# PHYTOPHTHORA ROOT ROT OF *PINUS* IN QUEENSLAND

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**SUMMARY**

**The incidence of Phytophthora root rot of *Pinus* spp. in Queensland is reported. *Phytophthora cinnamomi* was found to be the pathogen associated with the disease in the nursery and the field. The pathogenicity of *P. cinnamomi* to a number of species of *Pinus* was investigated in greenhouse inoculation tests.**

***P. boehmeriae* was recorded from *Pinus patula* in one locality and pathogenicity was proven.**

## I. INTRODUCTION

Root rot of species of *Pinus* caused by infection with *Phythophthora cinnamomi* Rands. has been described from the south-east of the United States of America by Campbell and Copeland (1954). A widespread chronic disease of *Pinus echinata* Mill., and to a lesser extent *P. taeda* L., was attributed by these workers to infection of the root tips and fine roots by *P. cinnamomi*. The foliage symptoms resulting from the root decay have been termed "littleleaf".

Subsequently Newhook (1959) reported a Phytophthora root rot of *P. radiata* D. Don and other conifers in New Zealand. Serious losses of trees in shelter belts and ornamental plantings occurred in seasons of prolonged rainfall. Some affected trees entered a state of chronic degeneration similar to the American littleleaf condition; others died rapidly after the onset of symptoms. Several species of *Phytophthora* are involved in the disease complex in New Zealand. *P. cinnamomi* is the most common species associated with the disease of *Pinus radiata* (Newhook 1960).

*P. cinnamomi* was first isolated from *Pinus* roots in Queensland in 1957. It was found to be present in high population in the roots and soil under slash pine (*P. elliottii* Engelm.) trees which had died during drought at Beerburrum in south-eastern Queensland. This paper outlines subsequent records of the disease in Queensland and reports investigations of the pathogenicity of the causal fungus to a number of *Pinus* species.

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## II. FIELD INCIDENCE OF *P. cinnamomi* IN PINUS

*P. cinnamomi* causes widespread and severe root rot of avocado (*Persea gratissima* Gaertn.) and pineapple (*Ananas comosus* (L.) Merr.) in Queensland. The first association of this fungus with a species of *Pinus* was recognized at Beerburrum in 1957. During a drought, which was preceded by three years of above-normal rainfall, some 15 per cent. of trees died in a 15-year-old area of a slash pine plantation (Figure 1). This badly affected area comprised about 10 acres, but scattered deaths also occurred in nearby sections of the plantation. The average annual rainfall in this district is 61 in. Precipitation in 1957 was 25 in., whereas in the three preceding years it was 79, 74, and 79 in. respectively.

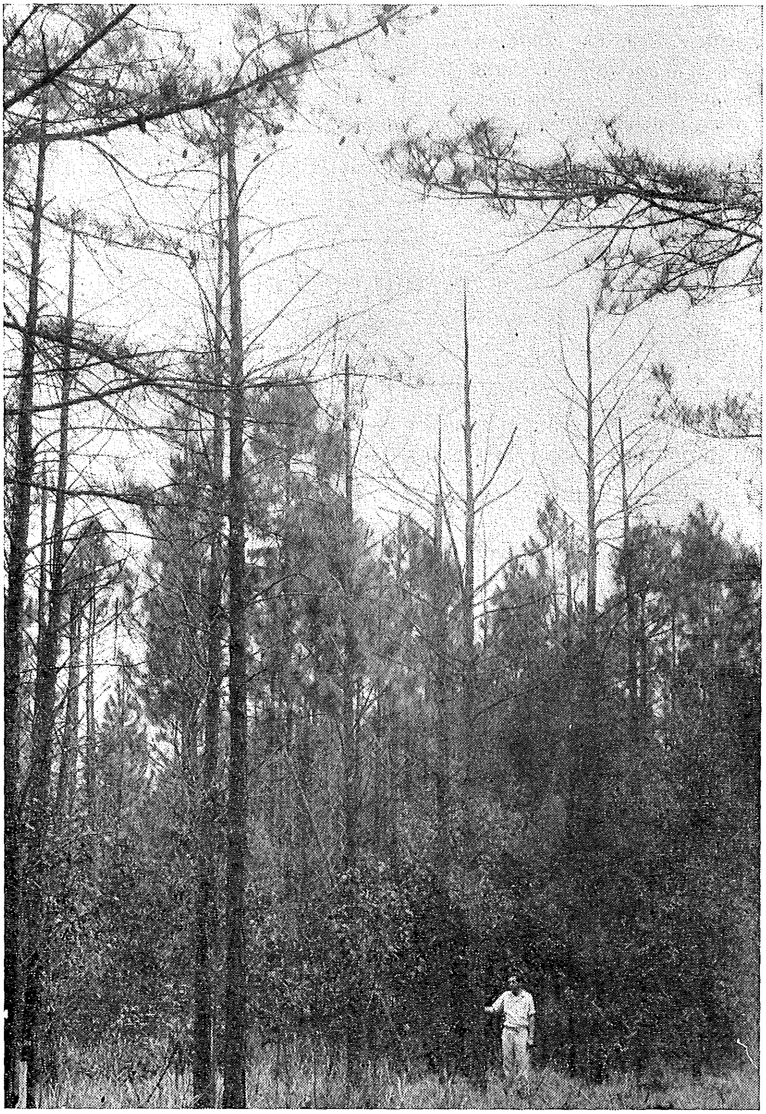

Fig. 1.—Slash pine trees, affected by Phytophthora root rot, which died during drought, Beerburrum, 1957.

