JARRAH DIEBACK

Research Report and Technical Information.

File	428/65	period	August 1965 to August 66.
	403/66	period	October 1966 to January 68.
	122/68	period	Feb. 1968 to July 71
	194/69	period	Nov. 1968 to October 70
	319/70	period	Nov. 1970 to April 72
	224/72	period	Dec 75
	109/76	period	Dec 1975 to. Current (May 81)

Full copy of [illegible]'s file. 7/82 -

NB (over) - [illegible] on [illegible] & [illegible] etc.

Also

126/69 Jarrah Dieback — Mapping
156/69 " " — Management – Logging
36/70 " " — Research general
391/69 " " Anatomical & pathological investigation
457/60 " " Reports by F. Podger
246/68 " " Report by Dr D. Pratt.
394/69 Fungi affecting roots & soil – general.

* wp 36/66 – The role of nutrition in determining host resistance to P. cinn (Hartley)
35/66 – Field resistance to P.c. (Harvey)
* 38/66 – Field resistance of P. radiata to P.c.
* 37/66 – Field resistance of P. pinaster to P.c.
wp 41/66 – Field resistance to Phytophthora root rot
<122/68 12/68 – Influence of moc, drought & nutrition on resistance of Pp and Pr to P cinn
* 13/68 – " " moc, soil type watering – – – –
* 14/68 – " " moc, watering, drought – – – –

302/79

Dieback File

NOTE

CONSERVATOR OF FORESTS

PHYTOPHTHORA CINNAMOMI - ITS ATTACK ON PINUS RADIATA IN THE SUNKLAND

In accordance with your request, below please find a brief outline for the Minister of Forests, should the matter be raised in the media.

1. Deaths of pinus Radiata have been noted in 2-7 year old plantations in the sunkland. So far, the level of death is low (10-15 stems per ha.), so that the losses are insignificant as a management problem. The number of deaths appear to fall off as the plantations become older.

2. Phytophthora cinnamomi has been associated with these deaths, but in most but not all cases, the deaths are most frequent in areas of forest which was infected before clearing for plantation establishment.

3. The deaths are virtually confined to two soil types:

   a) Type 7 (poorly drained alluvial soils on valley floors) which occupies only a small proportion of the plantation area and which will be exlcuded in future.

   b) Type 4 (somewhat better drained sands and sandy loams of lower slopes and valley floors) which occupies approximately 20% of the total plantation area.

4. At this stage, Phytophthora cinnamomi attack is not seen as a major threat to pine, but intensive research is in progress to ensure that the problem is not aggravated with time e.g. it is mainly potential threat which is being considered.

5. Should the deaths prove a real problem in the case of Pinus radiata, Pinus pinaster can be planted instead in the more susceptible sites. In addition, as research has shown, there is marked genetic variation in the susceptibility of Pinus radiata to the disease and the accent on future tree breeding will be on the resistant strains. The substitution of Pinus pinaster for Pinus radiata may lower the productivity and increase the complexity of the utilisation of the resource.

6. In addition to the work directly financed by the department, a grant has been obtained from the Rural Research Fund for the study of mycorrhiza as a defence mechanism against the disease. An officer hired under the scheme has made considerable progress.

Noted [signature] 16/5.

J.J. HAVEL

14th May, 1980.

CONSERVATOR OF FORESTS

PERTH. W.A.

DIEBACK INVESTIGATIONS IN THE SUNKLANDS

In my report of the 14th December, I gave you the summation of findings up to that date. As it is a high priority research project, considerable additional information has been obtained since then, and I have visited the area with Messrs. Quain, Van Noort and Hopkins. The brief resume of the field trip is as follows:

Of the site types present in the sunklands, sites 1 and 2, which represent laterites and the adjacent lateritic sands, are already excluded from pine planting. Type 6 is no longer mapped, presumably because its original definition was ambiguous. Of the types that are planted with pine, the highest occurrence of the Phytophthora attack on pines is on site 4 (basically sands and loamy sands which are leached and acid), and site 7 (loamy, seasonally waterlogged valley bottoms). Sites 3 and 5, which are basically sand loams intermediate between 4 and 7, contain much lower level of Phytophthora attack.

The question that arises is what can be done about minimising the risk of the disease. Site 7 is less of a problem, in that it is much more restricted in area and can probably be dealt with quite simply by adding it to the stream reserves. This would have the additional benefit of reducing the opportunity for criticism from the fauna and hydrology point of view. Site 4 is a more serious problem in that it is much more extensive and represents a significant proportion of the total plantation area. Because of its extent, it has been subdivided in the 3 sub-types and these may provide a rationale for clarifying the situation. Type 4a, which consists of the deepest and driest leached sands is a doubtful proposition for pine planting except perhaps where clover is used. Radiata on these sites has acute nutritional problems and its performance is inferior to pinaster. However, even performance of the latter species is only equal to, or below, the average pine plantation north of Perth. The form of pinaster on these dry sites is satisfactory, and there is some hope that the use of clover and the associated heavier application of phosphate may improve the nutrient situation. It is just as likely that the deep, leached sands also represent an obstacle to successful establishment of clover. The most likely solution on our present knowledge is to plant these sites up with genetically improved pinaster where their exclusion would create boundary problems, and leaving them out of the planting area where they represent extensions into the laterites. Site 4d is characterised by wet humusoid sands with a particularly bad track record for disease. This presents considerable problem, in that the form of pinaster is unacceptably bad even when improved seed is used. Although some satisfactory establishment of Pinus elliottii and Pinus taeda has taken place on this site, this is not without problems in that particularly Pinus elliottii is probably more susceptible to Phytophthora than pinaster. Here, even more than in the case of 4a, exclusions of this type is desirable, but where this is not feasible, the

.../2

Other relevant observations are that several species of Pythium and two additional species of Phytophthora (cryptogea and megasperma) are present in the soil and the roots of diseased trees. Pathogenic fungi are sometimes found in the roots of up to 1.8cm diameter and even in the collars of some of the young pines.

It is not easy to conclude out of the available information which of the two alternatives we are facing. It is probable that the real test will come when we encounter a particularly wet winter and spring. However, it is not intended to leave this to chance and a trial in which the soil water content will be raised by artificial irrigation is planned for next year. In the meantime the best recommendations that can be made are:

(a) our nurseries should be carefully screened for the pathogenic fungi, so that the stock going out of them is not a source of infections;

(b) sites on which Pinus radiata performs poorly and incurs a high level of infection should either be left out or planted with alternate species;

(c) the situation should be kept under continuous review.

19/2/1980

1 ~~CONSERVATOR OF FORESTS~~ 21.2.80

2 Mr ~~[illegible] rep 2/4~~ 17/4

3 Mr ~~[illegible] rep 3/4~~

Chevis is now studying the moisture levels and temperatures in thinned and unthinned stands and will attempt to tie these to the actual occurrence of dieback.

A tie between the work carried out by Chevis and Stukely and the genetical work being done at Wanneroo would indicate that some of the strains of Pinus radiata appear to be less susceptible to the dieback than others. One logical outcome of this would be the deflection of our breeding from the pre-occupation with growth potential and form to some consideration of resistance to dieback.

The work of Boughton is so far in the early stages. The mycorrhizal work is particularly difficult in that the organisms involved are very hard to identify. It would seem that presence of mycorrhiza within an area is not an automatic guarantee that Phytophthora attack will not occur. In fact, there is indication that in the Sunkland as a whole, and particularly in the poorer soils, the level of mycorrhizal activity is definitely below par. It would be desirable to improve it either by modifying the nutritional conditions, or by introducing strains of mycorrhizal fungi better suited for this difficult environment.

The implication of these findings are already being worked upon. There is an increasing acceptance by the Central Region that radiata, despite its greater initial growth potential, may not be the best species for all sites. The work currently going on, such as McCutcheon's work on site quality for the various species, and nutritional studies, particularly that on subsequent fertilisation, is going to provide the basis for change in management practice, which may become necessary as our knowledge improves.

Examination of the performance of the genetically improved Pinus pinaster has lead to greater acceptance of this species as a viable alternative to radiata, particularly on sandy soils where adequate nutrition is very difficult to provide for Pinus radiata, or on water gaining sites where dieback is a risk.

Summing up the observations, there is at this stage no cause for panic, but the investigations should continue at the present high level. When the situation has been clarified, the findings should be subject to a policy review meeting and there should be early transmission of the conclusions of that meeting to the field.

J.J. HAVEL
CHIEF OF DIVISION.

December 14, 1979.
JJH:ALB

19.12.79

1. Noted with interest.

Mr. Havel.- Pl. let me know how things develop, with view to meeting when approp.

Mr F.J. Campbell 25/1

Mr B.J. McNamara 31/1

Mr S.J. Shea 17/4 3/1/80

FILE MEMO File ~~102/78~~

Research Activity: P. radiata and Phytophthora cinnamomi.

There has been some concern that ~~P~~ the establishment of Pinus radiata in the Donnybrook Sunkland could present a problem with respect to Phytophthora cinnamomi. This concern was recorded in the "Statement of Intent" and most of the ~~areas~~ plot plots so far planted have been in areas of known dieback infection.

The literature records problems in the first 2 or 3 years and in old ~~stands~~ open grown stands, but ~~time~~ in site situations quite different from those of the Sunkland.

In recent weeks the incidence of scattered deaths has increased, and samples collected by Drs Shea and Shearer have been found to contain Phytophthora cinnamomi in ~~root~~ P. radiata roots greater than 1 cm in diameter.

In the light of this development, the research programme was reviewed at a meeting on July 15th and a re-direction of research effort has been approved by the Acting Conservator.

The initial approach will involve:

a) A survey of the incidence of tree deaths in the Sunkland, attempting to correlate deaths with soil type, topography and native ~~species~~ indicator species

b) A review of data collection methods to determine under what site and stand management conditions the ~~disease~~ pathogen is able to sporulate.

c) An increased baiting programme to ~~clarify the random relationship of random deaths~~ establish whether the random deaths are due to random disease distribution or to physiological variation of hosts.

/2

d) Innoculation experiments to determine conditions of ~~stand~~ the plantation under which the disease can survive

e) Investigation of the inter-relationship between Phytophthora cinnamomi and root mycorrhizae.

