JARRAH DIEBACK SEMINAR - HARVEY

OCTOBER 1965

NOTES ON THE CAUSE AND OCCURENCE OF THE DISEASE WITH COMMENTS ON PROSPECTS FOR CONTROL AND FACTORS INFLUENCING REFORESTATION

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Prepared by the Forest Research Institute

056311

THE DISEASE

A 1. Dieback was recognised as early as 1928 at least, but until relatively recent times it was not a problem of significant proportions. Historically dieback is apparently a recent factor in the jarrah forest.

2. Dieback is obviously a continuing process and not the result of some destructive event. In recent times the area affected has increased due to both the extension of existing areas and the appearance of new patches.

3. Rates of spread and intensification of damage in affected areas vary considerably from place to place and with time. There are years of "bad dieback" and years of little dieback. Rates of spread may vary considerably at different points around the perimeter of a single affected area. The rate of decline within a given area is not uniform and there may even be periods of apparent recovery. It is apparent that there are fluctuations in the level of the causative agencies.

4. The long term effect of the disease in a given area is the virtual destruction of the jarrah forest community Profound changes are wrought in the composition of the vegetation.

5. The change wrought by dieback appears to be irreversible in so far as the susceptible native plants are concerned. There is no evidence of any area being revegetated by these species and all attempts at artificial establishment with jarrah have failed.

B. A wide range of native plants are affected in tree, understorey and shrub layers including

Eucalyptus marginata
Banksia grandis
Persoonia longifolia
Persoonia elliptica
Dryandra sessilis
Xylomelum occidentale
Casuarina fraseriana
Xanthorroea preissii
Macrozamia reidlii

Podocarpus drouynians
Leucopogon verticillatus
Grevillea spp.
Isopogon spp.
Adenanthos spp.

SYMPTOMS

7. The first symptoms of dieback in an area are chlorosis and death of understorey and shrub layer members of the Proteaceae. Banksia grandis and Persoonia are probably the best indicators, but a number of shrub members of this family are also quite good indicators.

8. In the case of jarrah, death may be sudden from an apparently healthy condition, but in most instances there is a gradual deterioration in crown vigour. This deterioration is marked by thinning and chlorosis of the primary crown, microphylly, death of branchlets and replacement of the crown by epicormic shoots. Epicormic crowns display the same symptoms of poor health and there may be third and fourth order epicormic replacement before death. The process may take a few or many years and temporary recovery may occur.

9. There is no evidence of macroscopic fructifications, cankers, foliar pests in constant association with the disease. No evidence of major root rotting of structural roots has been found in rapidly killed trees. Feeder roots, however, are sparse and often rotted.

OCCURENCE

C. 10. Jarrah dieback occurs throughout the jarrah forest region. There is however a definite association of the main occurences of the disease with the higher rainfall areas of the forest north of the Blackwood River (Plate 3). Isolated patches however have been verified from Chittering in the north, Mt. Cook and Howse Brook eastwards, at Alco Tower near the Donnelly River, in the east Shannon River area, at North Walpole, Tingledale and near Mt. Lindsay north of Denmark as well as at Nannup, along the Brockman Highway, and near Margaret River.

11. Dieback occurs on a variety of lateritic soils but has not been observed on the deep well drained and generally more fertile soils of the main river valley. The most extensive areas are associated with gentle topography in the upper part of the landscape on the plateaus.

12. A 1962 survey of 264 randomly selected points on the western part of the South Dandalup catchment showed dieback occered equally on all aspects and was represented on all topographic classifications from gully heads to ridge tops. There was however significantly more dieback associated with gully heads and less dieback on ridge tops than any other category. This result supported the earlier observation that dieback developed most commonly in these areas and indicates that it can spread from these areas to any topographic situation.

13. Dieback has reached its major development in average to lower quality forest, but is known to occur in high quality forest of 110' codominant height viz. Karnet 6, Willowdale and on Urunga Road.

14. Dieback has been observed over a wide range of stand structural types, including sapling, pole and mixed veteran pole stands. Both high and low density stands are affected in both exposed and sheltered situations.

15. All size and age classes are affected. Advance growth of jarrah however appears to be more resistant, but eventually succumbs. Periodic resurveys over a 15 year period of the line transect established by Hatch and Teesdale show a gradual reduction in total advance growth numbers and number of stocked quadrats. In this period there was no effective recruitment to size classes beyond the dynamic sapling stage.

16. Dieback has been observed in virgin stands notably on Helio Road in the Dwellingup District, at east Shannon and in the low plateau east of Margaret River. In all of the cases noted however the patches were in proximity to recent or well established roadways. I have no knowledge of dieback in remote virgin forest areas.

17. There are no clear associations of the occurence of dieback with fire history.

THE PATHOGEN

E. 18. Evidence that Phytophthora cinnamomi is an important contributing factor to dieback has been reported (Podger Doepel and Zentmyer 1965).

19. This fungus was first discovered on Cinnamon trees in Sumatra by Rands in 1922. It has since been recorded from many of the tropical to warm temperate areas of the world.

20. The fungus causes serious root rot disease of a wide range of herbaceous and woody plants both broad leaved and coniferous. Thorn and Zentmyer 1954 list over 100 host species.

21. The fungus is a root inhabiting pathogen which normally invades only living host tissues. It has been shown however to be capable of invading dead host tissue against the competition of other soil organisms Kuhlman 1964, but only at high levels of inoculum.

22. Survival of P. cinnamomi in tissues invaded and killed by the fungus has been recorded after 6 years though at very low survival percent Zentmyer 1965. Survival up to five years Newhook 1959 and 2½ years Kuhlman 1964 have also been reported.

