Plant disease research in the Department of Conservation and Land Management

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Abstract

Plant disease research in the Department of Conservation and Land Management (CALM) aims to predict the occurrence and development of plant diseases under different site, climatic and management conditions, and develop methods of control. Much of the earlier plant pathological research in native plant communities was mainly involved with wood-decay fungi in the 1930s, and an explanation for the cause of jarrah death during the 1940s to 1960s.

By the late 1960s, Dr F.D. Podger's discovery of the association between the pathogen Phytophthora cinnamomi *and jarrah dieback provided the stimulus for plant disease research on the distribution of* P. cinnamomi *throughout Australia and the effects of environment on disease. Past research on* P. cinnamomi *can be divided into the following broad areas of highest priority: monitoring disease behaviour in relation to environment, pathogen development in the soil, detection of infested areas using aerial photography, host interactions, and prediction of hazard.*

In 1985, the departments of Forests, National Parks and Wildlife were amalgamated to form CALM. With the adoption of a program structure by the department's Research Division in 1988, research on plant diseases was consolidated into the Plant Diseases Program. Research projects on Armillaria luteobubalina, *canker fungi, and* Phytophthora *species were grouped under six primary objectives: diagnosis, assessment of damage, disease dynamics, disease management, control and communication. In order to facilitate interactions within research, the Plant Disease Program was disbanded in 1991. Current research on plant diseases in conservation areas was amalgamated with the Flora Conservation Program while research related to silviculture, plantations and nurseries was amalgamated with the Silviculture Program. Current and future research must integrate knowledge of behaviour of the pathogen and reaction of the host with new technologies like biotechnology. While the advanced tools and techniques of biotechnology offer promising options for the future, application needs more information of the genetics of pathogen and host. Thus basic plant pathological research on the behaviour of the pathogen and reaction of the host will have to be relied on for some time to come.*

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Introduction

Plant diseases caused by introduced *Phytophthora* species, *Armillaria luteobubalina* and canker fungi are a major threat to the ecology and conservation of many plant communities of southwestern Australia (Shearer, 1992). Development of effective control strategies requires knowledge of the biology of plant diseases in our native communities and the consequences of environmental changes resulting from mining, logging, fire, recreation pressure, insect pests, and climate. Plant disease research in the Department of Conservation and Land Management (CALM) aims to predict the occurrence and development of plant diseases under different site, climatic and management conditions, and develop methods of control. This paper describes the history, structure and accomplishments of research on plant diseases by CALM, incorporating the Western Australian Forests Department since the 1960s.

Historical perspectives

Pre-1960s

Much of the earlier plant pathological research in native plant communities was mainly involved with wood-rotting fungi in the 1930s, and an explanation of the cause of jarrah death during the 1940s to 1960s. In the early 1920s, unexplained deaths of jarrah (*Eucalyptus marginata*) and understorey species were observed near Karragullen 35 km southeast of Perth (Podger, 1968). These deaths were the earliest report of what is now commonly called "jarrah dieback". It was not until the mid-1960s that Dr F.D. Podger firmly established the association between death of jarrah and infection by the introduced soil-borne fungus *P. cinnamomi*.

Jarrah dieback

The discovery of the association between *P. cinnamomi* infection and jarrah dieback (Podger *et al.*, 1965) had far-reaching influences on the public and research priorities. By the late 1960s, Podger's breakthrough provided the stimulus for plant disease research on the distribution of *P. cinnamomi* throughout Australia and the effects of environment on disease. Historically, the threat that *P. cinnamomi* infection posed to timber production and protection of water catchments received greatest attention. Thus more is known of the interaction between *P. cinnamomi* and the jarrah forest than for other *Phytophthora* species and plant communities, and diseases caused by Armillaria and canker fungi. Our current understanding of the various interactions between *P. cinnamomi* and the jarrah forest ecosystem has been reviewed by Shearer & Tippett (1989).

