CHIEF DRAFTSMAN

REVIEW OF THE DIEBACK DISEASE SITUATION 1981

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PREFACE

The dieback disease caused by the root-rotting fungus *Phytophthora cinnamomi* is a serious and widespread problem in south-west Western Australia, affecting large areas of State forest and private property. Although the Forests Department has published reports on the disease (e.g. Forest Focus No. 14, 1975 (revised 1978) and Forest Focus No. 21, 1979), the progress of research has created a need to revise information on the disease at frequent intervals. This Technical Paper presents a review of the dieback disease situation as at mid 1981. It summarizes the current knowledge of the biology of the fungus, recounts the history of the development of the disease in State forests, comments on the future of the jarrah forest and set out the current management philosophy of the Forests Department in relation to dieback disease. It also contains a glossary of the technical terms used in the text.

It is intended to update this publication as significant research results come forward.

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CURRENT KNOWLEDGE OF THE BIOLOGY OF *PHYTOPHTHORA CINNAMOMI*

Phytophthora cinnamomi is an introduced, soil-borne pathogen that has some saprophytic activity. That is, it mainly attacks living plant tissue, but can also survive for a time living on dead plant material.

Its principal method of attacking plants is through infection of their roots by zoospores; small spores which are able to move toward plant roots when soil-moisture levels are high. Extension of the disease through the soil, by the growth of fungal mycelium, is very slow and can be ignored for all practical purposes.

An infection expands by downslope movement of spores in overland waterflow at a rate which varies with soil type, steepness of slope, soil moisture conditions and presence of highly susceptible hosts. At present we have no way of preventing this. Upslope extension of an infection is very slow indeed.

During extended dry periods, few zoospores survive in the soil under Western Australian conditions, but fungal mycelium persists in the roots of infected plants. The infected host may be alive or dead. A special type of spore resistant to desiccation, called a chlamydospore, has not been found to be important in Western Australian soils.

The zoospores are produced by fruiting structures called sporangia. Sporangia can be very rapidly produced, but only under suitable conditions, that is, in warm, wet soil and when soil temperatures are in the range 15 - 27^{O}C.

There is marked variation in the behaviour of the disease on different forest sites. On moisture-gaining sites, that is lowland areas and valley floors, soil moisture conditions are suitable for zoospore production for long periods in spring and early summer. On freely-drained upland sites, which constitute about 75% of the jarrah forest, conditions are suitable for zoospore production for a much shorter period of one to six weeks each year, depending on rainfall patterns. In certain soil types, such as the red loams found along major river valleys, the disease appears to be suppressed and susceptible plants are apparently unaffected.

There is a wide variation in the susceptibility of various species to the disease. Highly susceptible plants include *Banksia grandis* and *Persoonia longifolia*. These die rapidly after infection by the disease.

Moderately susceptible species include jarrah and sheoak. These species may persist for many years after infection and some trees may not die at all, whilst others may die suddenly depending on site conditions and disease inoculum level. Site conditions more favourable to the disease, or a high biomass of very susceptible plants leads to a build-up of fungal inoculum to the stage where jarrah may be attacked. Tolerant species such as marri do not succumb to the disease, although the disease may survive in their roots for many years and the host plant may decline in general health.

While the degree of susceptibility or tolerance of the major tree species to the disease is fairly well understood, we presently lack information on the situation regarding most understorey species.

Suitable conditions for zoospore production are found primarily during spring every year. The length of the suitable period varies from year to year with seasonal weather patterns. The build-up of fungal inoculum may also be significant in autumn, and the amount of build-up appears to be determined by the nature of early seasonal rainfall. Rains from the north-west maintain high soil temperatures and permit a rapid increase in inoculum, whereas the cold rains caused by Southern Ocean frontal activity cause a rapid drop in soil temperature which inhibits fungal activity. In autumn, after a build-up of the soil zoospore population, the spores may become encysted or go into a resting stage with the onset of cold weather. These spores become active as soon as soil temperatures rise sufficiently in the following spring.

New infections of the disease occur through the tranport of soil or plant material from an infected site to an uninfected site. This can only be prevented by all forest users maintaining effective forest hygiene procedures.

Once a new infection is initiated, it is usually 18 months to three years before the presence of the disease is indicated by the death or decline of susceptible plants, which is the only external indicator of the presence of the disease.

Zoospores can survive for extended periods in water and are frequently found in water running off infected areas in late spring and summer. It is possible for the disease to be introduced to nurseries through contaminated water supply systems.

The death of highly susceptible species results from the total invasion of the root system, and in some species, from the complete destruction of living tissue around the base of the stem. The death of less susceptible species results from the destruction of their fine feeder root system. It is probable that the disease affects jarrah in both ways: by destruction of the fine feeder roots under marginally suitable conditions and by total invasion under more favourable conditions. Where conditions are favourable for the disease, jarrah and most understorey species are killed.

In the forest, moisture-gaining sites are highly susceptible to disease intensification. Once dieback disease is established on such sites, all susceptible species will be very severely affected. Their survival depends on exclusion of the disease.