23. Despite these exceptional cases P. cinnamomi populations surviving in the absence of living host tissue are drastically reduced by 18 months in the absence of living hosts.

24. The various structures of the fungus and the mode of infection are described on following pages. The main survival is by chlamydospore and mycelium in host tissues. The more resistant oospores apparently do not occur in soil Kuhlman 1964.

25. The fungus does not survive drying out, temperatures above 95°F, or prolonged lack of oxygen. It can not be expected therefore to persist in swampy situations or to survive transportation in dust.

26. The requirements of the fungus for rapid growth and infection are:

a) Free soil moisture i.e. around field capacity.

b) Good aeration

c) Soil Temperatures in the range 77°F - 88°F (Figure 1).

d) A high level of susceptible host tissues.

27. The jarrah forest environment provides item a) and b) and d) during much of the autumn, winter and spring and periodically in places during the summer. The soil temperature regime at 1½" near Karnet since July this winter in relation to the temperature range required for P. cinnamomi mycelial growth and sporangial production is shown in Fig. 2.

28. The requirement for free soil moisture is enhanced on sites of impeded drainage and during periods of high rainfall. These conditions favour high levels of infection.

29. The fungus invaded mainly fine undifferentiated feeder roots in most plants and rarely occurs in woody roots of the order of 1/10" or more in diameter. Infection is mainly by zoospores. However, cross infection by mycelial invasion may occur where roots of an uninfected plant grow into the root zone of an infected plant and contact infected tissues.

30. Man is very effective in spreading the disease wherever he moves infected host tissues in earth moving operations and nursery stock. Roth and Kuhlman 1963. Zentmyer Paulus and Burns, 1962.

THE CAUSE OF THE DISEASE

F. 31. The effect of Phytophthora cinnamomi on a plant is equivalent to a severe and sustained root pruning. There are apparently no systemic toxins produced such as are associated with a vascular wilt fungi. This "pruning" effects only fine feeder roots and results in starvation particularly for nitrogen. Roth Toole and Hepting 1948. The loss of much of the absorbing root system reduces the ability of the plant to obtain its moisture requirement during periods of atmospheric stress. Phytophthora infected trees die of starvation and dessication.

32. The growth of a dieback affected tree and its survival are dependent on the degree of root damage and the stress placed on the tree by atmospheric conditions. Root shoot balance and the ability of a tree to regenerate a root system is important in this respect. Trees with a heavy crown and poor root regeneration capacity are much more likely to be killed rapidly than advance growth with a small leaf area in relation to its root system.

33. Because conditions favourable to Phytophthora vary with time and space the level of root damage varies also. Periods of severe dieback and lulls in activity are experienced depending on the season and on the year.

34. A possible explanation for the severity of Dieback damage in the jarrah forest is the sequence of root damage and atmospheric stress in this environment. Severe root damage by Phytophthora might be expected following every rainy period in spring. The tree must then survive several months of severe atmospheric stress on a damaged root system on soils

of poor moisture holding capacity and/or competition for soil moisture by non susceptible under layer plants. When the rainy season recommences conditions are once more favourable to fungal infection. The mid winter conditions which are unfavourable to the fungus produce relatively slow jarrah growth and therefore slow recovery.

35. Of the seven eucalypt species common in the northern jarrah forest jarrah is by a considerable margin the least tolerant to excessive soil moisture. Thus the conditions most favourable to the fungus are at the same time unfavourable to root recovery by jarrah.

36. Evidence for the causal relationship between Phytophthora cinnamomi and jarrah dieback may be summarised as follows:-

a) Pot trials have shown that the top 6" of soil around sample dying trees contains a factor pathogenic to seedlings of E. marginata (plate 4), Banksia grandis (plate 6) and Xanthorroeae preissii, but not to E. patens (plate 7), E. wandoo and E. calophylla.

b) This pathogenic factor can be inactivated by steam sterilisation, fungicidal drenching and formalin fumigation (plates 4, 5, 6).

c) The factor can be transmitted from diseased seedling roots of jarrah (plate 8).

d) The factor is capable of spread up slope from a source of infection (plate 9).

e) A known pathogen <u>P. cinnamomi</u> has been recovered from tissues of jarrah, Banksia grandis, Podocarpus drouyniana and Leucopogon verticillata plants growing naturally in dieback areas. No other known pathogen has been consistently isolated.

f) P. cinnamomi has been recovered from a number of dieback areas including Karnet 6, Willowdale, Kent Block and Alco.

g) P. cinnamomi has not been recovered from unaffected forest areas despite attempts on a number of occasions.

h) Symptoms of the disease have been reproduced in healthy plants by inoculation with pure cultures of the fungus.

i) The fungus has been recovered from tissues of these inoculated plants.

POTENTIAL OF THE DISEASE

G. 37. Much of the area of jarrah forest not at present affected appears to have the characters of climate, soil and concentration of host material necessary to support infection by Phytophthora cinnamomi.

38. The only local situations in which dieback does not appear to have established in generally affected areas are associated with the better soils of the steeply dissected main river systems.

39. Given continuation of the conditions of the last several decades we may expect continuation of the trend of dieback spread evident in that time. On the basis of other Phytophthora induced epidemics we can expect an increased rate of area spread.

40. The disease has more of the characters of an introduced pathogen than of a native gone wrong. It is therefore unlikely that inherent resistance to the fungus exists in any jarrah strains. There has been no evidence of such resistance in areas so far affected.

