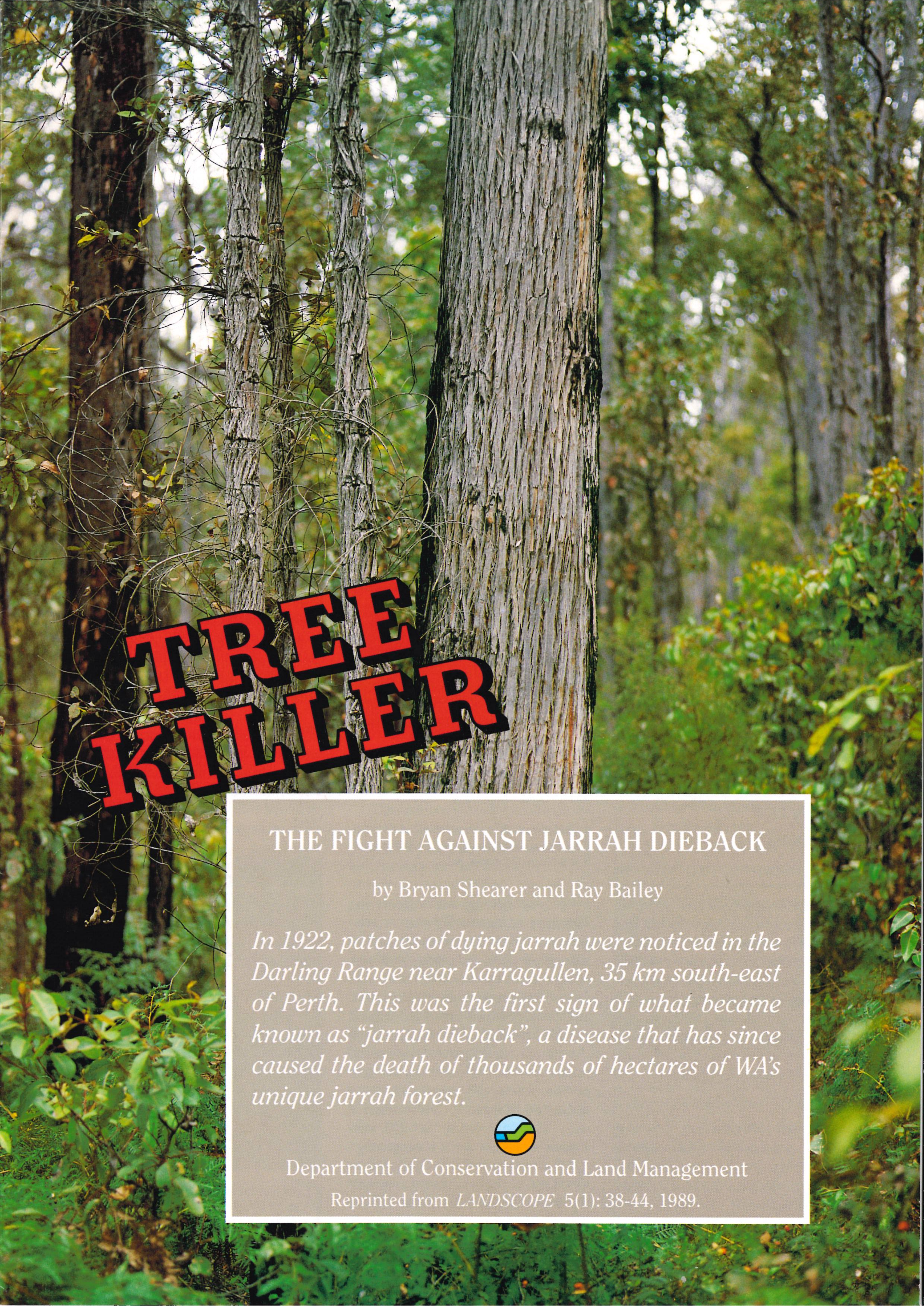


TREE KILLER

THE FIGHT AGAINST JARRAH DIEBACK

by Bryan Shearer and Ray Bailey

In 1922, patches of dying jarrah were noticed in the Darling Range near Karragullen, 35 km south-east of Perth. This was the first sign of what became known as "jarrah dieback", a disease that has since caused the death of thousands of hectares of WA's unique jarrah forest.

