PODGER, F.D. - Jarrah dieback in W.A.

Papers and commentaries from:
Professor E. Bjorkman
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At the invitation of the Director-General, Forestry and Timber Bureau, Professor Erik Bjorkman of the Royal College of Forestry, Stockholm, Sweden, an authority on mycorrhizae and forest tree nutrition visited Western Australia during March 1966 to examine the "jarrah dieback" disease.

The following papers have been compiled from commentaries on the visit provided by Mr. Angus and Mr. Batini, a written report by the Professor and my own comments on the Professor's report. They are presented in the order in which they were received.

F. D. Podger 8/7/66.

F. D. PODGER,
Western Regional Station,
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ON THE JARRAH (EUCALYPTUS MARGINATA) DIEBACK IN WESTERN AUSTRALIA - ITS CAUSE AND CONTROL

The dieback of the valuable jarrah (Eucalyptus marginata) in Western Australia has been observed for many years, and its cause has been widely discussed. The most common opinion among pathologists and foresters seems to be that the fungus Phytophthora cinnamomi is the real cause of the disease. Podger, Doepel and Zentmyer (1965) have demonstrated that this fungus occurs in the soils where the trees die. They have also shown that seedlings of jarrah and Banksia grandis are sensitive to a factor in the soil where Phytophthora occurs. This factor is able to disperse readily through the soil and is sensitive to soil sterilization. Many foresters have the opinion that the very dry summer period in this area is primarily responsible for the dieback of jarrah, and soil specialists have claimed that typical water-logging occurring in pockets in the soil might have something to do with the disease.

On my visit to the jarrah area in March 1966, it was impossible to observe where water-logging had occurred last winter. Mr. A.B. Hatch from the W.A. Forests Department, declared, however, that certain spots had been exposed to this phenomenon, but direct measurements of the water content in the soil at different times of the year had not been made.

Present experiments by Mr. Podger showed that different zones can be separated in the forest. In the most dangerous zone both Banksia and jarrah seedlings had died back. In another zone only Banksia had died but not the jarrah. The explanation of this phenomenon is supposed to be the more or less intensive attack by Phytophthora cinnamomi.

To solve the problem of the dieback of jarrah it seems most useful to compare this phenomenon with other known diseases of such a kind. Such diseases are the little-leaf disease of Pinus echinata in the South of the U.S.A., the dieback of birch in southern Canada and adjacent parts of the U.S.A., the pole-blight of Pinus monticola

and the Eutypella canker of white ash in the north-eastern part of the U.S.A.; from Europe similar dieback can be mentioned in Picea abies on very shallow soil and in the so-called hybrid aspen (Populus tremula x tremuloides) in very exposed sites. The most comparable disease seems to be the little-leaf disease. Also in this case Phytophthora cinnamomi has been isolated from the soil where the trees die. Comprehensive investigations by especially Zak (1961) on the life cycle of the fungus have shown that the formation of zoospores of the fungus - by which it is spread in the soil - is dependent on a very moist site and that aeration of the soil can very effectively prevent the development and spread of the fungus.

The above observation by Zak seemed to be confirmed on my visit to the jarrah areas for there were very similar conditions to those he describes where trees were healthy or dying respectively. Plants of jarrah and Banksia had died in experimental plots in a jarrah stand. There was, however, also an experimental field where jarrah plants and another Eucalyptus species (E. microcorys) were planted and growing healthy in a clear-cut area where all old trees had died and where the ground had been ripped before the planting.

An analysis of the known facts thus demonstrated seems to justify the following view of the problem, which, however, can only be definitely solved by further research, not at least field experiments combined with analyses of environmental factors such as soil moisture and its distribution, soil temperature, air temperature and transpiration of the trees.

During a drought period - especially in the second dry summer - the young roots of the trees will be very severely damaged by this drought. When the rain period begins the zoospores of the fungus Phytophthora cinnamomi germinate. Thus the fungus attacks the dead roots or weak living roots. The tree will then be still more weakened and eventually die.