Past research on *P. cinnamomi* can be divided into the following broad areas of highest priority:

- monitoring disease behaviour in relation to environment,
- pathogen development in the soil,
- detection of infested areas using aerial photography,
- host interactions, and
- prediction of hazard.

Initially, greatest emphasis was given to monitoring soil temperature and moisture to identify sites and seasons when conditions were most favourable for survival and sporulation of the pathogen and infection (*e.g.*, Christensen, 1975; Shea, 1975; Schuster, 1978). Symptoms were used mainly to monitor changes of the pathogen with time (e.*g.*, Shea & Dillon, 1980).

With improvements in selective agars and baiting techniques, the emphasis shifted to quantifying the effects of season, site and modification of the environment through manipulation of understorey composition on population levels of *P. cinnamomi* in the soil (*e.g.*, Shea *et al.*, 1978, 1980; Shearer & Shea, 1987). The importance of *Banksia grandis* as reservoirs of inoculum and a buffered environment for survival of the fungus was determined. Knowledge gained aided the development of hygiene prescriptions aimed at preventing the spread of the fungus, and the use of *B. grandis* as indicator plants in the interpretation of aerial photographs.

In the mid-1960s, disease distribution was mapped from black and white aerial photographs (Batini, 1973). Disease areas were recognised by a reduction in forest density caused by death of susceptible species and boundaries were determined. The accuracy of the maps varied from area to area depending on the original forest density and the scale and quality of the aerial photographs. By the late 1970s, the accuracy of detecting and mapping disease distribution was greatly increased by the development of 70 mm shadowless colour aerial photography (Bradshaw & Chandler, 1978). Muir (1984) described in detail the methods of photography and mapping. Disease boundaries could be accurately plotted onto 1:25,000 maps following identification of dead indicator species from the film, field checking, and sampling and recovery of *P. cinnamomi* in the laboratory from sampled soil and plant material. In the 1980s, mapping has been facilitated by the use of 230 mm colour shadowless aerial photographs.

In the mid-1970s, northern jarrah forest with little disease in high salt hazard areas was quarantined. Significant progress was made by the mid-1980s in the development of hygienic procedures and application to all operations in the forest as well as national parks and nature reserves.

Plant disease research was stimulated in the early 1980s by funding from a Foundation for Jarrah Dieback Research financed by the alumina and timber industries. The formation of the foundation was partly in response to concerns that bauxite mining was intensifying dieback and that the quality of Perth's water supply would deteriorate should disease extend into catchments with high salt hazard (Shea, 1988). Research areas funded by the foundation included jarrah forest ecology, understorey manipulation, host response to infection, tissue culture of jarrah, and activity of *P. cinnamomi* in the soil. Unfortunately, the end of the foundation in 1987 resulted in many groups discontinuing active plant-disease research. In the few remaining centres, research continued to improve knowledge on the impact of disease on conservation and resource management values, the major stimuli affecting disease development, and methods of control.

In 1982, *P. cinnamomi* was found at depth within the profile, commonly just above a horizon that impeded vertical percolation of water in upland areas of the jarrah forest (Shea *et al.*, 1983). This finding changed the accepted perception that the pathogen was mainly a surface-soil inhabitant. Emphasis was therefore given to determining the effects of soil profile characteristics on subsurface lateral movement of water and behaviour of *P. cinnamomi* at depth in the soil (Kinal, 1986). For the first time, disease behaviour in upland areas could be related to site characteristics that influenced pathogen sporulation, survival and dispersal, and the infection of jarrah. The determination of key site indicators that could be used to predict disease hazard was a high priority (Shearer *et al.*, 1987a; Grant & Blankendaal, 1988).