Department of Conservation and Land Management

Reprinted from *LANDSCOPE* 5(1): 38-44, 1989.

FOR half a century, the confusing behaviour of jarrah dieback was a big frustration for researchers. Susceptible understorey plants in affected areas died every year, yet jarrah died only sporadically. Then, for no apparent reason, swathes of forest would suddenly collapse. A forester would note the limits of a patch of dead jarrah, only to return in a fortnight to find the devastation advanced by as much as 50 m.

The destroyer was finally identified in 1965 by Dr Frank Podger as a killer fungus, *Phytophthora cinnamomi*. The disease is incurable, and has laid waste to large areas of trees, shrubs and plants in other parts of the world. Massive research was needed if the problem was to be curbed. The questions facing researchers were: How do we stop the fungus spreading? How do we detect it in the soil? How do we manage it, or even cure it? And how does it kill?

STOPPING THE SPREAD

Quite unknowingly, people spread the fungus throughout the South-West by moving infected soil. For example, before the fungus was identified, gravel from dieback areas was used in road construction. From the original small dead patches, the impact of the disease increased in range and severity. An estimated 280 000 ha of Crown land were infected by 1977.

QUARANTINE

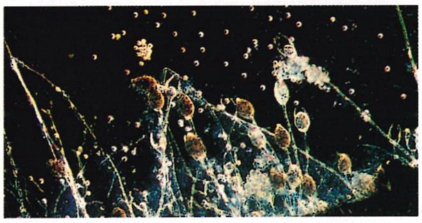
A comprehensive hygiene management program was developed in the late 1960s and large areas of forest were quarantined. Vehicle access was controlled by closing roads and restricting entry when damp soil was likely to stick to wheels and machinery. Washing down equipment became standard practice.

By preventing new infections and allowing existing ones to run their course, quarantine also aided the accurate mapping of disease distribution.

MAPPING

In the late 1970s, the development of 70 mm shadowless colour aerial photography greatly increased the accuracy of detecting and mapping disease distribution. Disease boundaries could be accurately plotted onto 1:25 000 maps, not only by sightings and by recovering *P. cinnamomi* from soil and plant samples, but also by identifying the deaths of susceptible trees and plants (indicator species) from the air. CALM staff were trained to interpret the photographs, and quickly became expert at mapping the patterns of death. By photographing the jarrah forest every few years, interpreters could identify every infection in the forest and locate areas for quarantine. Mapping further progressed with the development of 230 mm shadowless colour aerial photography.

The mapping system developed by CALM staff for the jarrah forest is arguably the most sophisticated forest disease detection technique in the world.



Mass collapse of jarrah occurred in the 1960s, 1970s and 1980s after summer rainfall fell in certain sites.
Photo - Bryan Shearer ▲▲

Spore sacs of *P. cinnamomi* release zoospores that swim in free water and infect nearby roots.▲

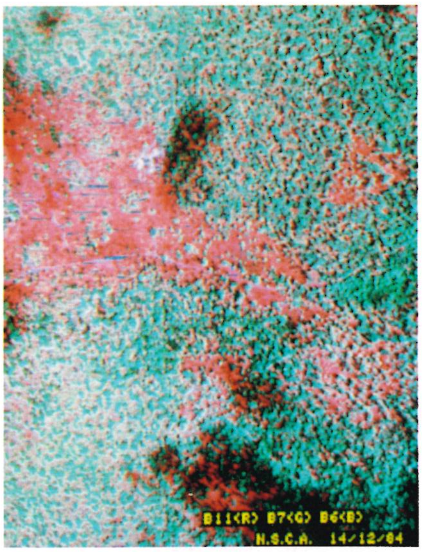
HYGIENIC FOREST OPERATIONS

Once the cause of the disease was known and its distribution mapped, all operations could be carried out hygienically to prevent the disease spreading.