41. The evidence available on recent climatological drift is overwhelmingly in favour of a world wide warming trend. Mitchell 1961. This trend would increase the length of the winter period suitable to Phytophthora activity. Gentilli (1952 and 1965) has reported evidence for increasing average annual precipitation in the South West of Western Australia.

42. None of the available evidence can be interpreted as indicating changes less favourable to Phytophthora activity. Hepting 1963 points to evidence of increasing forest disease and suggests an association of this increase with the above mentioned climatic drift.

PROSPECTS FOR CONTROL

H. 43. Approaches to control which have been considered for P. cinnamomi may be classified as:

a) Attempts to eradicate the fungus

b) Attempts to isolate

c) Alteration to conditions unfavourable for the fungus

d) Means of protecting the host from infection without eradication of the fungus.

e) Increasing host vigour and resistance.

Examination of these possibilities has been made in both Avocado areas of California, Zentmyer, Paulus and Burns 1962 and in the Shortleaf Pine Little Disease studies. Campbell and Copeland 1954. In the Shortleaf areas only approach e) has been considered feasible because of economic considerations. All methods have been investigated for Avocado.

44. It is pertinent that the recommendations made for Avocado groves are for groves valued on the current market at around £4,000 per acre (van Gundy personal communication) and watered by irrigation in an 8" natural rainfall zone. The soil moisture regime is thus much more amendable to control.

45. Attempts to eradicate P. cinnamomi by fumigation is not recommended except for areas under about 1/20th of an acre. The cost of fumigation in the jarrah forest even on small patches would be prohibitive. The recommended dosage of Vapam and Mylone cost £350 and £570 per acre for chemical alone and require large quantities of water. On the basis of experience at Dwellingup in carting water we could anticipate cost of fumigation at around £650 per acre. Other Chemicals such as DD and Telone cost around £120 per acre and use little water but require a seed bed standard site preparation.

46. Isolation by trenching is recommended in Avocado groves. This proceedure is effective since soil moisture movement across the trench can be controlled by lining or by cessation of irrigation until the fungus dies in the affected areas.

47. Difficulties facing the use of trenching in jarrah dieback are:

a) The boundary of infection is difficult to define. Trenching should be well outside the area showing clear symptoms.

b) The presence of large ironstone Floaters makes difficult the task of severing all root connection across the trench line.

c) During heavy rain the fungus could be moved across the trench by mass flow of watercarrying mycelial fragments and spores.

d) The cost per acre isolated will be high since a satisfactory job will probably require the use of a proportion of manual labour.

48. Protection from infection by the use of selective fungicides is not likely to be of use on a field scale since the fungicides recommended are expensive applied in water and regular applications are required at at least 6 monthly intervals.

49. The use of nitrogenous fertilisers to increase root recovery has been demonstrated for Shortleaf Pine but is not recommended on the ground of cost.

50. The only silvicultural approachs advocated by Campbell and Copeland 1954 as beneficial in the Littleleaf problem are soil rehabilitation by management to favour soil building species and the avoidance of practises which lead to site deterioration.

51. It is possible that some benefit may derive from removal of susceptible understorey species such as Banksia as a means of reducing inoculum potential of the fungus. However since dieback occurs on stands of low Banksia stockings it is unlikely that such practise would prevent the development of the disease even though it may slow the rate.

52. It should be possible to keep down the number of new infections in lightly affected regions by observing as far as practical certain sanitary proceedures. The movement of earth from infected areas by

a) Gravel borrowing

b) Vehicles carrying soil on wheels and undercarriage during salvage operations when soil is wet particularly during autumn and spring.

c) Bank cutting in dieback along road edges during grading operations.

Frequent movement of heavy equipment between dieback salvange and operations in unaffected forest can be expected to increase the risk of increased infection.

LIMITATIONS TO REFORESTATION

I 53. It is highly unlikely that any plant which is highly susceptible to Phytophthora cinnamomi will be satisfactory for reforestation programmes. Site preparations to the extent that all living host plants are removed will not be economically feasible. The fungus can therefore be expected to persist in these areas, albeit at low concentration, for very long periods. Reinfection of reforested areas from outside will be unavoidable in the normal course of operations. The chief requirement of any candidate species must be resistance to P. cinnamomi.

54. Some species which are moderately susceptible to the fungus under ideal test conditions may prove to be capable of satisfactory growth under field conditions where the rate of attack is less than the rate of root replacement by the host.

55. Good early performance is not a guarantee of resistance in that sites prepared for planting have had the fungal population severely reduced and a build up may take a number of years. Nonetheless the peformance of E. microcorys and E. saligna in dieback areas at Harvey and Willowdale is promising. Pinus pinaster, a suspected host, Newhook 1959, has performed well in dieback areas given site preparation and fertiliser. Newhook reported however that he had not verified P. cinnamomi on P. pinaster. If it is a host then it seems likely to be a resistant one.

56. Because of low inherent fertility of the soils, plants which show early promise may develope deficiencies at a later date.

57. Any large scale reforestation programme should be preceeded by a programme of testing for disease resistance, determination of suitable establish ment techniques and of nutrient requirements.