The first symptoms shown by the affected trees consisted of chlorosis and wilting of the needles on the leaders. This was followed by a general chlorosis and wilting of all the foliage and fairly rapid death of the trees. Root examinations revealed extensive death of the smaller roots at the stage when the trees first showed symptoms. There was a pronounced blue staining of the wood in the stems and main roots of the dead trees. *Diplodia pinea* (Desm.) Kickx. was consistently isolated from these discoloured tissues. This fungus is known to rapidly invade severely damaged or felled slash pine trees in coastal plantations but is not a primary pathogen of this species. Also, it was not possible to isolate *D. pinea* from the wood of trees showing early symptoms.

Slash pine is considered to be a drought-tolerant species in Queensland and root rot was therefore suspected to be a contributing factor. Isolations were made from the fine roots and adhering soil, using the modification of Tucker's apple technique described by Campbell (1949). *P. cinnamomi* was isolated in a few cases but the soil was extremely dry at the time and unsuitable for such isolations. Following heavy rains in early 1958 the surviving trees in the affected area were found to have considerable root decay although aerial symptoms were not evident. Isolations in this case consistently yielded *P. cinnamomi.*

The soil in the site was shallow, consisting of 12 in. of sandy loam overlying a poorly drained clay loam subsoil. A heavy mottled clay layer occurred at 24 in. The plantation area was thickly planted at 7 ft by 7 ft spacing and unthinned. Moisture stress would have been high during dry weather. It was therefore suspected that root rot occurring in the 1954–1956 wet years followed by drought in 1957 had caused the deaths.

A search was then made in other Queensland Department of Forestry plantations and also nurseries for further evidence of the disease. Table 1 summarizes the field recordings made in this survey and also during subsequent investigations.

**TABLE 1**

RECORDS OF *Phytophthora cinnamomi* INFECTING *Pinus* SPP. IN QUEENSLAND, 1957–1963

| Host Species | Age of Trees | Locality | Year | Degree of Incidence |
|---|---|---|---|---|
| *P. elliottii* .. | 15 years | Beerburrum Plantation .. | 1957 | 15% loss in 10-ac area |
| *P. elliottii* .. | 1 year | Toolara Plantation .. | 1958 | 30% loss in transplants |
| *P. radiata* .. | Seedlings | Passchendaele Nursery .. | 1958 | Severe |
| *P. elliottii* .. | Seedlings | Passchendaele Nursury .. | 1958 | Moderate |
| *P. elliottii* .. | 24 years | Imbil Plantation .. | 1958 | 5% loss in small area |
| *P. elliottii* .. | Seedlings | Toolara Nursery .. | 1959 | Severe |
| *P. elliottii* .. | Seedlings | Rocklea Nursery .. | 1959 | Moderate |
| *P. radiata* .. | Seedlings | Emu Vale Nursery .. | 1959 | Severe |
| *P. elliottii* .. | 12 years | Passchendaele Plantation | 1962 | No aerial symptoms |
| *P. elliottii* .. | 2 years | Beerburrum Plantation .. | 1963 | 30–40% loss in young planting |
| *P. elliottii* .. | 14 years | Beerburrum Plantation .. | 1963 | In windblown trees |

The implications of severe nursery incidence of root rot are rather complex. Firstly there is the direct loss of trees in the nursery (Figure 2), which in some cases has resulted in shortages of planting stock. Secondly there is the increased risk of transplant losses when nursery plants with a degree of root rot are set out in the field. Transplant losses from some nurseries have in fact been high when the disease was prevalent in those nurseries. There has also been recent evidence that the field planting of seedlings with an infected root system has resulted in subsequent shallow rooting of the established trees and proneness to uprooting in high winds. The third and not least important result of nursery infestation is the spreading of a potentially dangerous pathogen into virgin forest areas in the process of plantation establishment.

Fig. 2.—A bed of young *Pinus radiata* trees in Passchendaele nursery affected by Phytophthora root rot. The stand has been appreciably thinned out by the disease.

Plantation records of the disease are summarized in Table 1. Observed plantation damage has not been severe so far. The effect of root infection on the growth rate of trees is as yet unknown. However, plantings which are known to have been made from infected nurseries are being kept under observation to check further on the field performance of infected trees.

## III. SPECIES OF *PHYTOPHTHORA* INVOLVED

Newhook (1959) found that *P. cinnamomi* and *P. cactorum* (Leb. et Cohn) Schroet. were most frequently isolated from under conifers in New Zealand, but *P. citricola* Sawada, *P. syringae* (Berk.) Kleb. and *P. cryptogea* Pethybr. et Laff. were also found in some cases.