Because the partly saprophytic nature of the fungus, the variable presence of zoospores and the presence in the forest of tolerant plant species, it is impractical to use a fungicide to destroy the disease in the forest. However, specialized fungicides may have a role in preventing or controlling the disease in nurseries.

As the soil environment in Western Australia is only marginally suitable for the survival pf *Phytophthora cinnamomi* under most circumstances, it is important to reduce the population of plants, such as *Banksia grandis*, which are not only highly susceptible but also have large root systems providing a good food source for the fungus.

At present, dieback disease is believed not to affect the karri or wandoo forest.

HISTORY OF DISEASE DEVELOPMENT IN THE JARRAH FOREST

Although the symptoms of dieback disease were noticed in small areas as far back as about 1920, relatively few new infections were apparent until after World War II. After 1945 there was a massive increase in the use of wheeled vehicles in the forest. The widespread introduction of bulldozers, low loaders and graders greatly increased road construction and improvement, and greater mobility in forest areas generally. These factors, combined with ignorance of the cause of the disease, led to an ideal situation for the initiation of new infections over a large area of State forest. As a consequence, the disease spread very rapidly from about 1950 to 1975.

The total area of State forest affected by the disease was quoted in Forest Focus No. 12 as 220 000 ha and the rate of increase as 16 000 ha per year. Unfortunately, this publication may have given the impression that the expansion of diseased areas will continue at this rate until the jarrah forest is annihilated, but there is no real basis for such a simplistic extrapolation.

The rapid spread of the disease from 1950 to 1975 was due to two main factors:

(a) rapid and widespread initiation of new infection ,

(b) rapid deterioration of the plant communities on most highly susceptible lowland sites.

Seasonal weather conditions have had a marked effect on disease spread, both in the creation of new infections and in the extension of existing infections. The wet years around 1964 were responsible for mass deaths of jarrah in the northern jarrah forest and the wet 1973 winter in the Sunkland was followed by unusually extensive jarrah deaths in that area.

Although the cause of the dieback syndrome was established in 1965, there were many difficult technical problems with research on the fungus and the mapping of the disease which hampered development of forest management procedures appropriate to the situation. It was not until 1973, when the Forests Department carried out an intensive review of the dieback disease situation, that adequate legislation was enacted and hygiene procedures were applied more effectively on a large scale. The forest quarantine system was introduced in 1976 to overcome one of the main obstacles to proper forest hygiene: the inability to detect all centres of infection because of the time lapse between infection and the appearance of disease symptoms.

Currently, about 710 000 ha of forest are under quarantine, which means that access within the forest by vehicle and livestock is controlled. There is no restriction of access to quarantine areas on foot.

Another major development has been the Forests Department's dieback disease mapping and interpretation work during 1978-81. This is based on locally developed large-scale colour aerial photography techniques and has significantly improved our ability to locate and confirm disease infections.

In the long term, the forest can survive only if all forest users consistently practise a high standard of disease hygiene. It is already apparent that the hygiene measures progressively introduced and refined since 1975 have resulted in a marked reduction in the creation of new infections. However, there is not yet a uniform commitment to forest hygiene by all forest users. It is generally unappreciated that the forests are not only used by foresters and timber workers, but also by road and water supply authorities, mineral exploration companies, shire councils, farmers, beekeepers and many others. While co-operation with the hygiene rules has been excellent in most cases, there is still some antagonism to controls. There is a continuing need for educating all forest users in correct hygiene procedures and for updating management procedures as new research results become available.

THE FUTURE OF THE JARRAH FOREST

One of the most important factors influencing dieback disease intensification is the varying susceptibility of the forest on different sites. As previously explained, disease intensification and spread downslope are very rapid on moisture-gaining sites. In the northern jarrah forest most lowland sites west of the present quarantine area, approximately the 1150 mm rainfall isohyet, have existing disease infections. It is expected that all susceptible plants in these lowlands will eventually die, but at present there are few such sites left to infect.

In contrast, jarrah forest growing on well-drained upland sites, which constitute the bulk of the jarrah forest area, is much less susceptible to the disease. Natural downslope spread of an infection and consequently disease intensification is much slower than on the lowland sites. Jarrah trees may persist in diseased areas in upland sites for more than ten years without significant mortality.

We can therefore expect that the natural spread of existing disease infections will be much slower than during the 1950-75 period, provided there is continued attention to forest hygiene to minimize new infections of the disease.

Given this lower rate of disease spread in the future, and that jarrah on diseased areas will persist for many years, albeit with occasional setbacks caused by the periodic wet winters, there is scope for developing techniques of forest management which will create less favourable conditions for the disease and even further reduce its impact. Research along these lines has been one of the principal activities of the

Forests Department's research station at Dwellingup for some years and there are several publications available which report promising progress in forest management. There is now sound scientific evidence to support the Forests Department's contention that the jarrah forest is not doomed if strict hygiene procedures and positive attitudes are followed by all forest users. It is particularly important that new infections high in the landscape are prevented and that soil moisture patterns are not drastically altered, as this would create more highly susceptible sites.