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SPORE FORMS AND MYCELIAL CHARACTERS OF

P. CINNAMOMI

a. Mycelium is the main vegetative structure of P. cinnamomi and is typically coralloid. The mycelial strands or hyphae are usually about 8 μ long (1/120th of a mm). Mycelium in nature is usually confined to host plant tissues and by growth within the tissue can extend infection within a root system.

b. Mycelium commonly produces thin walled swellings which are called chlamydospores and are an asexual resting spore.

c. Spores formed by the union of two hyphal strands are called oospores. These are thick walled resting spores and are more resistant than chlamydospores. Although oospores are commonly produced by many species of Phytophthora they are rarely if ever formed by P. cinnamomi under natural conditions.

d. At high soil moisture levels and under favourable temperature conditions mycelium in infected root tissues produced, at the root surface, large numbers of spore bearing structures called sporangia. These germinate to produce motile kidney shaped spores called zoospores which are propelled through water by lashing movements of two tail like appendages called flagellae.

e. The zoospores are attracted by substances diffusing out of host root tissues into the water and swim towards host roots.

f. On reaching the host root the zoospores roll up into spherical blobs i.e. the zoospores encyst.

g. Within an hour the encysted zoospores germinate by means of a germ tube which under the influence of substances diffusing from the host root grow toward the host root and penetrate the tissues. This is the principal means by which new infections are established.

h. Mycelium within the newly infected tissue may shortly after produce new sporangia and thus initiate a further cycle of infection. No more than several days are required to complete a single cycle of infection.

(see over)