Research up to the 1980s concentrated on the behaviour and biology of *P. cinnamomi* with little attention being given to the physiology, growth and performance of jarrah, particularly in the presence of the fungus. In the past, conditions that favoured sporulation of the fungus in the soil and infection were often confused with those that affected symptom expression. In the first investigation of *P. cinnamomi*, Rands (1922) described invasion of woody tissue, but the relevance of this observation for Eucalyptus species was not appreciated until the early 1980s (Dell & Wallace, 1981; Marks *et al.*, 1981; Shearer *et al.*, 1981). Recognition that *P. cinnamomi* could invade the woody tissue of jarrah led to greater emphasis on the interactions between host and pathogen. Lesion development and resistance mechanisms in jarrah roots were described (Tippett *et al.*, 1983, 1985; Tippett & Hill, 1984), and the importance of host water-status on the host pathogen interaction identified (Tippett *et al.*, 1987). This work led to studies on the relationships between the ecophysiology of jarrah and infection (Crombie *et al.*, 1987, 1988).

While most of the research on disease in the jarrah forest concentrated on *P. cinnamomi*, there was a growing appreciation by the mid-1980s of the importance of other pathogens in the forest. A number of pathogenic fungi associated with stem and branch cankers of forest trees were identified (Davison & Tay, 1983; Shearer *et al.*, 1987b). The impact and distribution of *Armillaria luteobubalina* were documented (Shearer & Tippett, 1988).

Department of Conservation and Land Management

In 1985, the Departments of Forests, National Parks and Wildlife were amalgamated to form CALM. With the adoption of a program structure by the department's Research Division in 1988, research on plant diseases was consolidated into the Plant Diseases Program. The aims of the programme were to:

- "diagnose causes of disease;
- investigate the conditions that favour the increase and spread of pathogens;
- determine the effects of disease on the health, growth and reproduction of plants in native communities, plantations and nurseries, and on the quality of timber; and
- develop methods for control of disease".

The Plant Disease Program essentially evolved from the research described above on *P. cinnamomi* in the jarrah forest. However, research within the program also recognised that *P. cinnamomi* was a destructive pathogen in woodlands and heaths, and that *Phytophthora* species other than *P. cinnamomi* threatened plant communities in southwest of Western Australia. Pathogens other than *Phytophthora* were not ignored and research included *Armillaria luteobubalina*, the cause of death of a wide range of woody plants, canker fungi causing crown decline, and decay fungi destroying the quality of wood. Research projects within the program were grouped under six primary objectives:

- diagnosis,
- assessment of damage,
- disease dynamics,
- disease management,
- control and
- communication.

Research was aided by funding from Alcoa of Australia Ltd for projects on *P. cinnamomi* survival and water relations in jarrah, and also heavy-mineral sand-mining companies for a project on oospore production by *Phytophthora* species.

Members of the program have been involved in general enquires relating to diagnosis of disease for operational and nursery staff. The program maintained the Detection Service of CALM which tests over 1000 soil samples per year for the presence of *Phytophthora* species. The service maintains a high level of accuracy in dieback mapping and of hygiene in CALM's operations and nurseries. Improved methods of oospore production by *Phytophthora* species have been determined to facilitate identification.

Assessment of the economic and conservation importance of diseases has identified a number of priority areas. Hill (1990) showed the distribution and importance of *Phytophthora* species in the Northern Sandplains. Databases on the distribution and susceptibility of hosts have been developed for *Phytophthora* species and *Armillaria luteobubalina* in forests, woodlands and heaths. The threat of canker fungi to *Banksia* communities have been described.

Disease dynamic research has contributed to an understanding of the effect of environment on survival, increase and dispersal of pathogens, the infection of plants, and expression of host resistance. Such knowledge is important for the assessment of risk of infection and development of effective methods of control. Research within the program has compared the population dynamics of *P. cinnamomi* in *Banksia* woodlands with that in the forest, compared survival of *P. cinnamomi* zoospores in bauxite pits, forest, and Banksia woodlands, and determined the effects of site hydrology on dispersal of *Phytophthora* species.

Disease management research determined the effects of management practices, climate, site, and host susceptibility on consequences of disease in plant communities, plantations and nurseries. Projects investigated the development of a hazard system for *P. cinnamomi* in the jarrah forest, water relations of jarrah and lesion development of *P. cinnamomi*, soil temperature relations in jarrah forest soils, and selection of *P. cinnamomi* resistance in jarrah.