These proposals have necessitated a re-direction of some research effort, and a short-term involvement of some staff outside the research branch ~~e.g.~~ eg. SDFO Bradshaw examining the best method of photography, ~~SDFO McCutcheon is assisting in site evaluation~~. The proposal has also necessitated the transfer of T/O Stukely from Wanneroo to Como to carry out the additional baiting work.

I wish to emphasize that there is no suggestion of a panic situation. We have reacted to evidence of a potential threat and are making ~~the sea~~ prudent moves to gain the information needed to place the threat in true perspective. It may well be that after 12 months we will come to the conclusion that P.c is not a threat to the project as a whole. If so, we can continue the project with confidence.

If we do not resolve this question now, we will have left ourselves in a vulnerable position.

Acting Chief of Division
Head Office
3-8-79

Distribution: Mr PJ McNamara
Mr F.J. Campbell
Mr WH Eastman
Mr SJ Quain
Mr J B Campbell
Dr E R Hopkins
Mr J C Meachem
Mr D L Gra[illegible]
[illegible] N[illegible]t

Mr McNamara

Re: Phytophthora cinnamomi on P. radiata.

Further to the discussion with yourself and Dr McKinnell, I attach his submission for a "CRASH PROGRAMME" of research into a potential P.C. problem in the Sunklands.
As agreed, a re-arrangement of work loads within the research group will be directed to the five tasks outlined under 3 a) to 3 e) in the attachment.

Hewett
17/7/79

Mr. F.J. Campbell.
For info., please discuss with Mr Hewett approach to informing staff.

Arranged. FJC 3/8

McN
18/7

Mr Hewett.
Please arrange for Chiefs of functions & Ops group (Messrs Quain Curran & vanNoort) to be fully briefed on action taken & background to that action. Mr McKinnell's final para is a good assessment of position adopted by Dept. at this time.
FJC 3/8.

Mr F.J. Campbell,
I think the attached memo should provide enough background information for Chiefs.
Hewett 3/8/79.

CONSERVATOR OF FORESTS
PERTH

PHYTOPHTHORA CINNAMOMI AND RADIATA PINE

Since the commencement of the Sunkland project there has been some concern that *P.c.* might present a problem to radiata pine. There have been scattered deaths, mainly in the first 2-3 years after planting and the incidence of the deaths has been so slight that it was felt that it could be tolerated.

The situation has changed in recent weeks. The incidence of scattered deaths has increased (I cannot quantify this as no detailed assessment has been carried out) and for the first time we have seen an infection centre in operation, similar to that we get in jarrah forest.

The situation has been inspected in the field by Drs Shea and Shearer, who have expressed renewed concern at the potential problem we may have.

Roots of dead and dying pine have been tested at Dwellingup and found to contain *P.c.* in roots greater than 1 cm in diamater. We cannot, at this stage, say definitely that *P.c.* is causing death of the pine, but there is a strong association between death of trees and detection of the disease.

On Wednesday last the situation was reviewed at a meeting of all research staff involved. Arising from these discussions I have come to the following conclusions:

1. We may or may not have a potential disaster on our hands in the Sunkland.

2. On balance I believe we will eventually learn to live with a degree of *P.c.* damage there, but we cannot afford to take the risk of a major collapse after tree age 20 years (*P. radiata* appears to be physiologically more susceptible to *P.c.* after tree age 20). Quite apart from the economic and resources aspects, the damage to the Department's prestige would be incalculable.

3. The potential severity of the problem is such that we must immediately commence a crash research programme to increase our understanding of the *P.c.*/*P. radiata* relationship. This programme must be given the very highest priority.

   The initial lines of work will be:

   (a) Survey the incidence of tree deaths in the Sunkland and try to correlate deaths with soil type, topographical position and native vegetation indicators.

   (b) Review our methods of data collection on soil physical environment (i.e. soil moisture and soil temperature) to determine under what site and stand management conditions the disease is able to sporulate.

[2] Nature 101:615-616.

(c) Commence a massive P.c. baiting programme to establish whether the random deaths we observe are due to random disease distribution or to host physiological variation, and to increase, our knowledge of P.c. in the Sunkland generally.

(d) Carry out inoculation experiments in selected areas to determine the conditions of stand age, site fertility etc., under which the disease can survive.

(e) The inter-relationship of P.c. and root mycorrhizae needs urgent clarification.

In deciding how these tasks are to be carried out I have given consideration to diverting some of our Dwellingup staff to this problem, but this would present technical and "political" problems at the present time. It is also not possible to use our very inexperienced Busselton research officers in such a highly technical field as part (c) above. With regard to our physical, financial and staff resources I recommend the lines of work outlined be attacked as follows:

(a) The survey aspect will be covered by aerial photography, interpreted by Inspector Kimber and Busselton research staff with the assistance of Mr McCutcheon. S.D.F.O. Bradshaw is now examining the problem and will advise as to the best method of photography (oblique 35 mm or vertical 70 mm).

(b) Mr Kimber will coordinate the review of physical data collection and immediate steps will be taken to rectify possible deficiencies in equipment and to expand the data collection as necessary. Further funds might be necessary, to the extent of $5000. I will present more concrete proposals as soon as possible.

(c) I propose to transfer T/O M. Stukely from Wanneroo to Como to carry out the P.c. baiting programme. Mr Hatch will vacate one of his laboratories for Stukely and some further equipment will be required - this can probably be funded from existing estimates by reallocation.

I have in mind a major rearrangement of the Como building to facilitate this research, but even if approved, this would take some months to carry out and we must aim to have the baiting programme operational in two weeks in order to be ready for the spring flush of P.c. sporulation.

(d) Inoculation trials will be carried out by Busselton research staff in cooperation with Stukely.

(e) The mycorrhizal study by T. Boughton under the Reserve Bank grant will continue as planned.

In addition to the above, I propose to make contact with researchers in the Eastern States who have worked in the area of P.c./P. radiata in the past to evaluate any possible contribution they might make.

Nature 101:615-616.

In conclusion, I wish to emphasise there is no suggestion that we are in any way in a panic situation. We have simply realised there is a potential threat to the entire Sunkland project and we are making sensible and prudent moves to gain the information we need to place the threat into true perspective. It may well be that after 12 months we will come to the conclusion that P.c. is not a threat to the project as a whole and that some of the work can be discontinued. If so, we can continue the project with confidence. If we do not resolve this question now we will have left ourselves in a very vulnerable position.

FHMcKinnell

F. H. McKINNELL
SUPERINTENDENT, RESEARCH

FHMcK/me
Como Research
16/7/79.

[2] Nature 101:615-616.

Form F D 808

FORESTS DEPARTMENT

DWELLINGUP RESEARCH Office,

JULY 11, 1979

Western Australia

Reference-H.O.

Local

To SUPERINTENDENT McKINNELL
FORESTS DEPARTMENT
COMO RESEARCH

SUBJECT: OBSERVATIONS ON PINUS RADIATA DEATHS IN THE DONNYBROOK SUNKLANDS

This report details observations on Pinus radiata plantations in the the Donnybrook sunklands made on July 5, 1979 (Appendix 1) and the results of plating surface sterilized root pieces of P. radiata onto a selective medium for the detection of Phytophthora cinnamomi infection (Appendix 2).

SUMMARY OF OBSERVATIONS:

1. There is a strong association between death of trees and detection of P. cinnamomi (Appendix 2).

2. At some sites trees showing symptoms of P. cinnamomi infection could readily be observed (Appendix 1). Dead or dying trees were generally randomly distributed within the plantation. However, at the Vasse Highway plantation trees adjacent to one another were dead, at the Agroforestry plot tree deaths only occurred at the edge of the plot and at No. 3 road plantation an infection centre, similar to those occurring in the jarrah forest, was observed. 1.

3. At some sites (e.g. the 7-year-old Vasse Highway plantation) I was told that tree deaths have occurred every year after planting.

4. There appears to be no clear association between tree age and the incidence of symptoms or detection of P. cinnamomi infection (Appendix 1 and 2).

5. The incidence of symptoms associated with P. cinnamomi infection was very variable, with greater differences between sites than age of tree (Appendix 1).

6. Phytophthora cinnamomi was detected in roots greater than 1 cm in diameter (Appendix 2, photographs).

CONCLUSIONS:

1. There is a definite need to quantify, each year, the number of trees showing symptoms of P. cinnamomi infection. A true picture of the incidence of tree deaths could not be obtained since dead trees are removed during routine maintenance. Quantification of tree deaths associated with P. cinnamomi infection would be a relatively simple matter in a row crop such as pine.

   Assessment of the change in pine deaths between years and sites is needed for an objective assessment of the implications of P. cinnamomi infection in relation to P. radiata plantings.

2. More information is needed on the level of P. cinnamomi inoculum in sunkland soils, especially in relation to:

   (a) differences between soil types;

   (b) the depth of soil that viable inoculum is present;

   (c) spatial variation; and

   (d) seasonal variation.

This information is needed for the assessment of the potential threat of P. cinnamomi to P. radiata plantings and the implementation of possible control strategies.

3. Care must be taken in not placing too much reliance on the supposed resistance stage of P. radiata during the 3 to 20 year age period, since:

(a) Site appears to have a greater influence on the incidence of P. cinnamomi infection than does tree age.

(b) The expression of resistance appears to be very environment dependent. As noted by Newhook et al (1959)[1] "Where naturally poor drainage was aggravated by surface ponding, however, then apparent resistance of the young trees (12 to 15 years old) broke down and they died".

(c) The period during which P. radiata is "apparently resistant" was observed in New Zealand in shelterbelts and needs to be tested in plantations under the Mediterranean climate and soil moisture conditions experienced in the Donnybrook sunklands.

Koch's postulates needs to be satisfied in the field on trees of different ages and at different sites.

4. Phytophthora cinnamomi was detected in surface sterilized roots of P. radiata greater than 1 cm in diameter and the growth of the fungus in these roots was similar to that observed for the very susceptible Banksia grandis. Information is needed on the ability of the collar region of infected P. radiata to act as a source of inoculum of P. cinnamomi.

The ability of infected P. radiata to influence the inoculum potential of P. cinnamomi would have important implications as to how fast the pathogen can respond to conditions conducive to sporulation and infection and hence influence the severity of infection.

5. Information is needed on the incidence of non-lethal infection of P. radiata by P. cinnamomi (Newhook, 1961)[2] and the degree to which this type of infection retards tree growth.

The implication of P. cinnamomi infection to P. radiata planting would be underestimated if non-lethal infection was not taken into consideration.