MYCELIUM AND SPORE FORMS

A Mycelium

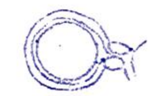
X 120

B Chlamydospores

X 120

X 300

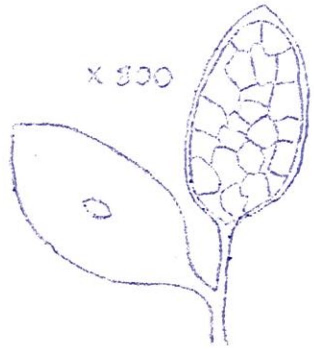
C Oospore



X 300

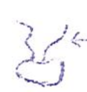
D 1 Sporangium

X 800



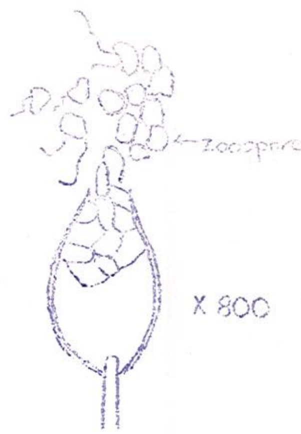
D 2 Zoospore

X 800



THE INFECTION PROCESS

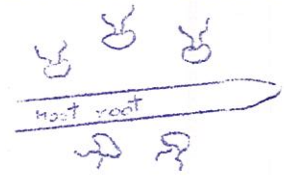
E Germinating Sporangium



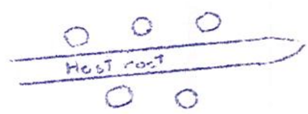
X 800

Note Diagrams F-I not to scale

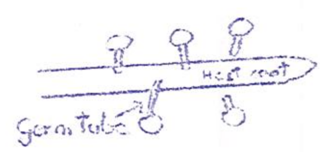
F Motile Zoospores



G Encysted Zoospore



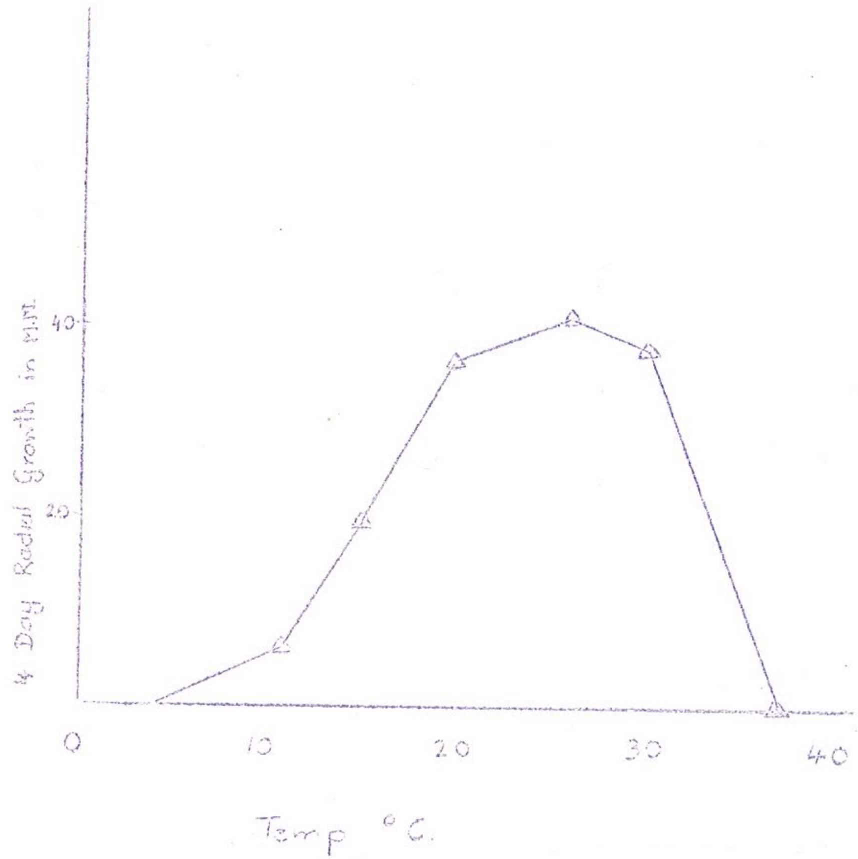
H Germinating Zoospore



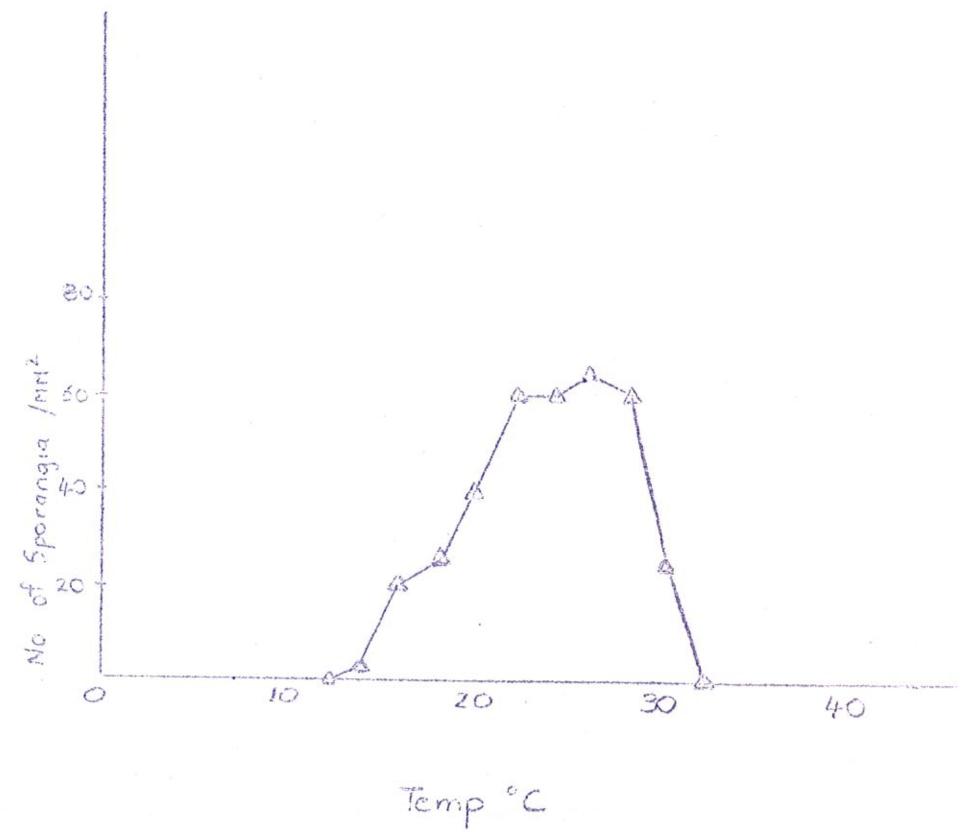
I Sporangium of 2nd cycle

Temperature Growth Curves for P cinnamomi

Mycelial Growth (Karnet Banksia Isolate)
(Data of Podger)



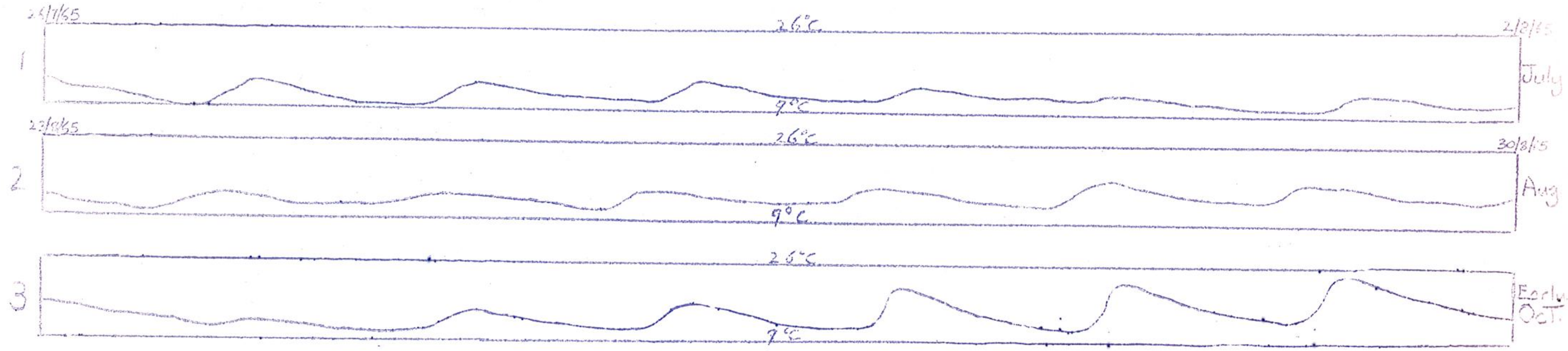
Sporangial Production (after Data of Chee & Newhook)



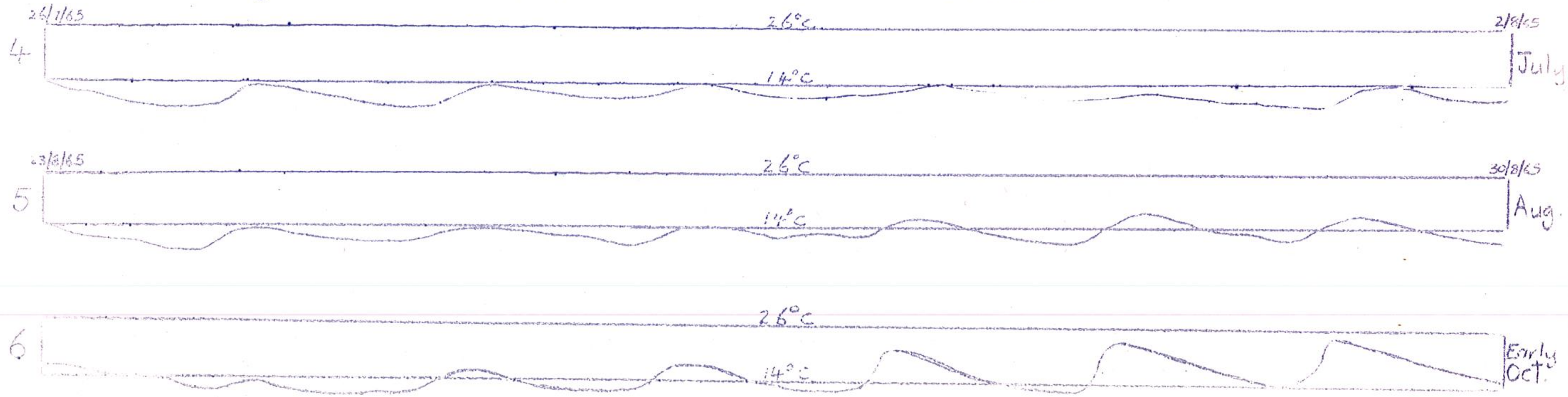
Thermograph Traces in Jarrah Forest of Soil Temperature Environment at 1½" during July, Aug, Oct in Relation to Cardinal Temperatures for Growth of P. cinnamomi