Although various hygienic logging techniques were developed early in the 1970s, increased knowledge made a new system possible late in the decade. It was applied to all operations, including fire control, road construction and maintenance, and timber regeneration. Hygienic procedures were aimed at minimising the consequences if any one element in the system accidentally failed. The system has three main components: planning, exclusion and training.

In the planning phase, maps of disease distribution are used to plan the areas of operation and to determine the best hygiene methods to use. During the exclusion phase, roads are isolated and vehicle cleaning points established. Activities are confined to periods of least risk to minimise the spread of the fungus. Finally, staff are taught the biology of the fungus during their training in protective procedures.

Hygiene methods developed in State forests are now being adapted to mining and recreation areas as well as to national parks and nature reserves in the South-West.



False-colour imagery of jarrah forest. A large infected area shows up in red, while green represents healthy forest.

AN EARLY WARNING SYSTEM

Bull banksia (*Banksia grandis*) is widely distributed in the understorey of the jarrah forest. It provides a foodbase for the dieback fungus and is usually the first species to die in infected forest. This gives dramatic warning that the fungus is present. The extensive root system of bull banksia provides a "freeway" along which the growing fungus drives through the soil in summer - as much as one centimetre a day - when the surface soil is too dry and hostile for the fungus to survive. Reducing bull banksia therefore inhibits development of *P. cinnamomi*, exposing it to the withering summers. One of the aims of the Forest Improvement and Rehabilitation Scheme (FIRS), begun in 1978, is the reduction of bull banksia in the understorey. This treatment, planned by CALM and funded by ALCOA, is now being applied to forest adjacent to areas being mined for bauxite.

CAUGHT IN THE ACT

At first, researchers could not account for the long periods of apparent inactivity before and after the dieback fungus struck, the sudden ferocity of its onslaught when it did, and its neglect of some areas of jarrah compared with others.

What gave researchers the answer was rain - rain in the middle of summer. In January 1982, continuous rain soaked parts of the jarrah forest for two days. The conditions for the fungus to produce spores and grow were ideal: midsummer warmth combined with saturated soil. Nothing happened at that time; but between one and two years later, jarrah stands in that area collapsed. The fungus had struck.

Researchers and field workers redoubled their efforts, sampling roots, soil and plant material. Still they found no sign of the fungus until, almost as a last resort, they disregarded the accepted belief that the fungus was only active in the topsoil and dug deeper into the ground. With a jarrah tree excavated to reveal the tops of its vertical tap roots, the diseased tissues caused by *P. cinnamomi* were at last found - two metres below the surface along the top of a layer of solid subsoil (caprock). Other freshly killed jarrah was excavated, with similar results. The killer was finally caught in the act.

Bull banksia is one of the jarrah forest species most susceptible to dieback, and is the first to die in infected areas.
Photo - Cliff Winfield ▲

HOW DOES IT KILL?

The fungus was being spread in three ways: at surface level by human activity; through the laterally spreading roots of bull banksia; and several metres below ground, by water flowing through the soil on top of the caprock layer. Every time it rained the fungus was spread further, though not necessarily to every jarrah site. Once spread it lay dormant in the roots of trees and plants, ready to become active only when warmth and moisture occurred at the same time - rare conditions which applied during the major outbreaks of jarrah dieback observed during the fifties, sixties, seventies and early eighties. When a period of hot weather was followed by sudden rain, the fungus pounced, attacking the major vertical roots of the jarrah and almost choking off their water. Once the hot weather returned, the trees, massively needing water yet suddenly unable to receive it, died within days or even hours.