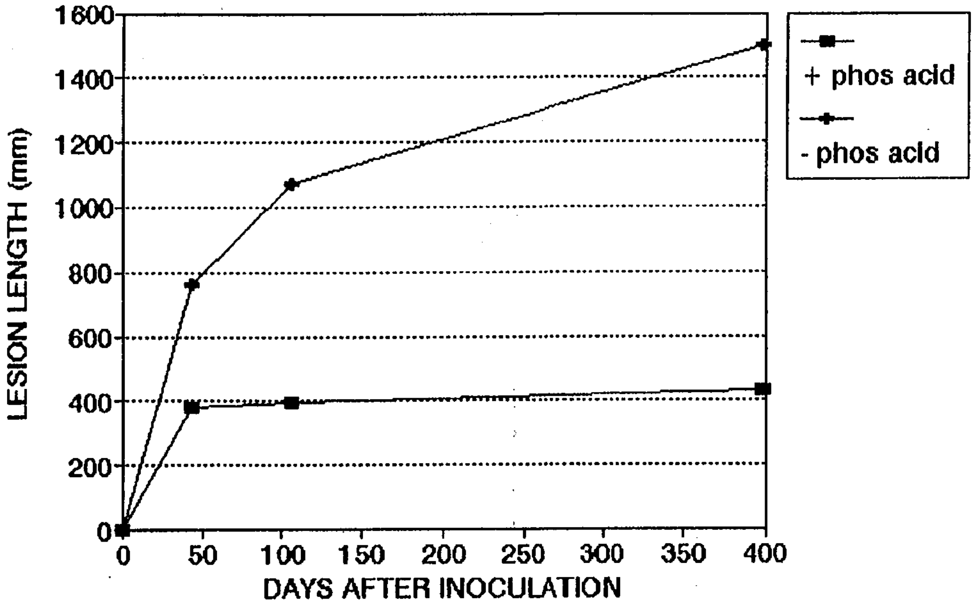

FIGURE 1. Inhibition of lesion growth of *Phytophthora cinnamomi* in stems of *Banksia grandis* trees injected with 10% "phosphorous acid" compared with lesion growth in trees receiving no fungicide. Most of the infected trees receiving no fungicide had died within a year. Lesions in trees treated with fungicide were completely contained by the tree's defence mechanisms.

Considerable progress has been made in the use of the fungicide "phosphorous acid" (see Freeman, this volume) to control *Phytophthora* species in native communities. *Banksia grandis* treated with "phosphorous acid" contained infection by *P. cinnamomi*. In comparison, infection by *P. cinnamomi* killed untreated trees within 12 months (Figure 1). Effectiveness, methods of application, and dosage have been determined for a range of plant communities.

Results of research have been communicated in the form of publications, popular and scientific talks, reviews of the current state of knowledge, and a video-recording on dieback on the south coast region of Western Australia.

Current situation

In order to facilitate interactions within research, the Plant Disease Program was disbanded in 1991. Current research on plant diseases in conservation areas was amalgamated with the Flora Conservation Program while research related to silviculture, plantations and nurseries was amalgamated with the Silviculture Program. The Dieback Disease Detection Service was incorporated into Science Services. With the appointment of a new director in 1992, the Division is renamed the Science and Information Division.

Within the Silviculture Program, plant disease research is investigating wood decay in karri, and nursery and plantation problems as they arise. Current priorities within the Flora Conservation Program are investigation of the disease dynamics and options for control of *Phytophthora* species, *A. luteobubalina* and canker fungi in susceptible woodlands and heaths of the south-west. This research will include prioritising and targeting highly susceptible plant taxa for germ plasm storage, understanding the biology of the pathogens to support biotechnological approaches and development of management strategies, and localised containment and control of the disease. Research has been supported by a major grant from the Australian National Parks and Wildlife Service (Armstrong, 1991) and mining companies.

Current projects being researched include those listed below.