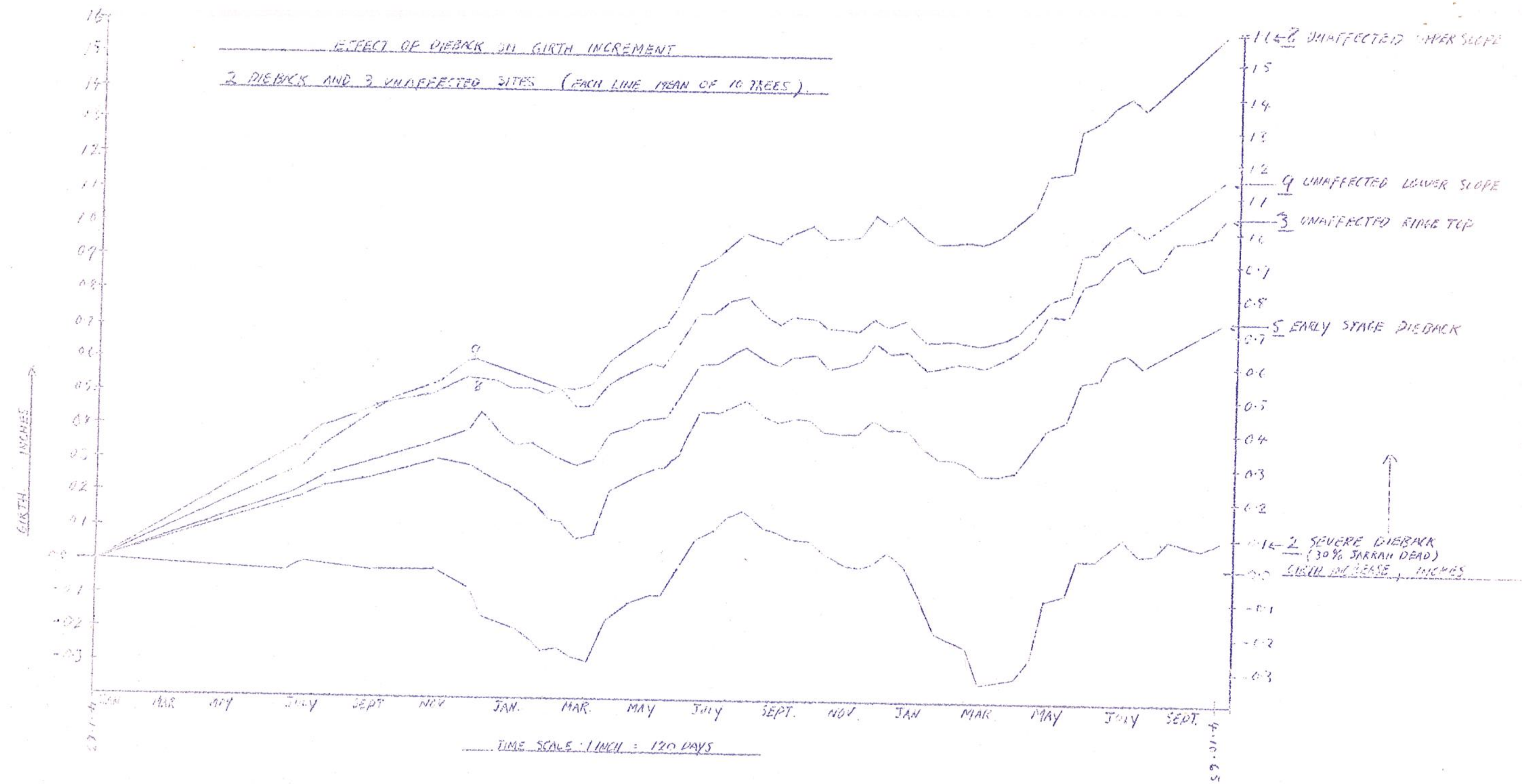
Thermograph Traces in Jarrah Forest of Soil Temperature Environment at 1½" during July, Aug, Oct in Relation to Cardinal Temperatures for Growth of P. cinnamomi

1, 2, 3 Mycelial Growth   Optimum 26°C.   Lower Threshold 9°C.



