomi* in the presence of *Acacia pulchella.* Mycological Research 111:355-362.

Shearer B L and Tippett J T. 1989. Jarrah Dieback: the Dynamics and Management of *Phytophthora cinnamomi* in the jarrah (*Eucalyptus marginata*) Forest of South-western Australia. Department of Conservation and Land Management, Research Bulletin No. 3. 76 pages.