B. L. Shearer

DR. B. SHEARER

BS/me
11/7/79

---

[1] New Zealand J. Agric. Res. 2:808-843.

[2] Nature 101:615-616.

APPENDIX 1

Observations on *Pinus radiata* plantations in the Donnybrook Sunklands, made on 5th July, 1979

Plot/Plantation	Tree age	Tree death/ infect-ion	Detection of *P.c.* (Appendix 2)	Soil type	Comments
Vasse Highway	1	+++[a]		4[b]	
Strike & No 6 Road	1	0		3	
Quilegup Road	3	+++	+ ve	4	
Agroforestry	4	+	+ ve		Deaths at edge. Vigorous growth.
Old Forestry Jarrahwood settlement	6	+++		4	Well drained. Vigorous growth.
Vasse Highway	7	+++		4	Poor vigour.
Cane Brook Road & Margaret Road	8	0			Vigorous growth. Seemed shallow rooted
Sues Road (Malloy Plot)	8	0			Vigorous growth.
Strike and No 6 Road	8	+		3	Vigorous growth.
No 3 Road		++			

a) Symptoms associated with *Phytophthora cinnamomi* infection:

- 0 - All trees observed healthy.
- \+ - Occasional tree dead.
- ++ - Trees recently dead (needles bright red-brown in colour), less than 5% trees dead.
- +++ - 5 to 10% trees recently dead or just beginning to die (needles light yellow green and wilting).

b) Soil types as described in Statement of Intent, Afforestation with Pines in the Donnybrook Sunklands, Forests Department of Western Australia, Sept. 1975.

PINUS RADIATA MYCORRHIZA AND P. CINNAMOMI STUDY

(a) INITIAL WORK PROGRAM as proposed for RCD grant.

1. Survey of incidence of mycorrhizas on roots of *P. radiata* at the following sites.

   Jarrahwood
   Willcock A
   Folly
   Nannup nursery
   McLarty
   Bussells Brook

   Sampling to take place in June, September, December and March.

   Status: sampling, mycorrhiza separation and counting methods tested. June sample collected.

2. Pot trial testing *P. cinnamomi* susceptibility of *P. radiata* ex Nannup nursery (1 + 0) under conditions of

   i) excess water all year low P, low N
   ii) excess water winter only low P, low N
   iii) excess water winter only high P, low N
   iv) excess water winter only high P, high N.

   Status: *P. radiata* has been established in pots; inoculation, fertilisation and waterlogging treatments to start in July.

* 3. Field survival of *P. cinammomi* under *P. radiata*.

   Status: not yet started, to be discussed.

4. Pot trial screening 10 *P. radiata* seedlots for genetic variation in resistance to P.c. infection. Comparison to be made of mycorrhiza inoculated and non-inoculated plants.

   Status: seed planted and inoculated, awaiting germination.

5. Pot trial to grow *P. radiata* with pure cultures of various mycorrhizal fungi and test each of the mycorrhizal pines for resistance to P.c.

   Status: isolation from fungal fruiting bodies at all mycorrhiza sampling points (see 1) is being carried out to obtain pure cultures of known fungi. These must be tested to see if they are mycorrhiza forming fungi before pot or test tube experiments can be carried out.

6. Field trial to correlate tree growth (e.g. 2 y.o. pine) with seasonal variation in mycorrhiza density, if any.

   Status: not yet started.

(b) OTHER STUDIES. These were not included in the initial program but have been started since the commencement of the work.

7. Pot trial comparing growth of *P. radiata* and survival of *P. cinnamomi* grown in pots with or without clover cover.

Design

2	x	2	x	2	x	4
± P. radiata		± sub clover		± P.c.		reps.

\+ sub clover pots fertilised with superphosphate Cu Zn A

\- sub clover pots fertilised with Agras No 1.

all pots to be waterlogged and watered at the same rate to show effects (hopefully) of increased water use by clover plants.

8. *P. cinnamomi* isolations from *P. radiata* plantations by lupin baiting and direct plating of *P. radiata* roots.

Sites	P.c. recovery
McLarty	-
Bussells Brook	-
Nannup nursery	-
Folly	-
Willcock A	-
Jarrahwood	
dead *P. radiata* 1+0	+
dying *Pultenaea reticulata*	+ (collar rot)
pot expt in Jarrahwood	
soil	+

9. *P. cinnamomi* mating type determination,

Status: commenced 2.7.79 using Jarrahwood isolates.

"SCREENING FOR RESISTANCE TO *Phytophthora cinnamomi*"

PART II — 32 month old P.pinaster

Introduction

The results of an artificial inoculation trial using 8 month old seedlings have been discussed in an earlier report. That trial was duplicated using older seedlings and these results will be discussed below.

Method

Species: *Pinus pinaster*, leiria strain, 2 yr.8months at initial inoculation.

E.marginata, 5 months at initial inoculation.

Treatments: All other treatments are as described for the previous trial.

Layout: 2 x 2 x 2 factorial with 6 replicates and 1 *P.pinaster* and 3 *E.marginata* seedlings/2 gallon bucket.

Note: A few of the jarrah transplants failed to establish prior to the first inoculation. As a result, the jarrah analysis was carried out as a 2 x 2 x 2 factorial with 3 replicates. Where the number of available replicates in a treatment exceeded three, the replicates used in the analysis were selected randomly.

Results

1) Effects of inoculation

P.pinaster. The mortality of *P.pinaster* seedlings was not affected by inoculation with *P.cinnamomi*. (Table 1). Similarly, their health and other parameters of growth, e.g. height, height increment and shoot weight, were not affected.

The ratio of fine roots/needles was significantly increased by inoculation (**). The root/shoot ratio was also increased significantly (*) but only in the inoculated, low water treatment.

(*) indicates significance at the 5% level

(**) indicates significance at the 1% level

E.marginata. The mortality of jarrah seedlings in the trial [was] extremely high in both the inoculated and control series (Table 1). Significantly, fewer deaths (*) occurred in the fertilised control than in any of the other treatments.

Table 1

Treatment		Seedling Mortality (Percent) at	
		6 Months	12 Months
P.pinaster	control	4%	8%
	inoculated	0%	4%
E.marginata	control	36%	84%
	inoculated	35%	86%

2) Effects of nutrition

P.pinaster. The effects of nutrition were not as marked as those observed in the previous trial using younger seedlings. Nutrient amendments did not significantly alter the total height, root weight, total weight or weight of needles. During the summer months, the height increment was increased (**) in the fertilised, high water treatment. Over the period of the trial however, fertilisation did not significantly alter height growth.

Shoot weight was increased (*) by fertilisation whereas a decrease occurred in the fine roots/needles ratio (**), the root/shoot ratio (*), the weight of fine roots (*) and the abundance of mycorrhizal roots (*).

E.marginata. Nutrition markedly improved the growth, leaf size and colour of jarrah seedlings. Up to midsummer, the survival of jarrah was much better (**) in the fertilised treatment. Once these plants were subjected to a water stress however, nutrition did not improve survival.

3) Effects of watering treatment

P.pinaster. Over the period of the trial, the height increment was greater (*) in the high water treatment. This treatment significantly increased the weight of the tap root (**) and reduced (*) the abundance of mycorrhizal short.roots.

E.marginata. Up to midsummer, the survival of jarrah seedlings was not influenced by watering treatment. From then on, the level of mortality was greater (**) in the low water treatment.

4) Recovery of P.cinnamomi

At the completion of the trial, 10 root pieces from each of the eight treatments were plated on 3P agar. P.cinnamomi was not recovered. These roots were surface sterilised again and replated. P.cinnamomi was not recovered from the controls and one piece from the inoculated series yielded the fungus.

Species of Pythium and Fusarium were recovered from both inoculate and control pots.

Discussion

Pinus pinaster

With these older seedlings, marked responses to the various treatments were not readily obtained. In contrast to the younger seedlings, the pattern of growth in these plants is partly determined by their environment prior to the trial. With only one seedling/pot, the variation within treatments was greater. It is likely that a larger number of significant differences between treatments would be obtained if a greater number of seedlings/pot or a larger number of replicates had been used. Nevertheless, a number of significant differences between treatments did occur.

As with the younger seedlings, no parameter of plant growth or plant health was affected by inoculation. Though the differences were not statistically significant, inoculation did reduce the shoot weight, needle weight and height increment slightly. The weight of fine roots and total root weight were again increased slightly.

The significant differences in the root/shoot and fine roots/ needles ratios resulted primarily from a greater weight of fine roots in the inoculated treatments. These inoculated plants thus appear to be better equipped to withstand adverse conditions, e.g. drought. However, not all of these roots need be functional. In fact, an examination of other parameters of growth indicates that the inoculated root systems are slightly less efficient.

Contrary to the previous experiment, the stimulus which resulted in an increased root/shoot ratio occurred in the low water and not the unfertilised treatment. In the former trial, the absence of fertiliser seriously limited growth under both watering regimes, whereas water only limited growth in the presence of fertiliser. In this trial, neither water nor fertiliser seriously limited plant growth. The reduced availability of water was apparently sufficient to stimulate root production in the inoculated low water treatment, though it was not serious enough to affect any parameter of plant growth other than height increment.

E.marginata

A high level of mortality occurred during the trial and the survival of these seedlings was markedly affected by nutrition and watering regimes.

Mortality commenced about two months after inoculation and occurred in all treatments. During this period, the soil was kept moist by a one inch water table in the bottom of the buckets. The symptoms observed were a scorching of the leaf, particularly at the tip and edges. This scorching progressed and the leaves were shed. A tip dieback of the leading shoots followed. Epicormic shoots developed on the stems and main branchlets. This new growth remained healthy for a period and then the process was repeated.

Fertilisation with Aquasol promoted shoot growth, leaf size and colour. Though mortality occurred in both fertilised and unfertilised treatments, the percentage survival was significantly increased by the addition of Aquasol. The symptoms indicate that death resulted from a combination of nutrient starvation and drought effects. It is considered that these effects were the result of root damage caused by poorly aerated soil conditions, probably accentuated by the presence of Pythium species.

From midsummer, the level of mortality in the low water treatment was increased significantly. This is to be expected if the root systems were damaged as suggested above.

On examination at the completion of the trial, the root systems of jarrah in all treatments were found to be extensively rotted, with few fine roots and a complete absence of any recent root growth. In the controls, roots up to $\frac{1}{4}$" were damaged. In the inoculated pots, the lesions extended into the stele of even larger roots and, in some cases, into the collar region.