4, 5, 6 Sporangial Production   Optimum 26°C.   Lower Threshold 14°C




EFFECT OF DIEBACK ON GIRTH INCREMENT
2 DIEBACK AND 3 UNAFFECTED SITES (EACH LINE MEAN OF 10 TREES)
GIRTH INCHES
6 UNAFFECTED UPPER SLOPE
4 UNAFFECTED LOWER SLOPE
3 UNAFFECTED RIDGE TOP
5 EARLY STAGE DIEBACK
2 SEVERE DIEBACK (30% JARRAH DEAD)
GIRTH INCREASE, INCHES
JAN MAR MAY JULY SEPT NOV JAN. MAR. MAY JULY SEPT. NOV. JAN MAR. MAY JULY SEPT.
TIME SCALE : 1 INCH = 120 DAYS

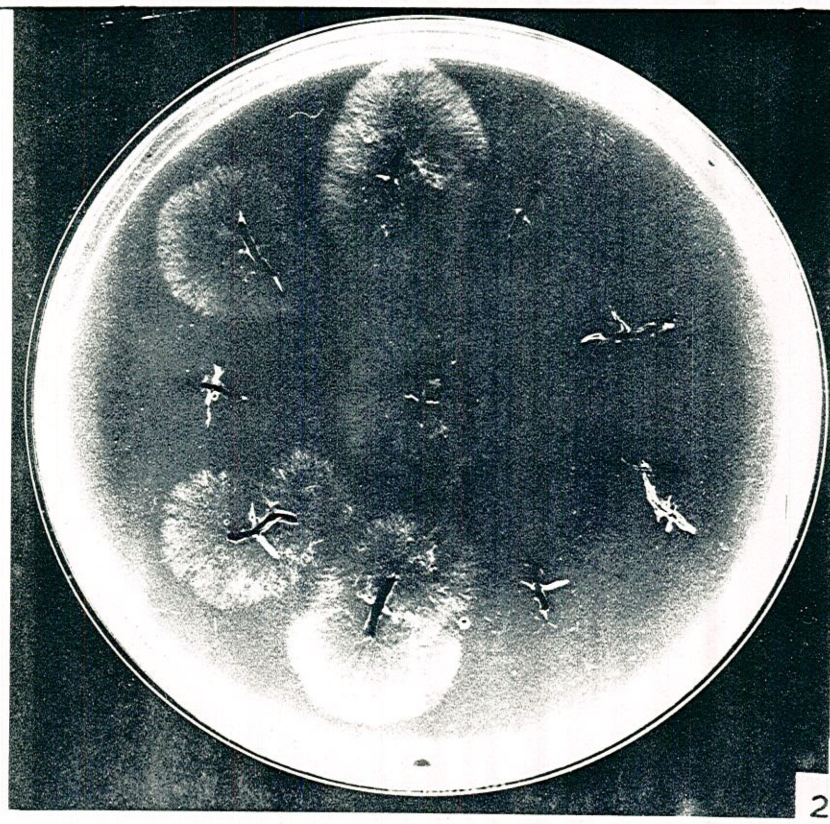
Recent work at the Forest Research Institutes Western Regional Station has established that root rot caused by the fungal organism *Phytophthora cinnamomi* is a major factor in the development of Jarrah Dieback.

This finding when related to the observed occurence and activity of the disease provides, for the first time, a sound basis for making predictions as to the potential of this disease and the prospects for control. Limitations to reforestation approaches can now be more clearly defined than previously.

This contribution to the Seminar provides information as a background to discussion. Those parts of the paper which are interpretive and predictive are not all supported by experimental evidence. As such they are my personal interpretations in the light of available knowledge and should not be cited as fact at this stage.