INTERIM FOUNDATION FOR JARRAH DIEBACK RESEARCH

The discovery of P. cinnamomi *in 1965 led to a research offensive through the 1960s and 1970s which had far-reaching effects on forest management. Joint Commonwealth-State ventures funded research into the biology of the fungus by the Forests Department, the CSIRO and the universities. In 1978, the aluminium and timber industries complemented government funding through a research foundation whose work was to last for nearly a decade. The role of the foundation, chaired by the Conservator of Forests with representatives from industry, universities and government departments, was to fund new and existing research. The foundation supported studies in jarrah forest ecology, understorey manipulation, host response to infection, tissue culture of jarrah, and the activity of the fungus in the soil.*

Contributors to the Dieback Research Fund

- *Alcoa of Australia*
- *Worsley Alumina*
- *Forest Products Association*
- *Wesfi*

Research Funded

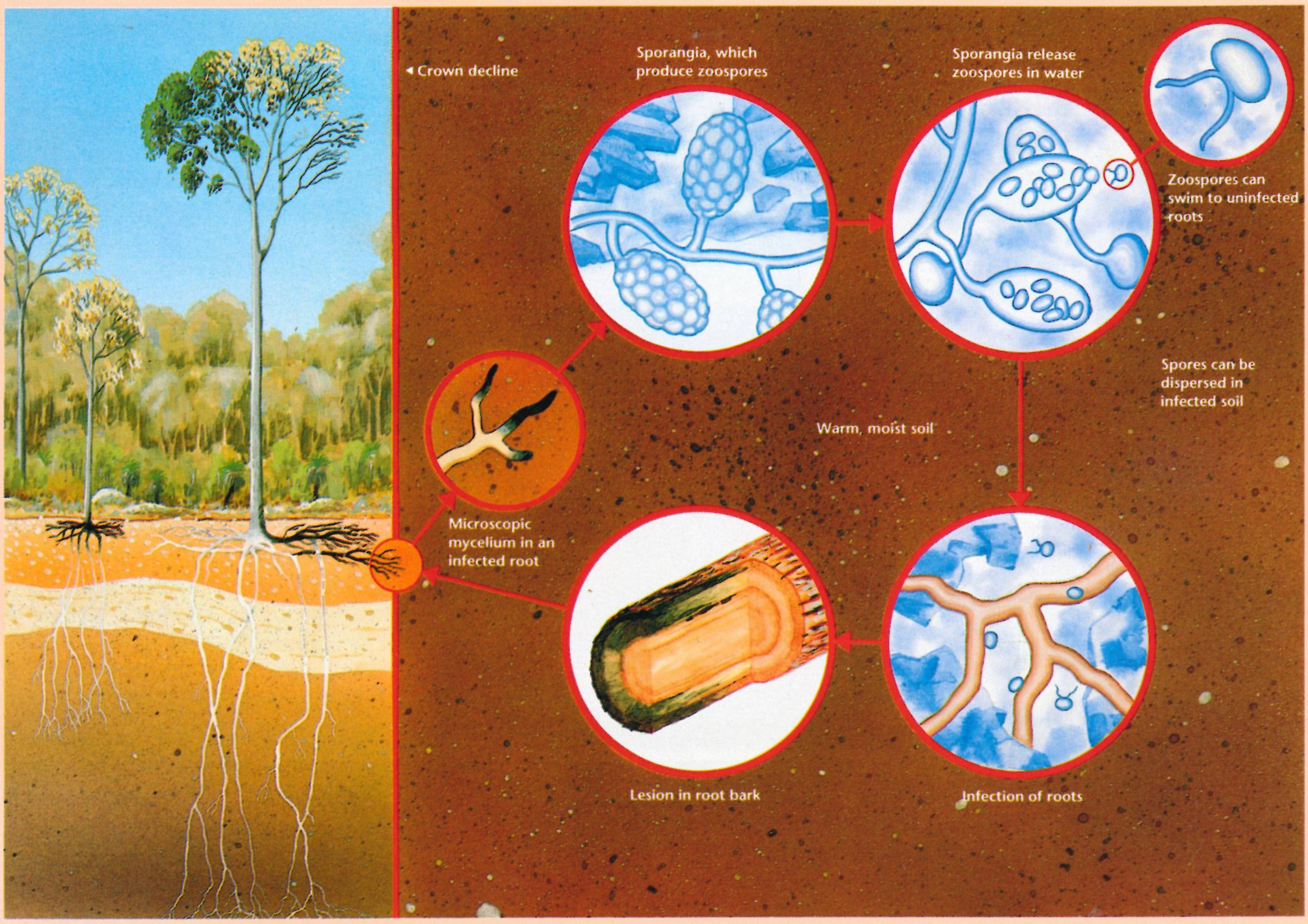
Forest ecology
(CALM, CSIRO, University of Western Australia and Curtin University)