A significant inoculum by nutrition interaction occurred in midsummer. The survival in the fertilised control was better than that in other treatments. This indicates that fertilisation is unlikely to increase the resistance of jarrah to P.cinnamomi root rot.

Conclusions

1. Inoculation with *P.cinnamomi* did not significantly affect either the health or growth of older *P.pinaster* seedlings.
2. As with the previous trial, inoculation appears to stimulate root production in *P.pinaster*, presumably to compensate for a reduction in the functional root system.
3. The resistance of *E.marginata* seedlings is unlikely to be increased by the application of nutrient amendments.
4. *E.marginata* seedlings are very susceptible to conditions of poor aeration though the watering treatment used was not detrimental to the growth of *P.pinaster*. This factor, coupled with the obvious lack of recovery of these root systems must contribute to the poor performance of this species in areas infected by *P.cinnamomi*.

F SATINI 'DIANNUAL REPORT 7.11.67 403/66 175

DIEBACK INVESTIGATIONS - FOREST RESEARCH INSTITUTE, KELMSCOTT.

INTRODUCTION:

1. This report summarises the studies being carried out on jarrah dieback reforestation and supplements the report submitted by D.F.O. P.Kimber and A.D.F.O. S.Shea.

2. The Commonwealth staff at the Western Regional Station consists of 1 Research Officer (Mr.C.Palzer) and 9 assistants. An A.D.F.O. from the West.Australian Forests Department is currently stationed at this centre. The Commonwealth is providing technical assistance for this officer as well as laboratory, glasshouse and office facilities.

SCREENING OF CANDIDATE SPECIES FOR RESISTANCE TO PHYTOPHTHORA CINNAMOMI.

Introduction.

The partial destruction of the jarrah forest community caused by the root rotting pathogen, Phytophthora cinnamomi, necessitates the reforestation of these diseased areas with an alternative forest crop. Tree species selected for the reforestation of dieback areas must make adequate growth in the West.Australian forest environment - an environment which now includes P.cinnamomi. The successful candidates should therefore possess a relatively high tolerance to P.cinnamomi root rot.

Candidate species must demonstrate their ability to survive and grow well in field plantings established under operational conditions. Ultimate success will be obtained once a species has reached rotation age or, at the very least, has been marketed for a return which is in excess of the cost of establishment.

The early promise shown by a number of species in divisional field trials should not be taken as a guarantee of ultimate success. These trials should be viewed in the light of the following factors :-

(i) They are normally established in the "Old Dead Zone" inside the diseased forest boundary. The inoculum potential in this zone is severely reduced and a build-up of inoculum may therefore take a number of years. Experimental plantings with Banksia grandis seedlings indicate that this species can survive for considerable periods in the "Old Dead Zone". Ultimately reinfection and mortalities of Banksia grandis do occur.

(ii) The planting site is usually cultivated thoroughly. This reduction of living host material would further decrease the inoculum potential of these sites.

(iii) The rooting system of the planting stock is limited and some time will elapse before a high level of host material has been produced. In the early years of establishment the plant and the fungus are physically separated and opportunity for infection is reduced.

(iv) The death of Eucalyptus saligna in plantations in Hawaii and the native habitat in New South Wales has been recorded. In both cases the disorder has been attributed to Phytophthora cinnamomi root rot. Eucalyptus saligna has shown good survival and growth in the trial plots established to date. On the plot evidence alone it could be regarded as one of our more promising species.

Considerable waste of effort and money can result from large scale plantings which, for considerable periods of time, escape the coincidence of high levels of host material and favourable conditions.

for the spread of the pathogen. This is particularly important in the case of P.cinnamomi where susceptible species, such as Pinus radiata and P.echinata have been shown to have a resistant phase between the ages of 3 and 20 years approximately, but may then fail from attack by P.cinnamomi.

The number of possible candidates is large and must be reduced to a manageable figure prior to inclusion in field trials. Some species may be excluded as being non-commercial by current standards; others will prove to be unsuited to the West. Australian climate and/or soils; some will fail because of severe root rot induced by P.cinnamomi.

A large number of factors can influence the resistance of a candidate species to Phytophthora root rot. These may be listed as follows :-

1. Factors of the pathogen.

   (a) The number of propagules at the host surface

   (b) The virulence of the propagules at the host surface

   (c) The genotype of the pathogen.

2. Factors of the host.

   (a) The genotype of the host.

   (b) The ontogenic (developmental) stage of the host.

3. Environmental factors.

   (a) Their effect on the pathogen

   (b) Their effect on the host prior to and post inoculation.

It would be impracticable to accurately assess the influence of all of these factors if one relied solely on field trials. Clearly a concurrent field trial and glasshouse screening programme is warranted. Screening for resistance to P.cinnamomi should initially be carried out under glasshouse conditions where the factors under study may be more closely controlled.

It will be necessary to extend the results obtained from these trials into field experiments. In the initial stages, selected plants which are susceptible to P.cinnamomi in the glasshouse, will be included in the field trials, to test whether they exhibit any degree of field resistance. The field trials should test the candidate species under conditions suitable for the growth and spread of P.cinnamomi. The use of planting stock at close spacing in areas where there is evidence of a high level of inoculum, is recommended. Adequate site preparation and fertiliser treatments should be provided to the species under test so as to minimise losses which may occur as a result of inadequate establishment practice.

These trials will test both the disease resistance of candidate species under field conditions and the ability of these species to grow successfully in our environment.

Screening trials will be discussed under these major headings :-

1) Pot trials

2) Nutrient culture trials

3) Field trials

POT TRIALS.

(a) "To test the resistance of 43 species of Eucalyptus to P.cinnamomi, in sand culture". Lit SP p 125

Results. P.cinnamomi has been recovered from dying seedlings of the following species :-

Eucalyptus cloeziana	Eucalyptus wandoo
baxteri	globulus
pilularis	sieberi
obliqua	salubris
micrantha	andrewsii
radiata	

In some species a marked resistance to inoculation as expressed by mortality, top growth and root development, has occurred. All inoculated plants of E.sieberi, E.scabra, and E.cloeziana collapsed. In E.obliqua a marked depression of top was evident. In some species, including E.marginata, there was no noticeable depression in shoot development.

The root systems of E.obliqua and E.baxteri were noticeably better in a control series. With E.globulus, E.saligna, E.robusta, E.microcorys, E.grandis, E.goniocalyx and E.blakelyi, some damage to the root systems in the inoculated series did occur. However, the root development of these species in the inoculated pots was much better than that of E.marginata, E.obliqua and E.baxteri.

(b) "To test 31 species of Eucalyptus and Pinus pinaster (Leiria) for resistance to P.cinnamomi in sand culture".

The trial is still in progress and no results are available as yet. Lit SP p 123

(c) "To test seedlings of some coniferous species for resistance to P.cinnamomi in sand culture".

The experiment was designed to test whether P.cinnamomi is pathogenic to Pinus pinaster and to compare the response of this species with that of other coniferous hosts.

Results: P.cinnamomi has been recovered from root tissues of all species except Araucaria cunninghamii and Callitris glauca.

Species	Average Root Rot Rating	Remarks.
A.pyramidalis	5	Root Rot rating:-
P.halepensis	4.3	0 indicates Nil Root Rot
C.lusitanica	3.75	1 " 0-5% " "
C.glauca	3.5	2 " 5-20% " "
P.insularis	3.4	3 " 20-50% " "
P.radiata	3.3	4 " 50-90% " "
P.pinaster (Leiria)	3.3*	5 " complete Root Ro
A.cunninghamii	3.0	
P.pinaster (Corsican)	2.9 ø	
P.taeda	2.1	
P.elliottii	1.0	

* Mean of 2 pots
ø " " 7 "

(d) "The influence of nutrition on host resistance to P.cinnamomi".

The effect of eight nutrient regimes on the resistance of E.marginata and P.pinaster to P.cinnamomi is being studied in this trial.

The pots were sown in April and inoculated in October, 1967. A growth response to some of the nutrient amendments has occurred. No mortalities have been recorded to date.

(e) "Susceptibility of Pinus pinaster seedlings to infection by P.cinnamomi".

The influence of seedling age, nutrition and watering levels on host resistance is being studied. The trial was inoculated in May and October, 1967.

A marked response in height growth to nutrition has occurred. Inoculation with P.cinnamomi has resulted in a slight depression in height growth.

NUTRIENT CULTURE TANKS.

Detailed root examination is difficult when plants are growing in soil and small seedlings are capable of surviving for long periods with very little functional root system. Because of these difficulties a liquid culture tank has been employed by a number of Research workers studying host resistance to P.cinnamomi. This technique provides a rapid standard screening test and is admirably suited for screening large numbers of candidate species. The Forest Research Institute has recently purchased a large nutrient culture tank.

Prior to the installation of this tank it was decided to test some of the techniques developed by other Research workers. A number of small experiments were therefore commenced

The first aim was to successfully establish seedlings in a nutrient culture solution; the second to infect these with zoospores of P.cinnamomi. Both of these techniques have been successfully carried out.

FIELD TRIALS.

These trials are located in the Gleneagle Division. Tubed stock was raised at Hamel according to the "U.C." system. Areas were planted in July, 1967. The species chosen exhibited varying degrees of tolerance to P.cinnamomi in pot trials. The stock was planted on the following sites :-

Lateritic gravels
Lateritic silts
Red loams, and
Sand

SOIL BAITING.

A number of soil samples have been collected and baited for the presence of P.cinnamomi, using the lupin baiting technique. The major results are listed below :-

(a) E.diversicolor - Bridgetown/Nannup Road:

Soil samples collected from beneath a stand of dying Karri yielded P.cinnamomi. The fungus was not recovered directly from the Karri roots. Further research on the resistance of Karri to P.cinnamomi, is being planned by Mr.C.Palzer.

(b) Hamel Nursery:

Several plants were collected and plated at the request of the Hamel staff. The following recoveries were obtained :-

E.lehmanii	P.cinnamomi and nematodes
P.radiata	Pythium species, Fusarium species and nematodes.
P.pinaster	Pythium species, Fusarium species and nematodes.

(c) Shannon Division - Westcliffe 1/65:

P.cinnamomi was recovered from the roots of P.pinaster and a species of Pythium from those of P.brutia, P.patula and E.redunca.

