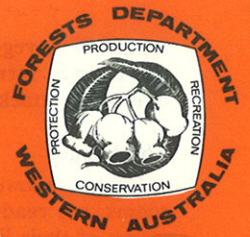


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JARRAH DIEBACK

A threat to W.A.'s unique jarrah forest

Dr. S. R. SHEA

DEPARTMENT OF
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Its rugged, resilient appearance and apparent never-ending capacity to supply timber has perhaps caused many Western Australians to be complacent about the jarrah forest. This forest, however, is now being attacked by a microscopic soil-borne fungus which has the potential to destroy it.

Phytophthora cinnamomi the organism which causes jarrah dieback, can kill not only jarrah trees but the majority of species which grow in the forest. It is this almost total destruction that has led many plant pathologists throughout the world to recognise jarrah dieback as the worst plant disease ever recorded.

There is much evidence to suggest that the jarrah forest is one of the world's most unique forest ecosystems. Jarrah trees may attain a height of 56 metres and in some virgin forest areas, on one hectare, there is enough merchantable timber to provide wood for 29 average suburban homes or enough railway sleepers to build 2 kilometres of railway line.

Jarrah, however, is only one component of the ecosystem. Within an area smaller than the size of most suburban gardens it is not unusual to find over 40 different plant species from the delicate spider orchid to the bizarre blackboy. The forest provides a habitat for a variety of animals—many of which are unique to Western Australia—and in preliminary surveys near Dwellingup over 40 species of birds have been recorded (see *Forest Focus* No. 7).

The productivity and diversity of the forest is all the more remarkable because it occurs in a very harsh environment. The laterite soils on which jarrah grows are infertile, and dense, cemented sheet cap rock often occurs a few centimetres below the soil surface. These harsh soil conditions are not compensated by a favourable climate. Desert-like conditions prevail from December through to March. Fire is a natural factor of the environment with which the vegetation must contend, and the frequency and intensity at which it occurs would destroy many other types of forest. The jarrah forest is adapted to withstand severe fire and in fact some species, including jarrah, are stimulated by fire.

To survive and attain high productivity many of the components of the forest have evolved peculiar adaptations. Jarrah trees have adapted to the harsh, dry conditions by evolving a remarkable root system which penetrates the cap rock layer and extends often more than 15 metres to tap the water table deep in the soil profile. Banksia trees cope with the infertile soil by developing a special root to trap nutrients which are normally unavailable to plants.

The forest abounds with structures which have been developed to cope with fire. For example, jarrah trees commence their life in the form of a shrub which sprouts

from a bulb-like fire-resistant structure called a lignotuber.

All these adaptations are evidence that the jarrah forest is a specialised and finely balanced eco-system. Unfortunately, its unique character, which results from its adaptation to this harsh environment, has made it extremely vulnerable to a new factor of the environment—*Phytophthora cinnamomi*.

The Disease

The first evidence of jarrah dieback is the death of members of the understory and shrub layer. Bull banksia (*Banksia grandis*) is one of the first trees to succumb. The leaves of banksia which have been killed by the fungus turn yellow, contrasting markedly with the dark green forest vegetation. Deaths occur predominantly in autumn and to a lesser degree in late spring. Many other shrub and tree species such as zamia palm and blackboy are killed by the disease. In some diseased areas, however, susceptible species may persist for long periods after the fungus has been introduced.

Jarrah trees may not show disease symptoms for some months or even years after understory symptoms have been observed. The first symptom in jarrah is crown thinning. The trees "die back" from the branch tips, although death of branches is merely an indication of a damaged root system and does not indicate that the pathogen is present in the above ground part of the tree.

Some tree and shrub species are resistant to the disease. For example, marri, blackbutt and bullich have demonstrated their capacity to survive in diseased areas for many years and in some diseased areas marri has formed a woodland-type forest with a scattered shrub layer composed of resistant species. However, introduction of the fungus to a jarrah forest area will, on most sites, eventually result in the irreversible destruction of all but a few resistant species in that area.

In the latter stages of disease development jarrah dieback is easily recognised, but in the initial stages identification of infected areas may be difficult. Poor jarrah crowns or a single mortality in the shrub understory do not necessarily indicate that the fungus is present. However, patch dying in the understory layer particularly if banksias, zamia palms or blackboys are affected, usually indicates its presence.

The disease is not restricted to jarrah forest occurring on the Darling Ranges nor to the jarrah vegetation type. Poorer quality jarrah growing on the coastal plain is highly susceptible. Karri and wandoo forests, and the vegetation growing on the coastal limestones appear resistant. But banksia woodlands, a major vegetation type on the coastal plain, are highly susceptible to the

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fungus. The vegetation in many public reserves, parks, golf courses, farmlands and gardens has been destroyed or is being attacked by the fungus.

