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Special Contribution

COST Action FP0801 – established and emerging Phytophthora: increasing threats to woodland and forest ecosystems in Europe†

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Summary: With the rapidly growing international trade in plants and ongoing impacts of climate change, impacts of plant pathogens in the genus *Phytophthora* are increasing, threatening the biodiversity and sustainability of European forest ecosystems. Through the European Cooperation in Science and Technology (COST) framework Action FP0801, scientists and disease-control experts are working on phytophthora in forest ecosystems with the overall aim of increasing understanding of the biology and ecology of *Phytophthora* species with potential to cause damage to European forestry. This knowledge will be used in the development of effective control and management protocols for the problems caused. Outcomes of the Action will be promoted in an effort to increase knowledge and awareness of the problem by disseminating information to end-users and authorities in the forestry sector, and to the general public. Four interrelated working groups have been established to (i) examine the ways in which *Phytophthora* species spread into and within Europe; (ii) determine how phytophthoras kill woody plants and elucidate mechanisms for host resistance; (iii) disseminate state-of-the-art rapid molecular diagnostic techniques, and (iv) seek sustainable protocols for management and control of the diseases. The project is expected to increase understanding of threats to forest ecosystems by phytophthora, improve the ability to rapidly detect phytophthora in environmental samples, and provide sustainable management solutions to the diseases caused by these destructive organisms.

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Introduction

Forest and woodland ecosystems throughout the world are under serious threat from increasing numbers of decline and dieback syndromes. Dieback is the rapid mortality of forests, whereas decline describes reduced overall vigour, usually of the dominant or climax tree species, in the ecosystem (Ciesla & Donaubauer, 1994). These problems appear to be exacerbated under the present conditions of rapid climatic change. A range of abiotic and biotic factors may be involved in decline and dieback phenomena, but certain pathogens appear to be of particular importance. Current models of climate change predict rises in average rainfall and temperatures, and more pronounced differences in seasonal precipitation for many parts of Europe. These are all changes that will encourage increased disease problems particularly in poorly adapted ecosystems (Deprez-Loustau et al., 2007). Moreover, the latitudinal climatic ranges of pathogens will be altered: increased temperatures will enable survival and activity at higher latitudes than in the past (e.g. Brasier & Scott, 1994); increased precipitation coupled with alterations in seasonal precipitation and higher temperatures further exacerbates this problem (Coakley et al., 1999). The overall outcome of these changes will be, at best, reductions in sustainable yields from, and amenity values of the affected forests, at worst large areas of forest could suffer decline and dieback, as witnessed with jarrah dieback in Western Australia (Shearer & Tippet, 1989).

Introduced invasive *Phytophthora* spp. are consistently associated with the most significant forest declines all over the world. Jarrah dieback is caused by *P. cinnamomi* Rands, a particularly virulent and widespread pathogen with a recorded host range of several thousand plant species (Shearer et al., 2004; Hardham, 2005). *Phytophthora lateralis* Tucker & Milbrath emerged in Oregon, USA in the early-mid twentieth century and has totally altered forest productivity in the north-western USA. Specifically, it has seriously reduced the amounts of *Chamaecyparis lawsoniana* (Murr.)Parlatore timber available to both local and international forest industries (Hansen et al., 2000). This species has also been reported in France (Hansen & Delatour, 1999). Recently, Brasier et al. (2010) provided evidence that *P. lateralis* is native to Taiwan and probably other regions of south-east Asia and was introduced to the north-western USA. Examples in Europe include ink disease of sweet chestnut (*Castanea satina* Mill.) and the recently emerging problems of oak decline. Ink disease is caused by *Phytophthora cambivora* (Petri) Buisman (Vettraino et al., 2001; 2005) and *P. cinnamomi*, while *P. quercina* Jung is frequently a primary factor in oak decline, sometimes in combinations with other *Phytophthora* species (Jung et al., 1999, 2000). Riparian alders in Europe are suffering from a lethal root and collar rot disease caused by a novel heteroploid hybrid *Phytophthora, P. alni* Brasier, which was first noted in south-east England in the early 1990s but spread throughout northern and central Europe within less than 10 years (Brasier et al., 2004). More recently, beech decline has been associated with a number of invasive *Phytophthora* species (Jung et al., 2005; Jung, 2009). Newly recognised threats include, amongst others, the aerial pathogens *P. ramorum* Werres, De Cock & Man in't Veld and *P. kernoviae* Brasier, Beales & S. A. Kirk. First characterised in a Dutch – German collaboration in 2000 (Werres et al., 2001), *P. ramorum* causes widespread disease on a range of tree species, and is particularly noted for the 'Sudden Oak Death' phenomenon in Oregon and California, USA (Rizzo et al., 2005). Two other species of *Phytophthora*, *P. nemorosa* E.M. Hansen & Reeser and *P. pseudosyringae* T. Jung & Delatour are sometimes associated with *P. ramorum* outbreaks in the Pacific North-West USA (Wickland et al., 2008); *P. pseudosyringae* was first recorded in Europe (Jung et al., 2003). *Phytophthora ramorum* is commonly intercepted by plant quarantine authorities in European countries and is considered a great threat to European forest ecosystems. In 2009, *P. ramorum* was found on Japanese larch (*Larix kaempferi* (Lamb) Carriere) in the UK, causing a lethal needle blight which forced the premature harvesting of more than 2000 ha of larch (Brasier & Webber, 2010). *Phytophthora kernoviae* was first formally recorded in 2003 in the south-west of the UK where it causes serious stem cankering and dieback on both beech and rhododendron (Brasier et al., 2005). However, it has since been identified as matching an unnamed *Phytophthora* species recovered from soil over 50 years ago in a planted exotic forest in New Zealand (Ramsfield et al., 2009). In 2007, it was confirmed that a new needle disease occurring in 60,000 ha of radiata pine plantations in Chile was caused by a previously unrecognised species of *Phytophthora*, now formally named *P. pinifolia* A.Durán, Gryzenh. & M.J.Wingf. (Durán et al., 2008).