(d) Dwellingup Division - Teesdale Plots.

A species of Pythium was recovered from the root tissues of dying seedlings planted in this trial. The fungus was recovered from the following species :-

P.caribaea, P.elliottii, P.insularis, P.patula, E.globulus, E.pilularis, Cupressus lusitanica, Callitris calcavata.

(e) Soil samples collected by A.D.F.O. S.Shea from logging equipment working in dieback areas, has been baited for the presence of P.cinnamomi. Several positive recoveries have been obtained.

CO-OPERATION WITH A.D.F.O. S.SHEA.

"Predisposition of jarrah dieback".

Inoculum for the field infection of jarrah stands in the Dwellingup area has been produced at the Forest Research Institute. Lupins infected with P.cinnamomi have been used as the source of inoculum.

CONCLUSIONS.

A.G.H. //

1. It appears that a wide range of Eucalypts are hosts of P.cinnamomi but that a number of these could be moderately tolerant to root rot.

It is recommended that those species which have exhibited a more marked response to inoculation than has E.marginata, should not be planted in dieback areas. E.obliqua, sieberi, scabra, baxteri and cloeziana fall into this category. Of the 13 new hosts, 8 belong to the Stringy-bark/Ash group of Eucalypts (Blakely's section Renantherae). This section includes the bulk of the hardwood species of economic importance to Australia. Some species in this group have not exhibited severe symptoms of root rot at this stage and may ultimately prove to be field resistant to P.cinnamomi. For the time being, however, this group of species should be regarded as suspect and are not recommended for large scale single species trials. At this stage no single Eucalypt can be recommended for large scale planting trials. A number of species have shown some degree of tolerance to root rot. It is recommended that a mixture of the following be used in Divisional planting trials :-

E.globulus
E.saligna
E.propinqua
E.goniocalyx
E.grandis
E.resinifera
E.microcorys

2. Pathogenicity of P.cinnamomi to the Leirian and Corsican strains of P.pinaster has been demonstrated. The root rot rating of P.pinaster is higher than expected in view of the field tolerance shown by this species in a range of dieback sites and over considerable periods of time. Although severe cortex rotting did occur, the vascular steles of P.pinaster were affected only on the tips of the primary roots. The field tolerance of this species could be due, in part, to a high capacity for regenerating a damaged root system by budding off new laterals through infected cortical tissues. Because of its current field tolerance the continued use of P.pinaster is recommended. Further trial plots with P.taeda and P.elliottii are warranted.

3. It is considered that planting trials in dieback areas should aim to fulfil the following needs :-

(a) The establishment of trial plots to demonstrate to the public and farmer alike that a tree crop can be successfully grown on dieback areas.

(b) The establishment of research plots to investigate the following factors :-

(i) Field tolerance of candidate species to P.cinnamomi.

(ii) Fertilized treatments

(iii) Site preparation

(iv) Species siting

(v) Type of nursery stock

(vi) Suitability of various soil types

(vii) Climatic conditions

(viii) Direct seeding trials

(c) The extension of stage 'b' into large scale field practice.

TRIAL PLOTS.

1. These need not be large and plots of 1 to 2 acres are considered to be adequate.

2. With these plots success, rather than cost, should be the ultimate criterion.

3. The following proceedures are recommended :-

(a) The plots should be established well within the "Old Dead Zone" where the inoculum of P.cinnamomi is already low.

(b) The level of inoculum should be further reduced by a pre-ploughing kill of host species with Tordon. ?

(c) The sites should be cultivated thoroughly by ploughing, fallowed over summer, and re-ploughed before planting.

(d) Where necessary, adequate drainage should be provided.

(e) Tree species tolerant to P.cinnamomi should be planted at wide spacings.

(f) For the time being, planting should be restricted to the better sites.

(g) Production should be improved by fertilizer amendments with nitrogen and phosphate.

(h) It may prove unwise, at this stage, to plant exotic Eucalypts alongside highways and major roads. Where this is unavoidable, it is recommended that a screen of P.pinaster should be provided.

RESEARCH PLOTS.

The establishment of these plots will require a great deal of co-operation between Research and Divisional staff and co-ordination within Divisions if we are to obtain the maximum return per dollar invested. A meeting between Research Officers and Divisional staff should be considered so that a policy on these trials may be prepared.

LARGE SCALE FIELD TRIALS.

The extension into this final stage for species other than P.pinaster, is not considered to be warranted for the present. To date this is the only species which has been extensively tested in existing trials and which has demonstrated its ability to survive in dieback areas for considerable periods of time.

P.pinaster has several other advantages :-

1. Proven adaptability to climate.

2. It already supports an existing and growing industry.

3. A considerable knowledge on the silviculture, genetics and nursery practices with P.pinaster has already been accumulated by the Department.

Frank Batini

F.BATINI,
A.D.F.O.

7/11/67.

Ack. 22.2.68

FILE 194/69.

Phytophthora cinnamomi Rands at Ourimbah State Forest, Wyong, NSW

D. T. HARTIGAN

Forest Pathologist
N.S.W. Forestry Commission

INTRODUCTION

Bell-Birds feeding on Psyllids are an old association in wet valleys around Sydney even though conclusive evidence of the feeding habits of the birds has only fairly recently been produced (Moore 1962).

The Psyllids are parasitised by other insects as well as eaten by birds and for this reason populations where they occur rapidly become static. Weather conditions also play a part in Psyllid "plagues."

There is speculation amongst Entomologists about the effect of Psyllids on the health of trees.

Obviously there is debilitation and this varies with the extent of the infestation. On the other hand most Entomologists look for another cause when tree deaths ensue at the rate observed in some areas near Wyong. This is why Moore has suggested in the publication cited above that Psyllid attack may only be part of a disease syndrome.

Previous work done with tree poisoning has shown that hormone weedicides of the type of 2.4.5-T drastically reduce starch reserves in trees and in part at least, this explains the way such weedicides work.

Using this analogy, an investigation was carried out with trees showing varying degrees of Psyllid attack (Hartigan, Humphreys and Kelly 1961) in the Wyong area, and it was demonstrated that sapwood starch content could be correlated directly with severity of insect attack.

This means that continued Psyllid attack could possibly explain tree deaths without having to postulate any other circumstance. The evidence is however only circumstantial.

The taxonomy of the Psyllidae still remains to be worked out and there are considerable gaps in our knowledge.

Some Psyllid infestations seem to be relatively ephemeral and not necessarily associated with Bell-Birds while elsewhere the constancy of populations and presence of Bell Birds has been established by local place names such as "Bell Bird Hill" near Kurrajong.

The Wyong area is of the latter type and Bell Birds have been a feature of this district for many years. The Psyllid is Glycaspis (Spondyliaspis) spp.

Present position at Wyong

It may seem surprising that the die-back described by Moore in Wyong forestry sub-district has attracted so little attention over the last 20 years but the onset has been very insidious and is masked by seasonal variations in forest cover.

E. saligna	E. propinqua
E. deanei	E. paniculata
E. microcorys	Syncarpia Laurifolia

It is possible at this time to detect the areas of debilitation by inspection with a fair degree of accuracy and local farmers have indicated an apparent spread of 2 miles in 10 years.

It seems that the affected area covers about 12 square miles between Wyong and Gosford on both sides of the railway line but it is broken up considerably by low ranges and creeks with natural brush forest.

There is also a lot of land development and small farms so that trees are tending to be cleared all the time and this confuses the picture.

In previous years these forests have been exploited very intensively for rail sleepers and constructional timber and they have also been damaged by fire, so that from the timber point of view the trees remaining do not have a great economic value.

There has so far been no spread of the disease to the better areas of Ourinbah State Forest and the pattern of attack to date seems to indicate that any movement will be slow.

The disorder appears in patches of several hundred acres in extent usually originating from about half way up a hill to the ridge itself and then spreading along the ridge. It is assumed that this pattern is due to the distribution of susceptible species which is in turn a reflection of soil conditions.

In the creek bed for example, Turpentine flourishes and is apparently unaffected but this tree is also more or less free from <u>Glycaspis</u> - It is susceptible to a more rarely found Psyllid (Moore - private comm.).

Such an observation as this would appear to tie-in the die-back conditions squarely with Psyllid infestation and more specifically <u>Glycaspis</u> infestation.

However, this is not necessarily the complete story as will be indicated.

<u>Presence of Phytophthora</u>

Up till 1967, it was generally assumed that starch depletion as a result of continued Psyllid attack satisfactorily explained the condition of trees in Wyong sub-district.

In that year however, an officer of the West Australian Forest Service pointed out that the conditions of the trees resembled that of the Jarrah forests affected by Phytophthora.

An investigation for the presence of Phytophthora was then commenced and <u>Phytophthora cinnamomi</u> Rands was found in soil samples taken from the base of moribund trees at Lisarow (1967) and Palmdale (1968) using the apple trap technique (after Campbell 1949).

The Lupin trap method (after Kheng Hoy Chee & Newhook 1965) proved unsatisfactory.

Later this year (1968) recoveries dropped off and at the beginning of 1969 contamination principally with <u>Fusarium</u> reduced Phytophthora recoveries to zero.

It should be mentioned that 1968 was a drought year in the Sydney district. Recorded rainfall was 24.55" comparec with average of 47.75".

It also proved difficult to obtain soil cores on the slopes of the ranges because of the dryness of the soil.

In March 1969, after heavy autumn rains the picture changed dramatically and once again Phytophthora was recovere gradually building up to about 30% of sampling, and it conti ued at about that level for some months until recently, (Sept. 1969).

It is probably an over simplification however to say that low soil moisture is the only factor involved in reducing Phytophthora recoveries.

Under conditions favourable for Phytophthora recovery little trouble was experienced with Fusarium, Mucor and Penicillium in the isolation procedure used so that one can assume that the soil metabiotic balance is completely altered after rain.

Marx and Bryan (1969) have made pertinent observations in this connection claiming that soil moisture (by encouraging soil bacteria) alters the mode of infection by Phyt. cinnamomi which is none the less infectious under conditions of lower moisture.

By encouraging Zoospores production in Phytophthora as apparently soil bacteria do the time required for population by other fungi may be decreased and this might account for th greater success of the apple technique after rain. Lack c recovery therefore might not mean that the fungus was not present but only that Sporangia were suppressed.

Identity of the Phytophthora cinnamomi Rands was established by comparison with a culture imported from CML(England measurements of chlamydospores and sporangia.