The Fungus

Fungi are lower forms of plant life. Some, like mushrooms, are readily visible to the naked eye at certain stages of their life cycle. Others such as *P. cinnamomi* can only be seen under the microscope. Some fungi are very beneficial as they break down dead plant material and in the process allow nutrients to be recycled. Others attack live plants and cause severe economic losses.

P. cinnamomi is recognised throughout the world as a major plant pathogen. It is a serious problem in the pine forests of south-east U.S.A., avocado orchards in California, pineapple plantations in Hawaii, and recently has been found to cause severe damage to some eucalyptus forests in eastern Australia. Over 400 plant species are attacked by this fungus including many horticultural species such as azaleas, camelias, plums and peaches.

Of all the areas in the world where this fungus has caused damage, the south-west of Western Australia is the most serious.

P. cinnamomi occurs in the soil and roots in various forms which make up its 'life cycle'. The vegetative form of the fungus is called mycelium, which consists of microscopic tubular structures. During the asexual cycle of the fungus, which occurs only when the soil is moist and warm, sporangia are formed from the mycelium. Inside the sporangia a further spore type called a zoospore is formed, which on release can swim through wet soil. The fungus has the capacity to produce many sporangia from a small amount of mycelium and within each sporangia there are several zoospores. This process of zoospore production can occur in less than 48 hours and hence the fungus has the capacity to produce millions of spores in short periods from a small amount of mycelium. Two other spore types, a chlamydospore and a sexual spore called an oospore, are produced by the fungus. These spores are relatively thick walled and permit the fungus to survive in soil indefinitely, even in the absence of host tissue, provided the soil is kept moist.

P. cinnamomi, principally during the zoospore stage, causes damage to plants by attacking their root systems. In some plants, as in the case of jarrah, only the fine feeder roots are attacked. Destruction of these roots prevents the plants from taking up nutrients and it slowly starves to death. In some jarrah forest species such as banksia, the fungus can also invade the large roots and death in these species is more rapid. Unfortunately, many of the specialised root structures which have evolved to cope with the jarrah forest environment, such as the specialised banksia root, are highly susceptible to the fungus. This not only makes these species highly susceptible, but it contributes to the spread of disease through the forest by providing a large food base for the fungus. It is somewhat of a paradox that the unique character of the jarrah forest has made it extremely vulnerable to *P. cinnamomi*.

Distribution and Spread

Jarrah dieback is widely distributed throughout the South-West. It is found from Gingin 60 km north of Perth to Mount Manypeaks 40 km east of Albany. The distribution of the disease has been mapped in state forest using aerial photographs, and ground and aerial surveys. Preliminary surveys, using the same techniques have recently been carried out to estimate the extent of the disease in national parks, crown land reserves and private property. The *estimated* area affected by jarrah dieback at the 30th June, 1974, was as follows:

State forest and timber reserves	172 000 ha
National parks	1 000 ha
Other crown land	43 000 ha
Private property	66 000 ha
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	282 000 ha

Within the South-West it is estimated that the infected area is increasing by 20 000 hectares each year.

The disease is not randomly distributed and its intensity varies with site and vegetation type. Jarrah forest growing on the fertile, red, loamy soils formed 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 characteristic of the upland areas of the forest and the silty or sandy soils in the shallow valleys is susceptible but to different degrees. In lowland areas susceptibility is extremely high but uphill spread of the disease to the lateritic upland sites is generally very slow. A large proportion of the diseased forest area is restricted to the valley bottoms. The fungus, however, can rapidly destroy the vegetation on upland sites if infections are introduced at the top of the slope. If this occurs spores are rapidly distributed downslope in drainage lines.

Effects of Jarrah Dieback

The effects of any plant disease may be serious, but they are usually direct and definable, such as the diseases affecting cereal crops. Because it could destroy the total forest together with its multiplicity of values, the effects of jarrah dieback are more complex and in the long term potentially more serious than any other known plant disease.

The Water Catchments

Catchments located within the jarrah forest currently supply over 80 per cent of the total water used in Western Australia. It is no accident that the major source of fresh water to meet current and future demands in southern W.A. is in forested catchments. Clearing of the forested areas to the east of the state forest has caused streams to turn saline. Research by the C.S.I.R.O. indicates that unless these areas are reforested it could take up to 400 years before the streams become fresh.

Current research indicates there are large stores of salt in the soil in some catchments. For example, it has been estimated that there are 150 000 000 tonnes of salt stored in the soil and groundwater in the Wellington catchment. Paradoxically, the existing native vegetation is responsible for this large accumulation of salt. Over millions of years small quantities of salt contained in rainwater have been concentrated by the roots of the native vegetation. While this vegetation remains intact the salt is prevented from moving into the river systems and water in reservoirs remains relatively fresh. Disturbance of the vegetation by either man or disease in forest areas where salt accumulation has occurred will result in the release of salt into the weirs and reservoirs making the water unusable for either domestic or agricultural use.