The observation that the disease spreads along new forest roads could be attributed to the creation of favourable conditions for the development of the fungus such as wet spots. From such centers Phytophthora would attack first the more susceptible plants like Banksia, and on these host plants the fungal population would increase in such a way that enables it to attack the less susceptible species like jarrah.

A very important problem that should be investigated further, is the presence of the fungus in the soil. According to the published data the fungus is supposed to occur only sporadically in certain spots of the soil. It is recommended that this problem should be investigated more intensively. In other investigations the fungus Phytophthora cinnamomi has been demonstrated to be very widespread in the soil. Therefore, it seems likely to be the environmental conditions in the soil - especially the distribution of the moisture - that can be the most important factor for the development of the zoospores, which will be able to germinate only in very wet sites such as can be expected in connection with water-logging. Thus, the characteristic occurrence of the disease in spots can be explained.

Zak (1961) has demonstrated that the zoospores in dry soil are dormant and also that aeration of the soil can prevent their development and thus eliminate the dieback of the trees. If the physical structure of the soil, where water-logging is normal in certain spots, can be changed for example by ploughing, it seems likely that the environment will become so unfavourable for the germination of the zoospores that the fungus cannot attack the roots. Thus, this interpretation can explain the sound plants of jarrah on the ploughed clear-cut area, where the fungus earlier had completey killed the trees.

A possible control of the dieback of jarrah could be by ploughing or scarifying the soil in living stands where water-logging usually occurs during the wet season. This treatment may be relatively expensive but not too costly compared to the timber value, and perhaps only a slight treatment would be necessary. Further research on this point is recommended.

Stockholm, April 7, 1966.

(Signed)

Erik Bjorkman

VISIT OF PROFESSOR BJORKMAN

PROFESSOR BJORKMAN

a) Expresses doubt that P. cinnamomi is the primary agent.

b) Considers probable - in spite of your failure to indicate presence in "healthy" areas by baiting - that P. cinnamomi is present throughout the area.

c) If present in healthy areas may be in relatively dormant state until and unless there is some disturbance to the site - e.g. temporary waterlogging.
(On your own evidence such conditions are favourable to the fungus and unfavourable to jarrah.)

d) Wonders if you have tested whether Banksia and Personia are more susceptible to waterlogging than jarrah, which would make them quicker targets for P. cinnamomi.

e) Considers you should make intensive efforts to try to obtain P. cinnamomi from "healthy" areas. e.g. from roots of healthy jarrah or other plants, not merely proving presence in actively hostile state by lupin baiting of soils.

f) Appears to consider the water logging an extremely vital factor (Alan Hatch emphasised that true waterlogging is not common in jarrah soils, which are relatively well-drained. A temporary supersaturation could occur).

g) Thinks more intensive field studies of the soil moisture aspect of the disorder should be made if an outbreak occurs under any particular set or level of circumstances.

h) Was impressed with your field experiments at Karnet but suggests that these could be intensified, particularly in regard to (g).

* The formalin treatment did not provide complete immunity. The treatment effect broke down after about 9 months. After 17 months 6 weekly thiram drenches have been applied to the original formalin treated plots.

F. B. Podger, 8/7/66

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g) Thinks more intensive field studies of the soil moisture aspect of the disorder should be made if an outbreak occurs under any particular set or level of circumstances.

h) Was impressed with your field experiments at Karnet but suggests that these could be intensified, particularly in regard to (g). Was particularly intrigued as to why the formalin treated patches of natural regeneration of jarrah should have retained comparative immunity for so long, when closely adjacent to attack seedlings.*

i) Suggested trial of such measures as soil cultivation i.e. a die-back area, on the basis of soil disturbance, improved aeration and drainage in the surface layers interfering with or reversing conditions suitable to the growth and spread of P. cinnamomi.

j) Had no specific comment as to why a focus of infection should spread steadily outward into apparently healthy forest, whereas a change in local conditions could - or should - presumably stimulate several simultaineous or massive overall outbreak.

k) Also had no specific comment on why there appear to be no such spontaneous outbreaks in isolated virgin or relatively undisturbed jarrah forest.