Assessment of Situation

Until pathogenicity tests are carried out it not possib to say that the presence of phytophthora cinnamomi is the ove riding factor in the Wyong die-back situation.

At this time and stage of investigations, it looks as i we have a rather complex problem in which soil condition, Psyllids and Phytophthora all play a part.

Whether the fungus would be pathogenic without the conditioning provided by the insect attack has yet to be show but one would suspect otherwise.

Experience with Phyt. cinnamomi in pinus spp has shown that it causes damage first to seedlings in the pre-mycorrhyz investment stage, second to young trees when they are planted out in shallow water logged soils, and thirdly in mature tree under conditions of severe competition.

The Wyong area has suffered more damage to trees than another close to Sydney which has also supported a Psyllid/ Bell Bird association for many years. This is Kurrajong about 20 miles west of Sydney.

No Phytophthora has yet been recovered from the Kurrajong area but in the light of the vagaries of the fungus this may not mean very much.

At Wyong a trial planting of Eucalypts about 1 acre in extent was put down in 1964 in a valley floor area adjacent to die-back Eucalypts and about 200 yards distant (Palmdale).

The trees in this plot principally Euc. grandis and Euc. pilularis are doing well but so far there is no evidence of Psyllid attack and of course soil conditions are better than on the hill side.

The restriction of die-back to shallow poor soils is not however a valid presumption because another area (called Static 4 in the current investigation) shows die-back along a creek side in deep loamy tho poorly drained soil.

Phytophthora

The most worthworthy observation which has emerged from studies made on Phytophthora in relation to Pinus spp., is the extreme of variability of toxicity among isolates under the difference conditions imposed by glasshouse tests.

One has the impression that the pathogenic character of the fungus is directly related to external factors affecting the host plant, eg. drought, water logging, nematodes, temperature, soil fertility and of course in the case of the Eucalypts mentioned herein attacks by foliage destroying insects.

Like Rhizoctonia and Thellophora, Phytophthora takes on a pseudo-mycorrhyzal habit with Pinus, and its activities as a pathogen are restrained by ectotrophic mycorrhizes.

It is now known to what extent Eucalyptus spp.offer the same form of resistance to Phytophthora cinnamomi but it seems highly likely that this is so and the external factors mentioned above could be then regarded as the first links in a chain which ultimately reaches the rhizospere inhabiting micro-organisms.

The highly pleomorphic character of the Pythiaceae generally makes their study difficult.

Small variations in artificial media such for example as exists between PDA prepared by boiling potatoes and "Oxoid" commercial preparation make an obvious difference to culture-plate appearance.

Sporangial forms of Phyt. cinnamomi often closely resembl Phythium spp.

The liberation of Zoospores often display curious variations not mentioned in text books of taxonomy, e.g. the partial loss of protoplasm and the reconstruction of zoospores from the residuum still remaining within the sporangium.

These and other peculiarities make the study of Phytophthora fascinating but extremely puzzling.

They stress the importance of environment in the aetiolo of the fungus.

An experiment conducted some years ago using a basal inorganic salts medium and 1% addition of 45 different carbon sources (including 16 sugars) showed that Glucose, Starch and Dextrin were the favoured carbon sources for Phytophthora cinnamomi and were superior to maltose and sucrose.

Reversing the order, the inorganic basal medium plus 1.0% glucose and 0.1% of 15 Nitrogen sources (including 8 amino acids) were tested and it was found that Phytophthora cinnamomi favoured peptone, ammonium di-hydrogen phosphate and L-Asparagine.

Unfavourable nutrients were indicated by sparse surface spreading growth and one would imagine that this would be the form the mycelin would have in soil.

At this time in Australia when the range and toxicity of Phytophthora cinnamomi is being established considerable care should be taken with taxonomy. This is said because the circumstances are difficult.

At Wyong for example only isolates which produced normally shaped sporangia and whose spore mass was not restrained for more than a few seconds on release were accepted as Phytophthora even tho' a number of isolates produced variations within a normal range of definition.

It is likely that workers in this field will postulate the existence of strains of Phytophthora cinnamomi to account for puzzling variation in toxicity but before this happens it is desirable to be sure of species.

The compilation made by Waterhouse (1956) gives an idea of the enormous host range of Phytophthora and must raise questions of the validity of species.

Phytophthora cinnamomi isolates from pinus spp closely resemble the fungus isolated from soil rootlets under Eucalypts and it is understood that the Western Australian eucalypt isolates are pathogenic to pinus spp. (private comm.). No particular species variation therefore seems to have yet appeared to identify the fungus with Eucalyptus.

Discussion

There is some circumstantial evidence to associate the dieback disorder in the Wyong-Gosford ares with Phytophthora damage but the presence of a major debilitating factor such as Psyllid attack complicates the assessment of the situation.

If the Phytophthora cinnamomi isolates at Wyong are identical with those from the Jarrah areas in regard to pathogenicity, it may be suggested that there is something missing in the host/pathogen relationship as we know it.

Shallow soils and periodic flooding are the conditioning factors so far mentioned in Western Australia and these same factors may be acting at Wyong, The point to be decided is whether the presence of Psyllids is an artifact or an additional casual factor in the Wyong decline.

Acknowledgement.

The assistance of members of the Pathology Section in carrying out the work described is acknowledged, particularly that of Dr. L. Cornell and Mr. M. Veorfkins.

REFERENCES:

(1) Campbell W.A. (1949). A method of isolating Phytophthora cinnamomi directly from soil. Plant. Dis. Rept. 33.134-135.

(2) Hartigan D., F.R. Humphreys and J. Kelly (1961) "A study of sapwood starch variations in E. saligna arising from insect attack". N.S.W. Forestry Commission internal report.

(3) Kheng-Hoy Chee & F.J. Newhook (1965). Improved methods for use in studies on Phytophthora cinnamomi Rands and other Phytophthora species. N.Z. J. Agric. Res. Vol. 8 No. 1.

(4) Marx Donald H and W.C. Bryan (1969). Effect of soil bacteria on the mode of infection of pine roots by Phytophthora cinnamomi Phytopath 59.5 614-619.

(5) Moore K.M. (1962) Entomological research on the cause of mortalities of Eucalyptus saligna Smith (Sydney Blue Gum) Res. Note No. 11 For. Comm. N.S.W.

(6) Waterhouse Grace M. (1956). The Genus Phytophthora C'wealth Mycol Inst. Miscell Publ. No. 12, Kew - Surrey.

SUMMARY

Bell Birds are associated with Glycaspis spp (F. psyllidae) in moist valleys in Eastern Australia around Sydney and in one area (Gosford-Wyong) there is a large proportion of moribund trees (Eucalyptus-Angophora) in Psyllid damaged stands.

Phytophthora cinnamomi Rands has been isolated from soil and rootlet samples in this area but not at Kurrajong which has been also subject to Psyllid attack over many years.

Mr Ef[illegible], This is a copy of Mr Hartigan's report on the occurrence of P. cinnamomi in NSW.

[illegible] 18 Nov.

Frank Batini
OFC

File 122/68

46136/4/61--10m—O/CH. Form: F.D. 30B

FORESTS DEPARTMENT

KELMSCOTT Office,

5th November 1968
Western Australia

To Conservator of Forests,
Forests Department,
PERTH.

Reference—H.O.
Local

SUBJECT: Resistance of Pinus pinaster to Phytophthora cinnamomi.

Attention Mr. Eastman

The world distribution map for Phytophthora cinnamomi (C.M.I. Kew) indicates that this pathogen occurs in all of the countries where P.pinaster is indigenous - e.g. Spain, France, Portugal, Italy and parts of the northern coast of Africa.

Pinus pinaster has demonstrated its resistance to P.cinnamomi root rot in the seedling stage. With other species of pinus - notably P.radiata and P.echinata, the disease may not exhibit severe symptoms until the stand is near or above twenty years of age. Our oldest P.pinaster stands in dieback areas are just approaching this critical age.

It was therefore considered worthwhile writing to Forestry sources in Europe and assessing their views on this pathogen and the resistance of P.pinaster to it. Mr. D. Perry offered to write to a personal friend in France and his letter and Mr. ILLY'S reply are enclosed for your information.

The reply obtained supports the inferences drawn from the literature i.e.

1) P.cinnamomi is present in the Landes region of France. This pathogen causes some damage to chestnut and oak trees in this and other regions of France.

2) P.cinnamomi is not considered to be a phytopathological problem on P.pinaster. This probably accounts for the absence of P.pinaster from all of the hosts lists published to 1967.

3) It is considered that P.cinnamomi is probably endemic to the Landes. Even if this is not so, it is obvious that the fungus has been present in this region for a considerable time and there is every likelihood that it has had the opportunity to spread into the existing P.pinaster stands.

4) If P.cinnamomi is truly endemic to this region of Europe, P.pinaster must have evolved with this pathogen as part of the environment and this may account for the resistance of this species to Phytophthora root rot.

5) Though this data does not suggest that P.pinaster will be resistant to root rot under all conditions, it does indicate that, in most situations, the degree of damage incurred will not be great.

Frank Batini
FRANK BATINI
SILVICULTURALIST

1, Mr. Eastman with 7 Nov.

2, Dr Hopkins

6/11/68 [illegible] 8/11/68.

26 Egham Road,
Victoria Park,
Western Australia. 6150

26th July, 1968.

Monsieur Georges ILLY,
Station de Resherches Forestieres de Bordeaux,
Domaine de l'Hermitage,
Pierroton, Gironde,
FRANCE.

Dear Monsieur Illy,

I am writing to you to ask if you can help me with some advice about the occurrence of the fungi, Phytophthora cinnamomi in the Landes region of France and the resistance to attack that may have been developed by Pinus pinaster.

In Western Australia, our very valuable Eucalyptus marginata forests are threatened with extermination by this fungus. It has been introduced accidentally into this country from Europe and this Eucalypt has no resistance to it.

Many of the sites where Eucalyptus marginata is being killed out are suitable for growing Pinus pinaster, and we hace instances of this pine reaching an age of 18 years and still in a healthy condition on such sites. The Forests Department would like to extend plantings of Pinus pinaster on these affected sites but before instituting large scale plantings would like to have further information from Europe concerning the occurrence of this pathogen and its effect, if any, on Pinus pinaster. We have found one example here of Pinus pinaster which had reached an age of 40 years in a shelter belt on an irrigated farm and then suddenly died. Phytophthora cinnamomi was subsequently isolated from both the roots and the soil. Our pathologist has carried out screening trials of Pinus pinaster in the glass house and these demonstrated that this species is resistant to Phytophthora attack.