- Aerial application of the fungicide "phosphorous acid" to control *Phytophthora* species and the nature of the plants responses.
- Development of DNA probes by Murdoch University to improve diagnostic techniques for *Phytophthora* species.
- Assessment of predictive geographical information systems to identify priority areas and plant taxa.
- Biology of *P. citricola*, *P. megasperma* and *Diplodina* canker on *Banksia coccinea*, for the development of disease management strategies.

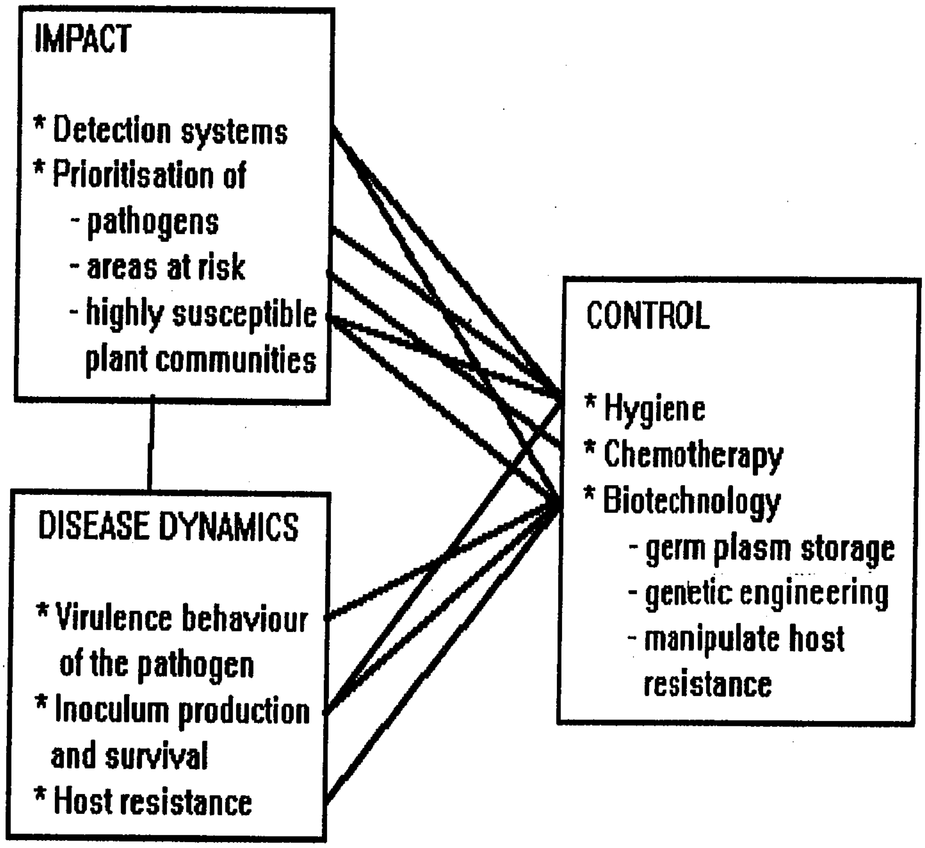

Figure 2. Some of the interactions between components for integrated research on plant diseases.

- Identification of the taxa and populations most at risk and development of methods for tissue culture and cryogenic long-term storage for eventual recovery.

Future options

Cost-effective methods are needed to control pathogens in native plant communities once established, without causing unacceptable damage to conservation values. Human actions affect different parts of the life-cycle of a pathogen to either aggravate or control disease. Care must therefore be taken to ensure that the management of plant communities does not consider a few pathogens to the exclusion of others that may occur.

Current and future research must integrate knowledge of behaviour of the pathogen and reaction of the host with new technologies like biotechnology (Figure 2). This form of integration requires and combines the expertise found in different research institutions and has been incorporated into the Australian National Parks and Wildlife Service grant described above. Although the advanced tools and techniques of biotechnology offer promising options for the future, their application needs more information on pathogen and host genetics. Thus, basic plant pathological research on the behaviour of the pathogen and reaction of the host will have to be relied on for some time to come.

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