Professor Bjorkman will, I imagine, be submitting a report to the Director General and presumably a copy will be available for you. Frank Batini will be interested if Professor Bjorkman does offer any written comments.

A. R. ANGUS,
Acting Officer In Charge,
Western Regional Station, Forest Research Inst.
6/4/66.

Harvey Working Plans Office,
6th April, 1966.

VISIT OF PROFESSOR BJORKMAN

The professor raised a number of interesting points during his field trip on the seventeenth of March, 1966. These notes have been compiled so as to supplement both the Professor's own report to Doctor Jacobs and the report which you will receive from Mr. J. R. Angus.

The Professor was very impressed by the extent of the disease and the effects which it has on the Jarrah community. He fully appreciated the economic importance of Jarrah as a timber specie and consequently the importance of the disease. He did not consider that Phytophthora cinnamomi plays the primary role in this disease, and suggested that silviculture and/or soils may.

Phytophthora cinnamomi - indigenous or introduced?

(1) The fungus is regarded as being "universal".
(2) The failure to recover Phytophthora by baiting in unaffected stands does not prove that the fungus is not present there.
(3) The fungus may be present in the unaffected forest but in a resting form. Lupin infection will not be achieved unless the dormancy is broken and the fungus given time to build up its inoculum level.
(4) Chlamydospores of Phytophthora can be produced experimentally in the laboratory. These could be used so as to arrive at a technique whereby the resting stage can be broken.
(5) Direct plating of roots of known host plants from unaffected areas could be tried to see if these will yield Phytophthora.
(6) Could the present west - east trend of dieback be due to factors such as rainfall or cutting rather than the eastward movement of the disease?
(7) It is very important to establish conclusively whether phytophthora is indigenous or introduced. Such a decision will greatly influence the methods used to control both the outbreak and the spread of the disease.

Primary or secondary function of phytophthora cinnamomi?

(1) A degree of predisposition is usually necessary before a fungal pathogen attacks a plant.
(2) The primary role of Phytophthora in the "littleleaf" disease has not yet been conclusively proven. This is regarded as a complex disease involving soils of impeded profile drainage,

shallow depth and low nutrient status in combination with a fungal pathogen.

(3) It was suggested that the same conditions may apply in Western Australia. Among the factors listed were -

(a) The periodic wetting and drying of the soil and the subsequent movement of the water table.

(b) The low fertility of the soil.

(c) Aluminium toxicity.

(d) The loss of fertility in conjunction with a second rotation.

(e) Changes in the ecosystem as a result of man's activities. i.e. trade cutting and road construction.

(4) The point was raised as to whether a soil condition or silvicultural treatment allowed a large buildup of inoculum of Phytophthora to occur. The fungus could then take over and become the primary cause of Jarrah dieback.

(5) The fact that of the 7 eucalypts tested, Jarrah was the least tolerant to excessive soil moisture, interested the Professor. He suggested that similar tests should be conducted on both the susceptible and resistant species of the understorey with particular emphasis on B. grandis.

(6) The extension of soil temperature and soil moisture studies in all zones ranging from "unaffected" through to "old dead" was suggested. The Professor also suggested that the soil moisture regime in the unaffected forest may not be adequate for the buildup of inoculum unless the conditions are changed as the result of man's activities.

(7) Pathological disorders caused by root rotting organisms are often kept in check by soil antagonism caused by such species as Mortierellas and Trichodermas. The role of antagonistic fungi and mycorrhizae in disease resistance needs to be more fully investigated.

GENERAL

(1) It is surprising that the understorey species are the first to be affected. This is contrary to the Professor's experiences overseas.

(2) Great care must be used when interpreting the results in potted and sterilized soils. When testing for disease resistance in nutrient solutions the role of mycorrhizae in disease resistance must not be forgotten.

(3) Pot trials under varying soil moisture regimes should be carried out to test the effect of soil moisture content on the development of the disease.