Understorey manipulation
(CALM, CSIRO, Curtin University)

Host response to infection
(CALM, Melbourne and Murdoch Universities)

Tissue culture of jarrah
(Murdoch University)

Factors affecting activity of the fungus in the soil
(CALM)



THE KILLER FUNGUS

It was not until 1965, after years of research by many scientists, that Dr Frank Podger identified the cause of jarrah dieback as Phytophthora cinnamomi. *This pathogen was first described by a Dutch expert on plant disease in 1922 - ironically, the same year as the discovery of dieback in Western Australia.*

An introduced, soil-borne fungus, P. cinnamomi *is believed to have evolved in South-East Asia. The word* Phytophthora *comes from Greek* phyton *(plant) and* phthora *(destruction). Even though it grows best in tropical conditions, the fungus attacks nearly 1000 plant species throughout the world and is one of the most widespread plant pathogens known to man. It was probably introduced to Western Australia before the early 1900s when quarantine procedures were not in place.*

Phytophthora cinnamomi *has only relatively recently been introduced into the plant communities of south-western Australia, so they have not had the chance to evolve much resistance to the disease. South-West plant species have adapted to poor soils and drought by developing specialised root systems for maximum intake of nutrients and water, but that is precisely what makes them vulnerable to the fungus.*

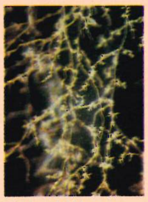
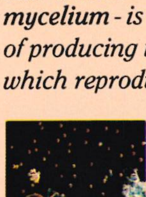


Photo - L. Harman

The life cycle of P. cinnamomi *depends on moist conditions. The fungus is parasitic, and requires a living host on which to feed. The main body of a fungus - the* ***mycelium*** *- is a mass of threads, capable of producing the millions of tiny spores which reproduce the fungus.*



There are two main kinds of spores. One, the ***zoospore****, is small and spreads rapidly through water and moist soil. As they move through the soil zoospores lodge on plant roots, infect them, and, in susceptible plants, produce mycelium. The mycelium grows, feeding on the host, rotting the roots and cutting off the plant's water supply. The other type of spore, the* ***chlamydospore****, is larger than the zoospore, and can survive in the soil for long periods, provided conditions do not become too dry. They cannot move on their own, but can be transferred in particles of infected soil. When conditions are favourable the fungus again becomes active: the chlamydospores produce mycelium and zoospores.*

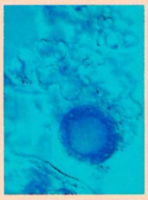


Photo - J. Tippett

After infection, the fungus invades root bark and forms ***lesions*** *which may extend into the tree collar. Infection of roots and collar results in death of host and crown decline.*


Photo - J. Tippett

PROGRESS IN THE FOREST

Forest pathology is a complex research area, needing a considerable commitment of resources. That is where the support of a foundation for jarrah dieback research was so vital (see p.41). Large trees are difficult to work with, and the soils on which they grow often have layers that resist penetration. Extremes of scale must be contended with. Jarrah trees over 30 m tall can live for centuries, with years between reproductive cycles; and a fungus that lives in microscopic soil pores and intercellular spaces has a life span of weeks to months, with a reproductive cycle of hours to days. The forest occupies a large area with a great diversity of microclimates affecting host and pathogen. The techniques needed for inoculation, excavation and assessment are therefore labour-intensive and expensive. Because trees are long-lived, factors affecting disease and attempted controls cannot be adequately tested within a few years.