F. D. PODGER.

1



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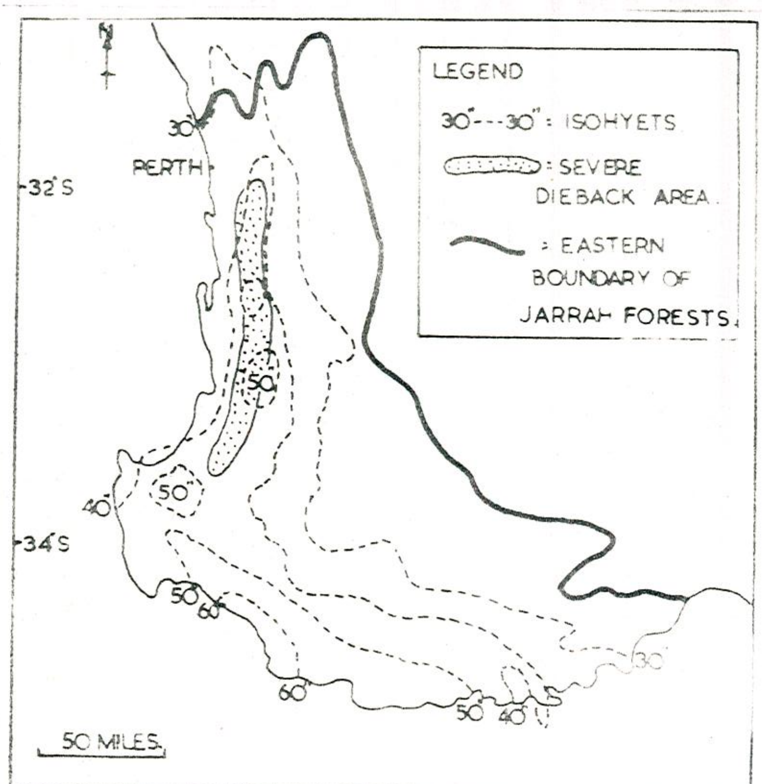
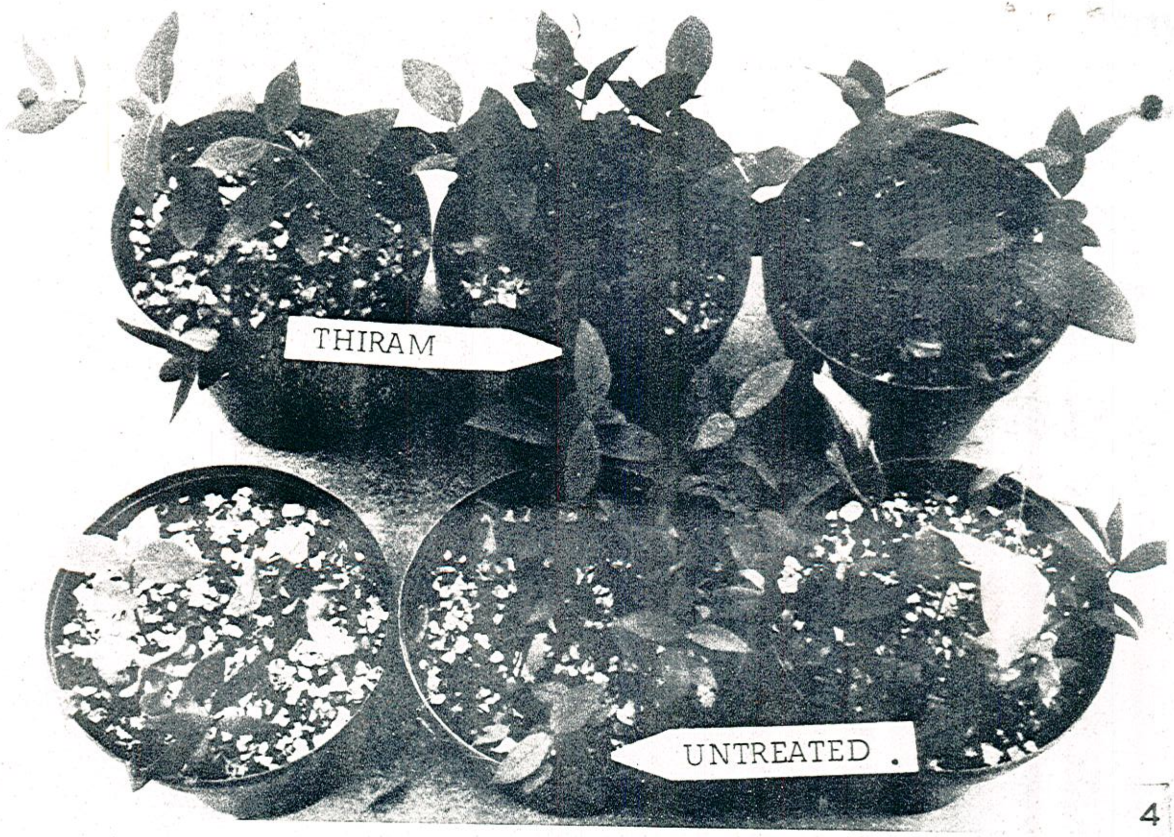

LEGEND
30"---30" = ISOHYETS
= SEVERE DIEBACK AREA.
= EASTERN BOUNDARY OF JARRAH FORESTS.
PERTH
32°S
34°S
30"
50"
40"
60"
50 MILES.

3



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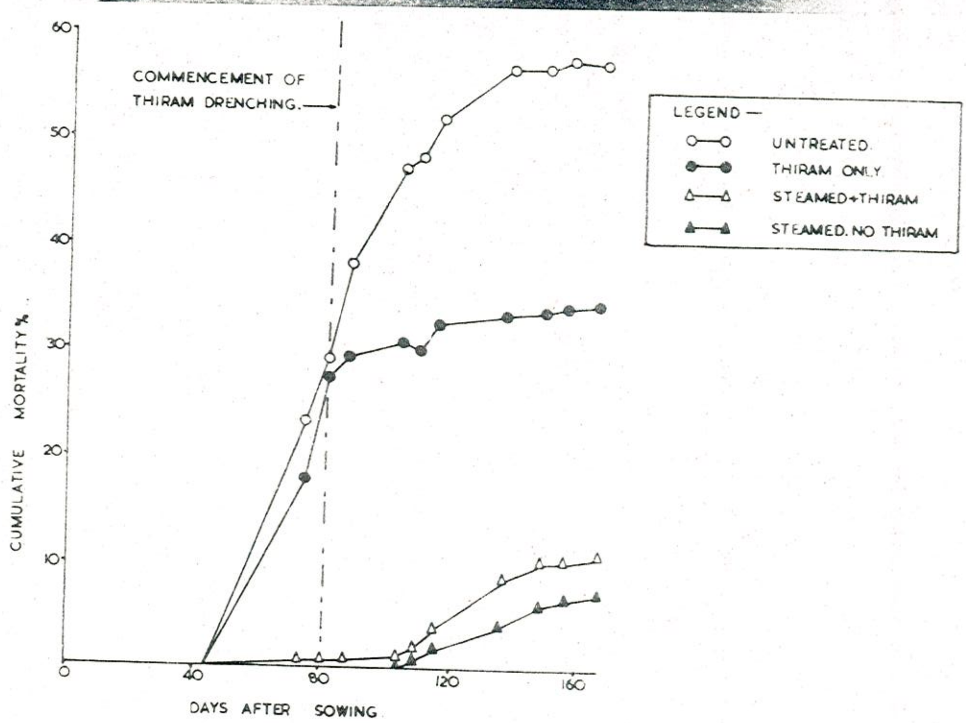

5

STERILE

UNTREATED

7


131
191.
120
174
INOCULUM - ROOTS OF PLANTS GROWN
IN STERILE SOIL
IN UNTREATED SOIL

8


SPREAD INTO STERILE SOIL FROM

9