Spread of *Phytophthora* species between countries and on an intercontinental scale undoubtedly results from human activities (Brasier, 2008). Trade in live plant materials, through horticulture, is the most likely route for long-distance transmission between affected and unaffected areas. For example, *P. cinnamomi* was first recorded on dying cinnamon (*Cinnamomum burmanii* Blume) trees in Sumatra in 1922, although this pathogen was already widespread in the world at that time. Currently, it is known on all continents. Outside the horticulture industry, the biggest problem in Europe appears to be the dieback caused to oak species in Spain and Portugal, although *P. cinnamomi* has been recorded recently in latitudes as high as the north of Scotland (Chavarriaga et al., 2007). Another recent example of the spread of *Phytophthora* species is the *P. citricola* Sawada complex, which is posing a serious threat to forests and natural ecosystems in Europe. Four taxa from this complex are now known to have been introduced through the European nursery trade. These are *P. citricola* I and *P. citricola* III, which are most likely native to North America, *P. plurivora* T.Jung & T.I.Burgess probably native to Asia, and *P. multivora* Scott, P.M.Scott

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& T.Jung which is most likely native to Australia The latter two species also cause dieback and mortality of a wide array of host plants in Europe and Western Australia, respectively (Jung & Burgess, 2009).

There are significant gaps in our understanding of the mechanisms underpinning the success of these aggressive and invasive pathogens. What are the relative invasive potentials of different species of *Phytophthora* threatening forests? What are the specific host-pathogen-environment interactions that promote the virulence of *Phytophthora* spp.? How can the species be rapidly and accurately diagnosed? What can be done to improve the management and control of phytophthora problems in the forest?

Increasing demand for both ornamental and forest/woodland trees with the concomitant increase in nursery production, and trade and distribution of susceptible woody plants has provided opportunistic pathways for the rapid spread of established species and allowed the introduction of several previously unknown alien species (Brasier, 2008). The number of previously unrecognised species of *Phytophthora* being described is increasing rapidly, and it is likely that there could be as many as 500 – 600 still awaiting discovery and characterisation (Brasier, 2009).

Much evidence indicates that climate change and increased occurrence of weather extremes are major factors in the rising incidence of phytophthora problems (Brasier & Scott, 1994; Jung et al., 2000; Jung, 2009). Current models predict a wide expansion in the distribution and impact of damaging *Phytophthora* spp. in Europe over the next 25 – 50 years (Marçais et al., 2004; Desprez-Loustau et al., 2007). Even the minimal climate changes predicted in some models suggest significant increases in the activity of *P. cinnamomi*, with a concomitant expansion in range eastward from the Atlantic coastline.

Mitigation of current and future impacts of *Phytophthora* spp. on ecosystems in Europe requires a concerted, multidisciplinary approach, combining ecology, epidemiology, diagnostics and control. Knowledge transfer to and from relevant organisations outside Europe is also required to strengthen international networks in plant quarantine and disease control, further protecting European ecosystems in the future. An interdisciplinary network within Europe, COST Action FP0801 has been set up to unite scientists, extension workers and end-users. This network provides hitherto unparalleled potential for collaborations addressing the problem of phytophthora at the European scale, thus reducing the likelihood of major epidemics. Improved understanding of the biology, ecology and impact of these damaging organisms will significantly improve our ability to manage current dieback and decline outbreaks, and to reduce the likelihood of future outbreaks.

The aim of COST Action FP0801 is to increase understanding of the biology and ecology of *Phytophthora* species with potential to cause damage in European forest ecosystems in order to improve our abilities to manage problems as they arise. The Action also provides a platform for enhancing collaboration between the European and wider international research community focused on phytophthora problems in woody plants. The objectives of the Action are to: (1) determine likely routes of spread of phytophthora into and within Europe and to establish an efficient and interactive monitoring system; (2) examine the physiological reasons for the development of rapid and lethal symptoms of disease following infection; (3) disseminate state-of-the art methods for rapid diagnosis of phytophthora infections at the individual tree and ecosystem levels; and (4) seek novel, ecologically benign techniques for management and control of these diseases.