(4) Instead of soil sterilization the use of pure sand as a culture medium was stressed.

(5) Both pathologists expressed surprise by the difference in the survival of Jarrah seedlings caused by thiram drenching. It was expected that the treated plots would be reinfected by Phytophthora as a result of spore wash. The persistant differences could be due to antagonistic fungi, which, having reinvaded the treated plots first, slowed down the re-entry of P. cinnamomi. *

(6) The study of the disease under field conditions with the minimum amount of soil disturbance was stressed.

(signed)

(F. Ratini, A.D.F.O.)

Harvey
7.4.66
FB:EJP

* The response is due to repeated applications of Thiram at intervals of 6 weeks and not, as the party appears to have been advised, the result of a single treatment.

F. D. Podger, 8/7/66

COMMENTS ON PROFESSOR BJÖRKMAN'S REPORT ON JARRAH DIEBACK

During March, 1966, Professor Erik Björkman of Stockholm, Sweden, in company with Mr. Stahl of the Forest Research Institute, visited Western Australia to examine the jarrah disease known as "Dieback". The Professor has since submitted a report which incorporates recommendations for possible control measures and suggestions for further research. A copy of his report is attached.

Because Professor Björkman visited the station during my New Zealand tour of duty I did not have the opportunity for discussion with him. Before leaving for New Zealand, however, I furnished Mr. Angus of the Forest Research Institute and Mr. Batini of the Forests Department of Western Australia with relevant data and literature for Professor Björkman's perusal. Mr. Hatch of the Forests Department also accompanied the party during the field tour. These officers were well qualified to conduct the Professor since Mr. Hatch was responsible for the early investigations on jarrah dieback to 1952 and has considerable knowledge of the soils of the jarrah forest, while Mr. Batini had recently spent a period with me to become familiar with the problem and our research. It could not be expected however, that all the evidence on which my conclusions are based would be familiar to the group since much of it has yet to be reported.

Undoubtedly due to the heavy programme of travel and inspection and to the limited time available, certain phenomena, which bear on Professor Björkman's observations, appear to have escaped the attention of the party. These are indicated below as they relate to the Professor's comments:

1. On the Role of Phytophthora cinnamomi

Professor Björkman proposes

1. that P. cinnamomi's role in this disease is secondary.
2. that P. cinnamomi is recognized as a universally distributed organism and probably occurs in both diseased and healthy jarrah forest.
3. that P. cinnamomi is sensitive to aeration therefore improvement of soil aeration might prevent development of zoospores and thereby elimate dieback of trees. Conversely P. cinnamomi germinates only during periods of poor aeration following waterlogging.

In so far as my own conclusions are contrary to those of the Professor in each case; and because these matters have an important bearing on the possibilities for control, and on the nature of future research at this station, a critical review of the relative merits of the two hypotheses is warranted.

a) On the sensitivity of P. cinnamomi to aeration

The Professor's authority for this conclusion is the 1961 work of Zak (1) on aeration and the Littleleaf disease. He supports this with the observation that healthy jarrah plants were seen growing in a cleared dieback area where he suggests, ploughing has improved soil aeration.

Littleleaf is recognized as a disease of eroded soils of poor internal drainage and low fertility and has been shown to be associated with P. cinnamomi (2). Zak 1961 carried out a series of greenhouse studies to determine the relative roles of:

1) Poor aeration on pine growth
2) P. cinnamomi root rot on pine growth
3) Poor aeration on the virulence of P. cinnamomi
4) Poor aeration on the susceptibility of pine roots to P. cinnamomi root rot.