The effect of jarrah dieback on water quality currently used is minimal as most of the seriously diseased forest occurs downstream from existing reservoirs or in areas which are not salt prone. However, in some areas the destruction of forest vegetation by *P. cinnamomi* has caused the streams fed from these areas to turn saline.

Timber Production

The most obvious and direct effect of jarrah dieback is its immediate and future impact on the milling industry. The long term future of any sawmill can only be assumed

if the amount of wood cut each year is equal to that produced by the forest. As the area of forest affected by dieback increases and more forest becomes unproductive the size of this "allowable cut" will become less, forcing many mills to reduce in size, or even close down.

Conservation

The effect of jarrah dieback on forest flora and fauna has not been widely appreciated. Many trees and shrubs of the forest which are renowned for their beautiful flowers are affected. Susceptible plants include species of *Banksia*, *Persoonia*, *Adenanthos*, *Podocarpus*, *Leucopogon*, *Dryandra*, *Xanthorrhoea* and *Casuarina*. Certain vegetation types, particularly those occurring in lowland areas such as the *Banksia littoralis* dominant understory type, are in danger of extinction. The loss of individual plant species extends beyond that species because in an eco-system, living organisms are dependant on one another. For example, Forest Research Officer Per Christensen (*Forest Focus* No. 10) has documented the role of *Banksias*, one of the trees most susceptible to *P. cinnamomi*, in providing food and shelter for many of the small animals and birds inhabiting the forest.

"For example, the red wattle bird, the little wattle bird, the yellow-winged or new holland honeyeater, together with the closely allied white-cheeked honeyeater, the western spinebill, the tawny-crowned honeyeater, the white-naped honeyeater, and the brown honeyeater are some of the honeyeaters commonly associated with banksia flowers, particularly on the south coast. Other birds, such as the silvereve and the black cockatoos, also feed on the nectar of the banksia flowers. The latter also frequents the banksia belts at a later date when the seed ripens. Birds come not only to seek nectar but also for the numerous wasps, moths, butterflies, beetles and ants attracted to the flowers. At night boobook owls and bats feast on moths attracted to the nectar. At this time another small creature, the tiny noolbenger or honey possum, emerges to feed on the pollen and nectar of the flowers. This animal is almost entirely adapted to a diet of nectar and banksias are one of the main species it frequents.

"The equally tiny dormouse or pigmy possum also frequents the banksia groves at flowering time. They live mainly on an insect diet and have been observed to breed at the time of the banksia flowering on the south coast. Their tiny nests and those of the noolbenger are often found inside rotted out hollows in the trunks of the banksia."

Recreation

Apart from its water, timber and conservation values the jarrah forest is being increasingly used for outdoor recreation. During a forest recreation survey it was found that on one weekend 750 people visited one picnic site located near Dwellingup. Much of the appeal of the forest to those who visit it is destroyed by jarrah dieback.

Research

Jarrah dieback was first described prior to World War II but it was very restricted in area and the small areas of dead forest were assumed to be caused by fire. After 1945, following the large-scale introduction of mechanical earth-moving equipment, the disease became more widespread and a number of investigations were carried out in an attempt to find a cause. It was not until 1965, however, that Mr. Frank Podger of the Commonwealth Forest Research Institute, identified *Phytophthora cinnamomi* as the causing agent.

Research is currently being carried out by a variety of organisations. An intensive programme is carried out by

the W.A. Forests Department at its Dwellingup Research Station and the department also provides funds for research scholarships at the Western Australian and Australian National Universities. The Commonwealth's Forest Research Institute is maintaining a research station at Kelmscott which is primarily involved in jarrah dieback research and more recently the C.S.I.R.O. has initiated an investigation into the disease. The research programme being carried out in W.A. is only part of world-wide research into the fungus.

The development of methods to control the disease is hindered by its widespread nature in a forest which has a relatively low value per unit of area. In the horticultural situation it is possible, although expensive, to reduce the impact of the fungus by the use of fungicides and other intensive cultural treatments. In a forest such methods are impractical. Hence, research has been directed to evolving techniques to prevent the introduction of the fungus into uninfected areas, and changing the environmental conditions in the natural forest to make it resistant to the disease rather than attempting to eradicate the fungus.