Structure of the Action

The objectives will be achieved through a combination of literature searches and experimental work, carried out within nationally funded programmes.

- Working groups will review and collate current knowledge, with continual updating based on results emerging from extant nationally and EU-funded research projects.

- Collating the results of individual programmes in different working groups within the COST Action will enable pooling of effort on a much larger scale than would be possible in national projects alone.

- Knowledge gained in the Action will be transferred to end-user groups through the Action web site, through the production of information leaflets, via end-user-specific workshops to be held during the course of the Action and during the final Action conference.

- A major objective is to develop sustainable, ecologically acceptable control concepts for amelioration of infections through management interventions in affected ecosystems. The development and deployment

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of these measures will flow from both current national and EU research projects, and from the information gathered in the Action. To achieve this objective, the input from research groups in Australia and the USA with long-term and large-scale experience in the management and control of phytophthora diebacks in natural ecosystems is crucial. All data will be collated in the Action to establish a pathways approach to managing the threat of phytophthora to European forest ecosystems.

Four working groups have been established, each addressing several different aspects of phytophthora biology or management:

1. **Invasive Potential and Ecology**: including nursery-nursery and nursery-forest pathways for distribution of *Phytophthora* spp., and subsequent ecological adaptations and economic impacts. Potential sociological impacts of infections will also be considered. A European map of phytophthora impact in natural and semi-natural ecosystems will be developed.

2. **Host-Pathogen Interactions**: why do phytophthora infections result in such devastating consequences for infected trees? How do individual hosts resist infection? The outcome of this work on host parasite-interactions will be the basis for resistance breeding programmes.

3. **Diagnostics**: methods for rapid and accurate diagnosis of *Phytophthora* spp., quantification of infections, and genetic variability within and between species.

4. **Management and Control**: sustainable, ecologically acceptable control techniques and management concepts for amelioration of infections in affected ecosystems.

Data from the Working Groups will be used to prepare a case for a pathways approach to preventing imports of alien *Phytophthora* spp. into Europe, and for better management of pathways of spread within Europe.

Activities to be undertaken within the Action include:

1. **Scientific meetings** where working groups can discuss current research findings; these meetings are held in conjunction with management committee meetings, workshops and, when possible, training schools.

2. **Short-term scientific missions** (STSM): short-term exchanges between laboratories enable 'early stage' researchers (usually within eight years of obtaining their PhD) to spend time in another laboratory learning new techniques.

3. **An international conference**, to be held near the end of the Action in 2012, focused on: (i) potential threats of *Phytophthora* species to forest ecosystems; and (ii) management of pathways for transfer of *Phytophthora* spp. in international trade. Up to five experts from non-COST member countries will be invited to attend this conference to give keynote presentations. The proceedings of this conference will be published as a peer-reviewed book.

4. **Workshops** occur once per year to discuss phytophthora problems on trees, to disseminate up-to-date information to both the scientific and end-user communities. A workshop held early in 2012 will be targeted specifically at forest managers and policy-makers, to focus on their needs and provide them with up to date results of the four working groups. Up to three experts from non-COST member countries will be invited to attend each of these workshops to give keynote presentations.

5. **Training schools** to give training in sampling, characterisation and identification techniques to up to 30 early-stage researchers through field and laboratory work at a specified host institution.

6. **Creation of Databases** in the working groups, which will be made available via the web.

7. **Publicity**: a website is already running for the dissemination of Action results (www.abdn.ac.uk/woodland-threats/). Proceedings of two conferences will be published as a single volume after the conclusion of the Action in 2012.

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Conclusions

It is European Uniion (EU) policy to protect, enhance and maintain sustainability of natural and semi-natural ecosystems (European Union, 2006). The influx of damaging *Phytophthora* spp. presents an unprecedented threat to these aims throughout European forests. In the absence of a strong commitment to managing and controlling phytophthora, the damage resulting will seriously undermine products and services, both ecological and economic, provided by European forests, as illustrated by the severe outbreaks of *P. cinnamomi* in Western Australia, *P. lateralis* in the Pacific North West of North America and *P. ramorum* in California.

Numerous social and scientific benefits will arise from the Action. Societal benefits include the healthier forest estate, protection of biodiversity, increased yields of high quality timber, better protection of water catchments and consequent amelioration of flood potential, improved employment prospects throughout the sector and lowering of public concern over forest losses. Uniting the scientific community working on phytophthora problems in Europe under a single Action is enabling scientists to interact more freely, exchanging ideas and disseminating new techniques of, for example, diagnosis more rapidly to other groups. Moreover, involvement of end-user groups promotes better uptake of technological advances in management and control of phytophthora, including improved detection and quarantine procedures at ports of entry. Experts in the impacts of *Phytophthora* spp. on forest ecosystems in North America, South Africa and Australasia are also participating in the Action.

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