The sort of thing we would like to know is:-

1) Is this pathogen endemic to the Landes.
2) Has it been associated with agricultural or orchard crops, forest nurseries or adult trees of any species,
3) Do you know of any instances of other shrub or tree species growing in association with Pinus pinaster which have been killed by Phytophthora, leaving the pines unaffected.

Personally I think that it is highly probable that Pinus pinaster has evolved in association with Phytophthora cinnamomi and has developed a high degree of immunity in the process.

Please accept my apologies for troubling you with this matter, but any assistance you can render will be greatly appreciated.

With very best wishes to you and your family from my wife and myself.

Yours very sincerely,

D.H. PERRY.

PS. The progenies (half sib) from your Landes plus phenotypes are doing very well but no measurements are to be made until the trials are five years old.

Translation of letter from Mr. G. ILLY, Forest Research Institute, Bordeaux, in reply to a letter from Mr. D.H. Perry, Forests Department, Western Australia.

Dear Mr. Perry,

Thank you for your letter. I am pleased to hear from you and to be able to be of some assisstance.

The information you requested was obtained from Mr. Lanier of the Pathology Laboratory at Nancy as I am not conversant with this subject. He says:

" We have a fairly good knowledge on Phytophthora cinnamomi, especially since research has been carried out on the 'ink disease' of chestnut with which P.cambriora and P.cinnamomi have been associated. A few years ago we found cankers on red oak in the Basque region and P.cinnamomi was recovered by Movau of the Museum in association with these cankers.

In reply to question 1, it is certain that this fungus exists in the Landes region and that it is probably endemic to this area.

In reply to question 2, the fungus damages chestnut and oak trees.

In reply to question 3, this pathogen as far as we know has not been recovered from Pinus pinaster but it is possible that it is present within these stands.

We do not have any evidence that it is a serious phytopathological problem on maritime pine."

With best wishes,

(Signed) G. ILLY.

Fk ~~194/69~~ 122/68

Progress Report 1

Date: June, 1968

Dr. B. Pratt, Department of Forestry, A.N.U., Canberra.

1. Soil Type, Microbial Populations, Rhizosphere Effects and Phytophthora cinnamomi

One of the most outstanding features of the E. marginata - P. cinnamomi disease complex in W.A. is that the disease occurs in an intense form in a number of areas that are different in aspects such as drainage, water table, pore size, chemical constituents and physical constituents. Normally the disease intensity would be expected to vary greatly from one area to another. Possible explanations of this widespread high disease intensity in W.A. are:

(a) a highly pathogenic form of P. cinnamomi is present;

(b) there is an abundance of highly susceptible host material (both (a) and (b) have been discussed elsewhere), or that

(c) soil microbial populations are such that few biological restrictions are placed on one or more phases of the life cycle of P. cinnamomi in soil.

The phases can be classed broadly as:

(a) mycelial growth through soil, on the root surface and inside root tissue;

(b) production of resting or survival structures such as resting sporangia, Chlamydospores, oospores, encysted zoospores or hyphal pieces within dead organic material;

(c) production and movement of motile zoospores from sporangia.

Little is known of microbial populations in W.A. soils, and more specifically, of microbial populations in Jarrah soils. It would be interesting to obtain general comparisons of (a) total microbial populations and (b) specific microbial populations in different areas e.g. in W.A. Jarrah forest where P. cinnamomi is present and has become a dominant pathogen and in a N.S.W. coastal forest area where P. cinnamomi is present but has not developed into a dominant pathogen.

Preliminary dilution plating of W.A. soils for fungal populations indicates low total number of fungi and bacteria and actinomycetes compared with N.S.W. coastal soils. P. cinnamomi may have generally lower competition in W.A. soils leading to its dominance as a pathogen. Alternatively the presence of *Chromobacterium* spp. which stimulate sporangial formation may be a dominant factor - W.A. soils may contain more of this or other bacteria which act in similar manner resulting in increased *P. cinnamomi* populations. These are conjectures which require close study.

Progress: Currowan State Forest soil being examined for microbial population; attempt to stimulate zoospore production using two local soils in A.C.T.; plans to collect numerous soil samples in W.A.

2. Survey of Distribution of *Phytophthora cinnamomi* in Australia

Phytophthora cinnamomi is the most serious forest pathogen in Australia today. It is important to know how widely it is distributed in different areas. This survey would be useful in forecasting probable sites of future disease outbreaks, and could also be of use in analysing the reasons for the intensity of *P. cinnamomi*-induced disease in W.A. For example, if *P. cinnamomi* is found in areas climatically similar to those of the Jarrah forest and if hosts of known susceptibility are present in abundance in these areas, why is there no serious disease problem in these areas? Differences of soil type, host species abundance, or microbial populations may be highly significant. However, these may only be apparent after the initial *P. cinnamomi* populations have been detected by surveys. If we have obvious reasons for the absence of disease from certain areas we may be able to explain its significance in W.A.

Progress: Known distribution of *P. cinnamomi* in Australia:

Queensland: Mostly in southern and central districts, especially on pineapple, *Pinus* spp., avocado. Forest distribution unknown.

W.A.: South western area and southern area, especially on *Eucalyptus marginata* and associated understorey.

../3

N.S.W.: Entire eastern coastline and also in Murrumbidgee irrigation area, especially on Pinus radiata (nurseries) and on numerous ornamentals.
Victoria: Suspected on Pinus lambertiana and Pinus radiata in Mt. Macedon area. Suspected on ornamentals in Melbourne area.
Tasmania: suspected on ornamentals in Hobart area.
Currowan State Forest, Clyde Mountain-Bateman's Bay area surveyed on 29.5.67. Eucalyptus maculata forest, 60 soil samples taken from upper 2 inches of soil. Examined by dilution plating technique at 1:10 dilution on cornmeal agar + pimaricin 100 ppm, penicillin (penicillin G, potassium salt (?)) 50 ppm, + polymyxin sulphate 50ppm. Incubated 23°C in darkness.

3. Screening for Resistance to Phytophthora cinnamomi

It is important to establish which species of Eucalyptus and understorey plants are susceptible to P. cinnamomi. Thus potential replacement species for E. marginata would be available if this became necessary, and areas of potential disease outbreak would also be known.

Knowledge of resistance mechanisms, chemical and mechanical will be of value if attempts are to be made to breed resistant E. marginata lines.

Knowledge of the mechanisms whereby P. cinnamomi penetrate the host root tissues, the subsequent damage and methods of killing must be determined before potential control mechanisms can be devised.

Knowledge of the abundance of susceptible species in Jarrah forest may also explain varying intensity of P. cinnamomi - induced disease in various areas.

Pathogen-free seedlings can be produced in CSIRO Phytotron and planted in inoculated soils in glasshouse and reaction to P. cinnamomi examined; or seedlings can be grown in tubes of seedling agar and inoculated with P. cinnamomi at appropriate stages of root and hypocotyl development. The latter technique is highly useful for histological studies. It may be preferable to grow these seedlings in water-culture tubes and examine protein release after inoculation with P. cinnamomi, as described in fungicide testing. These techniques are presently being compared and Eucalyptus bicostata, E. calophylla, E. marginata, E. maculata, E. pilularis, E. resinifera, E. sideroxylon and Pinus radiata have been examined by the seedling agar-tube technique.

4. Screening of Antifungal Compounds

One potential hope for development of control measures for diseases of the P. cinnamomi - E. marginata type is that an efficient systemic or translocatable fungicide will be developed by one or more of the many chemical manufacturing firms carrying out research in this field. A fungicide of this type, with suitable activity against P. cinnamomi conceivably could be sprayed onto tree foliage, or injected into the tree trunk or roots, or dusted or sprayed on the soil; thus many of the present difficulties preventing the use of fungicides to control the disease could be overcome. Little is known of the stage reached by commercial researchers in this field but it is assumed that development of efficient translocatable fungicides specifically for Phytophthora would take many more years of work.

A field worthwhile investigating is the production of antifungal compounds by CSIRO as part of their routine biochemical research. Large numbers of new compounds are produced each year and are passed to commercial firms such as Geigy for intense screening for antifungal activity. The compounds and the results are then passed back to CSIRO for further examination. It is believed some 2000-3000 of these compounds are currently in stock at CSIRO after screening, and approximately 45 are known to exhibit antifungal activity to Phytophthora spp. Some of the compounds are known also to be translocatable in at least some plant genera. It would seem worthwhile testing these compounds specifically against P. cinnamomi in association with E. marginata.

../5

Progress: A technique is being developed to examine degrees of effectiveness of the test antifungal compounds in living host tissue. Test seedlings are to be grown under sterile conditions in weak solutions of the test compound. Seedlings are then transferred to tubes containing liquid cultures of P. cinnamomi. The extent of P. cinnamomi invasion and damage in host roots will be measured by assaying the total protein released from the roots, thus indicating degrees of protection afforded the host by the test compound. Protein assay will be carried out using the Technicon Auto-analyser in the Department.

5. Collection and Testing of Mycorrhizal Fungi

The role of mycorrhizal fungi on forest plants is not fully understood, but it is suspected that these fungi may be of value in protecting the host against attack by pathogenic fungi. Numerous fungi that occur commonly in Australian eucalypt forests are known to be mycorrhizal, and it is probable that most or all Eucalyptus spp. carry one or more mycorrhizal fungi.

It would be interesting to determine:

(a) which fungi are normally mycorrhizal on E. marginata in W.

(b) which fungi are normally mycorrhizal on E. marginata in areas other than W.A.;

(c) which of these fungi, if any, show antifungal activity against P. cinnamomi;

(d) which fungi, not yet known to be mycorrhizal on E. marginat could be induced to become mycorrhizal, and

(e) which of these latter fungi show antifungal activity toward P. cinnamomi in vitro or in situ.

Fungi will be collected:

(a) Personally by selection of sporulating structures in forest areas.

(b) Personally by growing of contaminant-free E. marginata seedlings in collected forest soils,

(fungi collected by (a) and (b) to be maintained in agar culture or maintained on living host roots where necessary).