Nevertheless, recent research has covered all this ground. Some of the results:

Natural Barriers: When *P. cinnamomi* infects jarrah, growth of the fungus in the outer bark can be limited by the tree's natural defences. However, these barriers are least effective when warm, moist conditions favour rapid fungal growth. Moisture level within the bark is affected by water availability within a site and the occurrence of summer rains. Once the jarrah's susceptibility is defined, the effect on the disease of different management options, under a range of site and climatic conditions, can be properly assessed.

Using Host Resistance: Testing the response of jarrah to infection has shown that some trees are genetically more resistant to the dieback fungus than others. Considerable progress in the tissue propagation of jarrah has meant that a small piece of plant material, like a bud or stamen, can be used to produce a new plant. Thus tissue culture can be used to propagate resistant plants and help re-establish jarrah on infected and mined areas.

Research has shown that changing jarrah forest understorey to favour prickly moses *(Acacia pulchella)* helps to inhibit the spread of the fungus.
Photo - Syd Shea ▲

Scientists washed down and exposed jarrah roots to study how they were infected by the dieback fungus.
Photo - Bryan Shearer ▲

Experimental burning of bull banksia, a strategy which may help reduce the spread of the fungus.
Photo - L. Harman ▼

Firing the Banksia: Research suggests that replacing susceptible species, such as banksias, with resistant legumes, such as prickly moses (*Acacia pulchella*), reduces dieback survival. Changing the understorey to one dominated by wattles alters the physical, chemical and microbiological environment of the soil to disfavour the fungus.

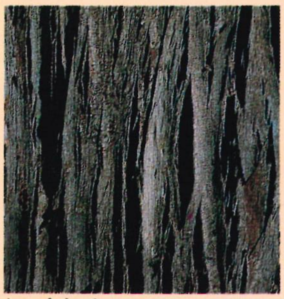
Burning the bull banksia-dominated understorey can result in one dominated by acacias. The use of fire to change the understorey offers a management strategy to reduce disease development over large areas, but practical application has not been as straightforward as initially hoped. More information is needed on fire ecology, acacia ecology and follow-up methods of bull banksia suppression.

Enemies in the Soil: The fungus is food for microbes in the soil. In some areas of the forest, such as under legume stands, these microbes help to suppress dieback. At present there is no practical way of applying such biological control to the forest on a wide scale. However, selected microbes could be used during rehabilitation of degraded areas.

Forest Floor Mosaics: Before the discovery that *P. cinnamomi* caused mass death of jarrah by attacking its vertical roots deep in the soil, it was thought that the whole jarrah forest could be at risk. After 1983, it was recognised that the site conditions that make jarrah vulnerable to dieback do not occur throughout the forest. These conditions include the impeding, water-spreading layer beneath the soil surface, enabling the fungus to

THE JARRAH FOREST

The jarrah forest is the most widespread forest type in the South-West of WA. It grows predominantly on the infertile lateritic soil of the Darling Plateau. Lateritic soils are deep clays overlain by gravel. They were formed millions of years ago by chemical weathering of the eroded surface of the far more ancient granite basement rock. The forest's dominant tree, jarrah, is a tall, straight eucalypt with dark grey fibrous bark. Its timber is renowned throughout the world for its red colour, durability and quality finish.



jarrah bark

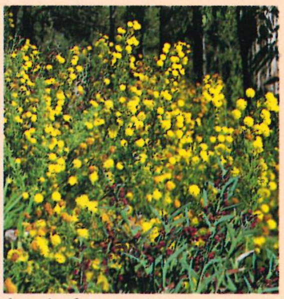
However, many other tree and plant species, including marri, blackbutt and sheoak, make up the jarrah forest ecosystem, each growing where soil type and soil water best suits their needs. Not all of them are susceptible to the dieback fungus, while others, such as bull banksia, quickly succumb to the disease.

fringed lily

Over the forest's range, 300 species of colourful wildflowers grow in identifiable plant communities. These make up the complex shrub layer. The jarrah forest is the only place

Western Spinebill

in the world where many of the species are found. Some of the most spectacular are members of the Protaeceae group; the banksias, dryandras, grevilleas and hakeas. Many have large flowers which attract numerous nectar-seeking birds, such as the