He showed that, in the absence of P. cinnamomi, lower levels of soil oxygen caused a significant reduction in both root growth and the abundance of mycorrhizae of Shortleaf pine. Further he demonstrated that P. cinnamomi caused greatest root damage where watering was excessive. It was concluded that both poor aeration and P. cinnamomi caused damage to pine roots. The increase in root damage by P. cinnamomi in wet soil was attributed to improved conditions for sporangial production and zoospore movement. Soil aeration per se however was found to have no effect on the activity of the fungus and Zak concluded "the greater virulence of P. cinnamomi in wet and poorly drained soils is not a function of poor aeration". Earlier Curtis and Zentmyer (3) working with Avocado seedlings in aerated nutrient culture found that injury from root attack by P. cinnamomi under conditions of ample moisture occurred at levels of oxygen from full aeration down to nearly total lack of oxygen.

Waterlogging and poor soil aeration are not essential prerequisites to Phytophthora attack as Professor Björkman suggests. Root rot by this group of organisms may occur on light and well drained soils provided there is excessive water. Braun (4) working with P. drechsleri root rot of guayule and Newhook (5) and Sutherland, Newhook and Levy (6) with P. cinnamomi root rot of Pinus radiata found disease on well drained soils. In the case of guayule, root rot followed excessive irrigation; in the case of P. radiata, prolonged heavy rain. Severe root rot of jarrah seedlings has occurred in pots of gravelly sands taken from dieback areas. The free draining pots were watered once daily. P. cinnamomi was isolated from rotted roots and the resulting pure cultures were added to jarrah seedlings growing vigorously on well drained coarse sand watered once daily. Further root rot occurred. It was concluded that P. cinnamomi causes extensive jarrah root rot in freely drained well aerated soils provided that moisture and temperatures conditions are favourable to the fungus.

b) On the primary or secondary role of P. cinnamomi

On the basis of the above evidence, P. cinnamomi appears to be capable of causing primary injury over a wide range of soil conditions, Whereas the extent to which root rot affects the plant is dependant on the susceptibility of the host, site factors may also influence the ability of the damaged root system to recover. Site factors appear to play a particularly important role in the case of the Littleleaf disease. Even so, among the Littleleaf researchers, the favoured interpretation is that Littleleaf is a disease due to primary root damage by P. cinnamomi aggravated by poor soil aeration and low soil fertility (1, 2). Professor Björkman proposes the reverse i.e. that roots are damaged by adverse site influences and further weakened by P. cinnamomi attack.

c) On the observation of healthy jarrah seedling growth in ploughed dieback areas

The observation made by the Professor page 2, para 2 of his report has been advanced by several local foresters as evidence that jarrah dieback might be cyclic and that areas might reforest to jarrah in time. In 1964 a close examination was therefore made of a number of areas similar to that described by Professor Björkman.

Two sets of conclusions are possible, depending on how soon after clearing and ploughing a dieback area is examined. Shortly after ploughing, and for up to a few years, new apparently healthy jarrah advance growth seedlings can usually be found. Thereafter they gradually die out. Their temporary survival is attributed to the greater resistance of jarrah in the advance growth stage and to low inoculum levels of P. cinnamomi. The reduction in inoculum is considered more likely due to reduction of living host material by ploughing than to any effects of ploughing on soil aeration. It is suggested that the observed later deaths occur whenever inoculum builds up, even temporarily, following more favourable conditions for fungal activity. Periodic extreme stress, following excessively wet or long dry periods, may also contribute to the mortalities.

The deaths of jarrah planted on thoroughly cultivated ground in van Noorts (7) trial at Halio Road and in my own experiments at Karnet and Huntly indicate that cultivation of dieback areas is unlikely to arrest the disease.

It is concluded that the experimental work of Zak and the experience of jarrah growth on planted up old dieback sites lends support to the hypotheses that pathogenicity of P. cinnamomi is primary and is not conditioned by aeration.

d) On the universal or limited occurrence of Phytophthora cinnamomi in jarrah forest soils

Professor Björkman suggests that the fungus, as dormant resting bodies, probably occurs throughout healthy areas. This hypothesis is not easy to refute since the absence of dormant spores can never be conclusively demonstrated.