An intensive research programme on the dieback disease problem will be continued in the foreseeable future. This research is taking place at several institutions in Western Australia and is partially financed by the Dieback Research Fund established by bauxite mining companies and the timber industry. The Fund has made an invaluable contribution to disease research. As new results come forward they will be put into practice as soon as it is feasible to do so.

We do not yet know the whole story of *Phytophthora cinnamomi* in the jarrah forest, but it must be recognized that lack of knowledge is no excuse for remaining inactive or for promoting a "doomsday" philosophy. We are developing management procedures from the best available knowledge to enable the forest to continue to be used, whilst also ensuring that these management procedures are updated as research proceeds.

FOREST MANAGEMENT PROCEDURES

The Forests Department has adopted a three-pronged attack on the dieback disease problem in State forests:

(a) the development of accurate maps of disease location,

(b) the application and continuous updating of stringent hygiene procedures,

(c) the management of the forest ecosystem to create conditions unfavourable for the fungus.

The desirable sequence of management begins with three years of quarantine, followed by aerial photography with the large-scale shadow-free colour system and finally the production of accurate maps of disease distribution. This will enable operations such as timber getting, bauxite mining and forest improvement treatment to be carried out under strictly controlled hygiene procedures, thereby reducing the risk of disease infections being spread to new areas. All forest activities need to be carefully planned and subject to intensive supervision.

Several different hygiene procedures are used, either separately or in combination, depending on the circumstances. These include confining forest activities to summer disease safe periods, vehicle washdown, limitation of vehicle access in the forest and specification of more appropriate equipment for some tasks.

Management of the forest as an ecosystem will progressively include more measures designed to render the forest environment less favourable to the disease organism. Based on the current state of knowledge, such measures will include:

(a) cooling and drying the surface soil by improving the density of tree crowns and promoting dense, low understorey vegetation;

(b) improving the proportion of certain plants in the understorey such as *Acacia pulchella*, which have been shown to contain substances which actively reduce zoospore numbers and inhibit their germination;

(c) improving the overall nutrient status of the site, e.g. by promoting an understorey of legumes;

(d) improving the ability of the most important host (jarrah) to resist infection through improvement of tree health;

(e) reducing the disease inoculum potential by removal of highly susceptible species such as *Banksia grandis*;

(f) avoiding any modifications to soil drainage patterns which would make soil more suitable for sporulation and zoospore survival;

(g) eliminating, or at least minimizing, any disturbance which leads to the puddling of soil that can stimulate zoospore production;

(h) ensuring that any water used in the forest is free of fungal inoculum;

(i) ensuring that all nursery plants are free of dieback disease.

It is important to appreciate that not all these measures are suitable for all sites. Ideally, we would have several measures operating at any one site so that if one measure is less effective for some reason, others will tend to compensate for it.

Finally, it should be emphasized that our knowledge of the biology of the dieback disease organism and its interaction with its host plants and the environment is constantly improving. We are dealing with a very complex ecological problem for which there is no simple answer. Nevertheless, we expect continued progress in the development of measures to inhibit the activity of the dieback disease and to help in learning to live with this unique situation.

GLOSSARY

dieback disease :	in Western Australia, the effects of the root rotting fungus *Phytophthora cinnamomi*.
dieback disease susceptibility:	the ease and rapidity with which the dieback disease is able to bring about the decline and death of a plant species.
dieback disease intensification:	the build-up of dieback disease activity in a locality, leading to the decline and death of a susceptible species.
encysted zoospore:	a fungal zoospore which is in a resting stage due to low temperature; the spore is still alive and becomes active again when the temperature rises above 15^{o}C.
fungus :	one of the lower forms of plant life which, lacking chlorophyll and being incapable of manufacturing its own food, derives its energy from dead or living plant or animal matter.
forest hygiene:	forest management activities designed to prevent transport of fungal inoculum from an infected area to an uninfected area.
inoculum:	portions of any pathogen capable of being spread to uninfected areas and initiating a new infection of the disease.
inoculum potential:	the amount of inoculum per unit of carrying substance, e.g. per gram of soil, as modified by environmental factors.
legume:	a plant belonging to the family Leguminosae and characterized by the ability, in combination with a special association with a beneficial fungus in its roots, of utilizing nitrogen from the atmosphere for its own nutrition.
moisture-gaining site:	an area, that due to local topographic or soil factors, tends to be more moist than the surrounding area.

mycelium:	the vegetative parts of a fungus, as distinct from the reproductive parts such as sporangia.
pathogen:	any living entity (in this case a fungus) capable of causing disease.
quarantine:	an area of forest to which access by vehicles is restricted under the Forests Act disease regulations, with the intention of preventing the transport of soil from infected forest to uninfected areas.
spore:	a single to many-celled reproductive body in a fungus in some lower plants, which can develop a new plant.
sporangium:	a plant organ that produced spores.
sporulation:	the production of spores.
zoospore:	a mobile spore of some algae and fungi.