Acacia drumondii

Western Spinebill. The forest also provides habitat for a variety of animals. Dieback is present in about 14 per cent of the State's jarrah forest. The disease is not randomly distributed and its intensity varies with site and vegetation type. Jarrah forest growing on the fertile, red, loamy soils in the young, dissected river valleys on the western edge of the Darling Scarp appears to be particularly resistant to the disease. Forest growing on the laterite soils of the upland areas and the silty or sandy soils in the shallow valleys is susceptible but to different degrees.

native cat

release spores, disperse, and infect the jarrah at depth. There are many jarrah sites where different conditions apply. This finding brought a much greater appreciation that the jarrah forest is comprised of a mosaic of site types with different drainage characteristics. Jarrah death ranges from high to low, depending on site characteristics and management. Time and further study of the mosaic nature of the forest floor will show whether the killer fungus is likely to erupt in any future mass killings of jarrah.

Systems have now been developed to rate uninfected areas according to the likely hazard of jarrah mortality, should the fungus be introduced. This will assist planning by determining the proportion of the uninfected landscape occupied by low, intermediate and high hazard sites.

Risk of Infection: More and more is being learnt about how conditions within the forest influence the activity of the fungus in the soil. The dispersal of spores in water seeping below the soil surface is being monitored and related to the type of forest and the climatic conditions. Determining moisture and temperature conditions that affect the dieback fungus's release of spores and even survival will help to assess the risk of infection.

Assessing Damage: Because jarrah trees die from lack of water after the dieback fungus destroys their roots, the damage being done to a living tree can be estimated by measuring the rate at which the tree uses water. This information can now be obtained by processes which no longer require the tree to be dug up.

Measuring the amount of water loss from living trees in infected areas shows how healthy the root systems are. Monitoring water loss from plants in different parts of the forest under different conditions will reveal how long some plant species are vulnerable to infection as the result of disturbance or climate.

Chemotherapy: The systemic fungicide Phosphorous acid has arrested lesion extension in bull banksia. This finding offers the first possible practical application of chemotherapy to infected plants in the forest. Promising results have been obtained in the use of chemicals to eradicate *P. cinnamomi* from the soil in spot infections. Evaluation of these control methods is continuing.

Dieback is threatening the remnant populations of *Banksia brownii*, a rare species of the South Coast.
Photo - Greg Keighery ▲

Vehicles are washed down in all important natural areas, as a precaution against spread of dieback disease.
Photo - John Green ▼

PROGNOSIS

CALM has developed hygiene methods that restrict the spread of the killer fungus, and methods that reduce its development in existing areas of infection. However, rate-reducing methods (such as using resistant biotypes and enhancing host resistance, altering the understorey, stimulating antagonistic microflora, modifying forest floor drainage, and chemical control), need further development and testing before practical application.

Phytophthora cinnamomi is a major problem in the jarrah forest. However, there is now a far better understanding of the conditions that favour pathogen dispersal and host infection; there is in particular a greater knowledge of the type of site and environment that may favour either the disease or the forest. This information, together with methods to prevent introduction and minimise spread, has shown that the cost of maintaining healthy forest is small compared to the irreversible loss in conservation, aesthetic and production values if forest is affected by disease.

The effects of the dieback fungus on plant communities other than the jarrah forest are not being ignored. Although *P. cinnamomi* has mainly been associated with jarrah dieback, it also threatens woodlands and heaths that have a high proportion of susceptible species. Hygiene methods have been applied to prevent introduction and minimise spread, and research into dieback in these communities continues.

About 75 per cent of the known plant species of the South-West are unique to the region, and many are susceptible to the dieback fungus. Introduction of the fungus threatens some plant species, such as *Banksia brownii*, with extinction. The co-operative efforts that have fuelled the fight against jarrah dieback must be maintained to help keep our unique flora free from disease. ◘

REPRINTED FROM *LANDSCOPE*, SPRING 1989

0754 1289 2M