Our own work in the spring of 1965 showed constant association between the fungus and dieback in some 180 samples from 31 localities. In every case an equal number of samples was taken from adjacent non diseased stands. In a number of instances the unaffected forest samples were taken within half a chain of the diseased forest samples; often on apparently identical soil, topographic and drainage situations. On no occasion was P. cinnamomi detected by lupin baiting soil samples from healthy forest.

At Karnet each two weeks for one year 15 samples each have been taken from healthy forest and from dying forest one chain away. Soil moisture and soil temperature records for the same places are available for the same period and show no marked differences. Nonetheless, P. cinnamomi has been recovered from the diseased forest soil on more than half these occasions, but never from the healthy area.

Professor Björkman was shown this information and considered the lupin baiting technique must be incapable of detecting resting bodies.

In his report Professor Björkman refers to the demonstration of widespread occurrence of P. cinnamomi in both diseased and unaffected forest. This is true of investigations in New Zealand (5, 8, 9) and of the Littleleaf disease (2), but does not reflect Zentmyer's (10) experience in California and Latin America where, despite many attempts, he has never recovered P. cinnamomi from virgin areas. Similarly the fungus was found in nurseries but not in forest stands in the Pacific N.W. of U.S.A. (11).

Newhook (5) isolated P. cinnamomi from under healthy P. radiata stands using the apple-baiting technique. Similar experience by Campbell and Copeland (2) in the Littleleaf area is reported. In view of the efficacy of this technique in both situations it might be expected that the use of a similar technique, involving the use of living highly susceptible host, might give similar results. Chee and Newhook (12) made comparative tests of the lupin and the apple technique and obtained generally higher recoveries with the former method.

Since Professor Björkman's visit Darling, at this station, baited for the fungus in healthy forest soil kept waterlogged in pots for 3 months; baiting every second week over the 3 months has failed to yield the fungus. Stimulation of the dormant spores under such poorly aerated conditions might have been expected if the Professor's hypothesis is correct.

Finally we have recently produced dieback symptoms in a previously unaffected stand both by transfer of small quantities of diseased forest soil and by pure cultures. P. cinnamomi was recovered from inoculated plots but not from immediately adjacent controls. This is regarded as evidence of the ability of P. cinnamomi, unaided by poor aeration or disturbance, to cause dieback and is consistent with the reported behaviour of the fungus.

Other queries raised by Professor Björkman

1) The east west trend of dieback (see Mr. Batini's notes item 6) Rainfall decreases rapidly eastward in the jarrah forest. This might be expected to influence the spread of a fungus dependant on a swimming spore stage; lower rainfall probably accounts in part for the lower incidence of dieback in eastern jarrah areas. On the other hand much eastern forest has only a recent history of logging and roading; the low incidence could therefore be due to lack of opportunity for introduction of the fungus. In my opinion the trend expresses the influence of both factors.

2) The need for intensive soil temperature and moisture studies is recognized. It is apparent from the comment that the party was not aware of the full extent of the installations at Karnet. Continuous records of temperature in the 0" - 3" soil level are maintained in each of the healthy, dying and dead zones at Karnet. All are on similar gravelly sands and all in a radius of 5 chains. At these same localities soil temperature between 6" - 9" and 9" - 15" are measured periodically. Soil moisture determinations and lupin baiting for Phytophthora are carried out once every two weeks on 5 replicates at each of the three soil depth zones on all three sites. Data from one years observations is now available. This indicates that soil moisture and temperature conditions were favourable for Phytophthora build up in all zones during much of spring and autumn. Winter temperatures were generally too low and in summer soils too dry for buildup of the fungus.

3) There has been no investigation by us of a build up of antagonistic fungi after treatment with formalin or thiram; it remains a distinct possibility however, that this could be part of the therapeutic nature of thiram treatment. The principal of thiram action according to Kreutzer (13) is interference in the citric acid cycle in the metabolism of sensitive fungi.

4) The professor's point concerning our lack of knowledge of resting stages and dormancy is acknowledged. This is of considerable importance to final resolution of the question. Work elsewhere (Zentmyer, in preparation) may soon provide some answers.

F D Podger 6/7/66.

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