Although *P. cinnamomi* can cause destruction of the forest on most sites, susceptibility varies markedly. *Recognition of this variation and the identification of the factors responsible for it have provided some hope that the disease may be controlled in the short term by forest hygiene techniques and in the long term by manipulation of the forest vegetation.*

Detailed measurements of the soil environment on various sites within the forest have shown that lowland sites are highly susceptible because they are water gaining, but on the freely drained upland sites where jarrah grows best, the soil environment is only marginally suitable for the fungus. Over a period of eight years measurements of the spread have shown that provided contaminated soil is not carried on to upland sites the natural extension of the disease from the lowlands is very slow. Current research indicates that it may be possible to increase the resistance of the upland sites by promoting a dense understory vegetation. Marked changes in the understory and shrub layer of the forest can be achieved relatively cheaply by altering the frequency and intensity of prescribed burning.

New lines of research are constantly being explored. On some jarrah forest sites the fungus is unable to become active because it is being attacked by other micro-organisms. *It is possible that with further research these natural antagonists may be used to achieve biological control of the disease.*

In areas where the fungus has already destroyed the forest there is little hope that the natural forest will ever be re-established. For these areas trials are being carried out with alternative tree species. Over 50 tree species with known commercial potential have been tested in the field and laboratory for resistance to *P. cinnamomi*. Three species of pine and at least eight eucalypts have been able to survive in the presence of the fungus and also grow on jarrah forest sites.

Trials are continuing and over 250 hectares of dieback-affected forest are being planted each year. In salt-prone catchment areas which are affected by jarrah dieback it will be necessary to replant with trees which have a deep root system so that the discharge of salt into reservoirs can be prevented.

Control of Jarrah Dieback by Forest Hygiene and Quarantine in State Forest

The major means by which *P. cinnamomi* is spread through the forest results from the activities of man. Unaided movement of the fungus uphill or on a flat

surface is less than a few centimetres a year. The fungus can survive and may be carried in less than one gram of moist soil and this amount of infected soil is sufficient to initiate a new diseased area. Any activity in the forest which involves movement of soil can cause the disease to be spread distances measured in terms of kilometres in one day.

Once new infections are established on uphill sites, disease spread downslope is rapid and over a period of years most vegetation downslope of the new infection will be destroyed. *Therefore prevention of artificial spread is the greatest single step which can be taken to control jarrah dieback.*

Reduction of artificial spread by forest hygiene techniques, although difficult, is not impossible despite the insidious nature of the fungus. *P. cinnamomi* cannot be transmitted in the atmosphere and although it will survive in moist soil for long periods it is rapidly killed when the soil is dried. Although only small quantities of infected soil are required to initiate new dieback areas in the field situation, the probability of this happening with small quantities of soil is low. Most of the spread in the forest has resulted from moving large quantities of soil like that adhering to bulldozers or moved in road building operations.

During the summer months the soil on all but the low-lying swampy sites is too dry for the fungus to survive and the chance of spreading during this period is low. Artificial spread of the disease can be markedly reduced by restricting activity in healthy forests to the summer months and washing down vehicles whenever they move from diseased to healthy forest.

Distribution of the disease within the forest was considered when implementing the hygiene programme. A large proportion of the diseased forest occurs within a distance of 8-12 km of the Darling Scarp. Another large area of high quality northern jarrah forest having a much lower level of infection lies to the east of the badly diseased area, and has been declared a quarantine zone by amendment to the Forests Act.

For a minimum period of three years entry to this quarantined area will be permitted only in special circumstances and a permit will be required. The legislation provides heavy penalties for infringements to the Act. Almost all forest activities involving vehicular movement, such as logging, will be restricted to the western edge of the forest which is badly affected by dieback.

The stringent quarantine will:

- Permit the identification of affected areas in the high quality forest zone;
- Provide time in which to introduce a logical basis for implementing hygiene measures;
- Provide time to develop work methods so that multiple-use management may be continued;
- Effectively curtail artificial spread in not yet hopelessly infected susceptible forests where disease is a threat to management objectives.

The co-operation of everybody who uses the forest, whether for work or recreation, is essential if jarrah dieback is to be controlled.

Information on forest hygiene and quarantine procedures can be obtained at any Divisional Office.

Control of Jarrah Dieback Outside State Forest

Control of the disease in national parks and reserves, crown lands, farmland and golf courses, can only be achieved by reducing artificial spread. In home gardens fungicides may give some control. On the deep sands on which most homes in suburban Perth are located infections generally remain localised. Therefore the best method of control is prevention of the spread of contaminated soil.

In badly affected areas the aesthetic value of the destroyed natural vegetation may be at least partially recovered by planting resistant trees and shrubs.

Conclusions

P. cinnamomi is a new and devastating factor of the environment in the south of Western Australia. Unchecked, the disease could eventually result in the irreversible destruction of the majority of the jarrah forest and many other vegetation types occurring in the area. It is a complex problem but there is some hope that a method of controlling the disease will be discovered. Control by hygiene and quarantine, however, is the only method in the short term which will ensure that the priceless value of the forest will be conserved for future generations.