(c) From culture collections of other forest pathology workers in Australia, e.g. CSIRO Division of Forest Products,

(d) From culture collections of overseas workers in various countries and from the collections of the Commonwealth Mycological Institute, U.K.

Progress:

Boletus granulatus collected from Blue Range forest area, A.C.T. and successfully cultured on malt agar.

The following fungi have been collected from Tidbinbilla forest area and plated onto malt agar: Cortinarius ochraceus Clel., Cort. cinnamomeo-badius Clel., Cort. cinnamomeus (Linn.) Fr., Cort. archerii Berk., Cort. lavendulensis Clel., Cort. largus Fr., Cort. albus Clel. or Cort. decoloratus Fr., Collybia butyriaca, Collybia tortipes, Boletus satanus, Tylopilus felleus, Russula sp.

The antifungal activity of B. granulatus to P. cinnamomi is being examined using the plate culture-cellophane technique.

6. Variation in Pathogenicity of Phytophthora cinnamomi

It is important to understand why P. cinnamomi has become a dominant pathogen in W.A. Jarrah forest. One possible reason is that a highly pathogenic variant of P. cinnamomi has established itself in the area. Zentmyer has mentioned that there has been surprisingly little variation in pathogenicity of P. cinnamomi isolates obtained from different parts of the world. Australian isolates have not been examined critically and this study should be carried out.

P. cinnamomi isolates from all parts of Australia from a variety of hosts have been requested. When these isolates have been assembled in Canberra their pathogenicity to Eucalyptus marginata and a number of other Eucalyptus spp. will be compared.

../7

Progress: Isolates received from Jan Titze, W.A. 7.5.68

P. cinnamomi	SC36	*Banksia grandis*	Karnet
	SC90	*Eucalyptus marginata*	E. Kirup
	SC99	*Macrozamia reidlei*	E. Kirup
	SC179	*Persoonia longifolia*	Karnet
	SC181	*Banksia attenuata*	Gosnells
	SC218A	*Eucalyptus calophylla*	Kirup
	SC238	*Eucalyptus diversicolor*	Pot trial

also isolates for comparison and for mating-typing
P. megasperma var. *sojae*, *P. citricola*, *P. cactorum*,
P. nicotianae var. *parasitica*, *P. cryptogea*

7. Chemotaxis, Biochemistry of Penetration, Biochemistry of Post-Penetration

This particular field of work contains probably our greatest gap in academic knowledge of the *E. marginata-P. cinnamomi* complex. We know little of the chemistry of *P. cinnamomi* spore germination under W.A. forest conditions, and we know little of the chemistry underlying movement of spores to the eucalypt host and subsequent penetration and destruction of host tissues. We do not know whether toxins are produced by the fungus within the host. We know little of the chemical interactions between mycorrhizal fungi and *P. cinnamomi* or of the interactions between rhizosphere organisms and *P. cinnamomi*.

More knowledge of these factors could be valuable in understanding the disease complex and in evaluating potential control measures. The refined chemical and biochemical techniques required in this type of study are beyond the scope of most pathologists, unless the pathologist has had specialised training in biochemistry e.g. as with a number of University of Adelaide or University of Sydney graduates.

This work is sufficiently important to justify consideration of another worker to study specifically the biochemical associations of the disease complex and their bearing on studies being carried out by other workers on *P. cinnamomi*.

403/66

NOTES ON TALK GIVEN BY PROFESSORS G.A. ZENTMEYER AND F.J. NEWHOOK IN THE BURGUNDY ROOM, HOTEL ADELPHI, ON FRIDAY EVENING, 3RD MAY, 1968.

In their talks on the die-back caused by Phytophthora Cinnamomi, the following points were made by Professors Zentmeyer and Newhook:-

* A serious diseas situation exists in Western Australia.

* The disease is unusual in its severity as it attacks the under-storey forest growth - e.g. banksia.

* It is not a native disease, as evidenced by the fact that banksia and other susceptible under-storey species have flourished in Western Australia.

* It is a world-wide disease, and a number of slides were shown demonstrating its effects on plants ranging from radiata, pineapple to paw paws and citrus trees.

* A slide on some land in Queensland growing (?) root vegetable gave a striking illustration of the use of resistant sub-species, but it is unlikely that such resistance can be engendered in jarrah.

* Phytophthora fungus breeds rapidly in temperatures approximating 70^{o}, but is killed off at low or high temperatures - i.e. less than 40^{o} or more than 90^{o}. This fact has little application in practical treatment as temperature variations in the soil would, of course, be relatively slight.

* Professor Zentmeyer's work for the past 20 years has centred mainly on the prevention of this disease in citrus orchards on the west coast of America, and some slides were shown demonstrating the effectiveness of the use of the chemical Dexon. The chemical is expensive - approximately $US6 - $US7 per lb., resulting in an annual cost of about $US15 for the treatment of an avacado pear tree. Best results are obtained with a solution of Dexon 100 p.p.m. applied at about four-weekly intervals.

* The suggested course of action for Western Australia is to take hygiene measures in the extraction of timber so as to minimize the spread of the disease, and to consider in the long term the replanting of affected areas with resistant-type species - either eucalypt or pinus.

* The fungus is known to attack radiata, but mainly where they are isolated, as in wind-breaks in New Zealand where the foliage growth comes almost to the ground with a consequent increase in water uptake due to transpiration, and also under these conditions there is usually free water available in the ground which is beneficial to the growth of the fungus.

  It is not known for radiata in plantations to be affected, and this is thought to be because of the smaller amount of foliage, and secondly, because up to 1" fall of rain is absorbed by the canopy and pine layer on the ground before water actually reaches the soil.

GWK:CF
7/5/68.

See F. Podger Report file

COMMENTS ON PROFESSOR BJORKMAN'S REPORT

ON JARRAH DIEBACK.

During March, 1966, Professor Erik Bjorkman 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 Bjorkman 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 Bjorkman'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 Bjorkman'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 Bjorkman 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 eliminate 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 improve a condition 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 Bjorkman 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 Southerland, 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 temperature 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 particular 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 Bjorkman 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 Bjorkman.

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 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 Helio 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 Occurrance of Phytophthora cinnamomi in Jarrah Forest Soils.

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

In his report Professor Bjorkman 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 Bjorkman'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 Bjorkman.

1). The east-west trand 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 recognised. 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.

(Sgd.) F.D. Podger

6/7/66.

AG. H... 7.10.66

REFERENCES.

1. ZAK, 1961.

"Aeration and other Soil Factors Affecting Southern Pines as Related to Littleleaf Disease." Technical Bulletin No. 1248, U.S. Department of Agriculture. Forest Service. See particularly p. 11 para. 6; p. 26 para 3; p. 28 para. 1.

ZAK, 1961.

Littleleaf Disease of Shortleaf Pine (Pinus Echinata Mill). in Recent Advances in Botany University of Toronto Press pp. 1525-1528. See particularly p. 1526 para. 3 and p. 1527 para. 1.

2. CAMPBELL, W.A. and COPELAND, O.L., Jr. 1954.

Littleleaf Disease of Shortleaf and Loblolly Pine. U.S. Department of Agriculture, Circular 940.

3. DENZEL, S. CURTIS and GEORGE A ZENTMYER, 1949.

Effect of Oxygen Supply on Phytophthora Root Rot of Avocado in Nutrient Solution, American Journal of Botany 36:6, 471-474.

4. BRAUN, A.J., 1947.

Phytophthora Root Rot of Guayule. Thesis Oregon State College.

5. NEWHOOK, F.J., 1959.

The Association of Phytophthora spp. with Mortality of Pinus radiata and other Conifers I. Symptoms and Epidemiology in Shelter Belts. New Zealand Journal of Agricultural Research Vol 2, No. 4, 808-843.

6. SUTHERLAND, C.F., NEWHOOK, F.J., and LEVY, J., 1959.

Association of Phytophthora spp. with Mortality of Pinus radiata and other Conifers II Influence of Soil Drainage on Disease. New Zealand Journal of Agricultural Research Vo. 2, No. 4, pp. 844-848.

7. van NOORT, A.C.

Unpublished Report, Forests Department of Western Australia.

8. BASSET, C.

Unpublished data New Zealand Forest Service.

9. GILMOUR, J.

Personal communication.

10. ZENTMYER, G.A.

Personal communication May, 1966, and in processed report of Conference on Phytophthora cinnamomi San Francisco, California, April 14 - 15, 1962.

11. ROTH, L.F., and KUHLMAN, E.G., 1963.
Field tests of the Capacity of Phytophthora root rot to damage Douglas fir. Journal of Forestry, 61:199-205.

12. CHEE, K.H., NEWHOOK, F.J., 1965.
Improved methods for use in studies on Phytophthora cinnamomi Rands and other Phytophthora species. N.Z. Journal Agriculture Res. 8:88-95.

13. KREUTZER, W.A., 1963.
In Annual Review of Phytopathology.

pp. 181-195

1 Conservator of Forests ACN 7/10/66
2. ~~Deputy Conservator~~
3. Mr Meachem [signature] 5/10/66
4. Mr Boggs BJB 17/11
5. Mr Stewart [initials] 18/11
6. ~~Mr Hatch.~~
[initials]

Herewith reports, papers and comments by Prof Bjorkman Mr Podger, Mr Angus & Mr Batini concerning Jarrah dieback. Original is in library and ~~[illegible]~~ copies have been sent to senior professional officers in the field. Covering letter from Dr Crow is at p. 150
[initials] SOA.

Aust Plant Pathology Soc Newsletter 1972 25-26

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. cinnomomi 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).

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 dieback 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.

* 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.D. Rodger, 8/7/66.

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 east-ward 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 "little leaf" 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 Phythophthora 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.

<u>GENERAL</u>.

(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 re-infected by Phytophthora as a result of spore wash. The persistant differences could be due to antagonistic fungi, which, having re-invaded 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. Batini, 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.

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 die-back 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* in northern Idaho, the dieback of *Pinus resinosa* in New York State 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*

finalised. The committee, composed of Professor E. J. Underwood 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.

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 fungi earlier had completely killed the trees.

A possible control of the dieback of jarrah could be by ploughing or scarafying 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.

Erik Björkman

was finalised. The committee, composed of Professor E. J. Underwood ... Advisory Committee (Chairman), Dr. D. A. N. Cromer (Forest Research Institute) and Mr. W. H. Eastman (representing the Conservator of Forests, Western Australia), will advise on the research programme of the Station from 1966.

....2/.