From 1957 to 1962 all isolates of *Phytophthora* from roots and/or soil under *Pinus* trees in Queensland proved to be *P. cinnamomi* and this species appears to be the most common associate of root rot in such hosts in this State.

However, in 1962 another species was isolated from under *P. patula* Schlecht et Cham. trees which had died during drought. These trees were located in depressions in the plantation rather than on the ridges, where water stress would be greatest. Root rot was therefore suspected as a contributing factor. The fungus isolated did not conform to any of the species of *Phytophthora* previously recorded in this State, and Dr. G. Waterhouse (Commonwealth Mycological Institute), who examined cultures, identified it as *Phytophthora boehmeriae* Sawada.

## IV. GREENHOUSE INVESTIGATIONS

Zak and Campbell (1958) reported from investigations in Georgia that *Pinus echinata* was more susceptible to artificial infection with *Phytophthora cinnamomi* than *P. taeda, P. palustris* Mill. and *P. elliottii* when the plants were grown in liquid culture. Most of the important plantation species of *Pinus* in Queensland were artificially inoculated in the greenhouse in various experiments from 1959 to 1962.

### (a) Experiment 1

In 1959, one-year-old potted plants of *P. radiata, P. taeda, P. elliottii, P. palustris* and *P. echinata* which had been raised in steamed soil were inoculated with *Phytophthora cinnamomi.* The first three are important plantation species in Queensland, while *P. palustris* and *P. echinata* are affected by littleleaf in the U.S.A. Two media, corn meal sand and diluted pineapple juice, were used for culturing the fungus and the inoculum was dug in around the roots of the plants. Similar quantities of sterile media were added to the appropriate uninoculated controls. The pots were dampened by standing in trays of water but were periodically dried out before returning to the trays.

Some of the plants from each treatment were harvested after 2 months and the remainder after 9 months. Root rot occurred in the inoculated pots of all species and the fungus was readily re-isolated. Both types of inoculum were effective. There was an indication that *P. taeda* suffered less root damage, foliage chlorosis and dieback than the other species. However, it was not possible at either harvest to discern appreciable differences in the degree of root rot or foliage degeneration between the species of pine. Detailed root examinations are difficult when the plants are growing in soil and small pine trees are capable of surviving for long periods with very little functional root system. With such a technique it would be necessary to measure growth increments over an extended period to detect specific differences in root-rot susceptibility. However, this experiment did illustrate the pathogenicity of local isolates of *P. cinnamomi* to the five host species.

### (b) Experiment 2

Because of the difficulty in rating for root rot in plants growing in soil, a liquid culture technique, similar to that described by Zak and Campbell (1958), was employed in a further pathogenicity experiment in 1961. This time *P. taeda,* *P. radiata, P. elliottii, P. caribaea* and *P. echinata* were the species tested. The seedlings were raised in steamed sand with two plants per pot. After nine months the plants were lifted, the roots were washed free of sand, and then each pair was transplanted into a lidded plastic bucket of liquid medium. The medium used consisted of tap water to which complete fertilizer tablets ("Gard'n Tabs") were added. In preliminary work it was found that a complete, balanced nutrient solution was not necessary for the short duration of such an experiment. The culture solution was aerated for 3 min every hour.

Twenty-six days after transplanting, sufficient new roots had been produced to permit inoculation. The inoculum of *P. cinnamomi* was produced on bundles of autoclaved lucerne stems and one bundle was suspended in each container to be inoculated. There were five inoculated containers and three untreated for each host species. Six days after inoculation, rotting of the soft white root tips was obvious; the first rating was made after 9 days and the final after 20 days. Excised root tips from all treatments were incubated in sterile water after prolonged washing. Typical sporangia of *P. cinnamomi* developed on the roots of plants from all inoculated treatments.

The root-rot estimations were made by counting all healthy root tips over 1 in. in length. A rating of 0 to 5 was also made on the general state of the root system, 0 indicating nil root rot and 5 complete rotting. Results are given in Table 2.

**TABLE 2**

RESULTS OF ROOT-ROT INOCULATIONS IN LIQUID CULTURE—EXPERIMENT 2

| Species | Treatment | Average Root-rot Rating | | Average No. of Healthy Root Tips Per Plant | |
|---|---|---|---|---|---|
| | | After 9 days | After 20 days | After 9 days | After 20 days |
| *P. radiata* .. | Inoculated | 4·8 | 4·6 | 1 | 0 |
| | Control | 0 | 0 | 23 | * |
| *P. caribaea* .. | Inoculated | 4·6 | 4·6 | 3 | 0 |
| | Control | 0 | 0 | 20 | * |
| *P. elliottii* .. | Inoculated | 3·2 | 3·6 | 9 | 0 |
| | Control | 0 | 0 | 26 | * |
| *P. taeda* .. | Inoculated | 4·4 | 3·0 | 3 | 0 |
| | Control | 0 | 0 | 51 | * |
| *P. echinata* .. | Inoculated | 4·8 | 3·8 | 1 | 0 |
| | Control | 0 | 0 | 30 | * |

* Too numerous to count

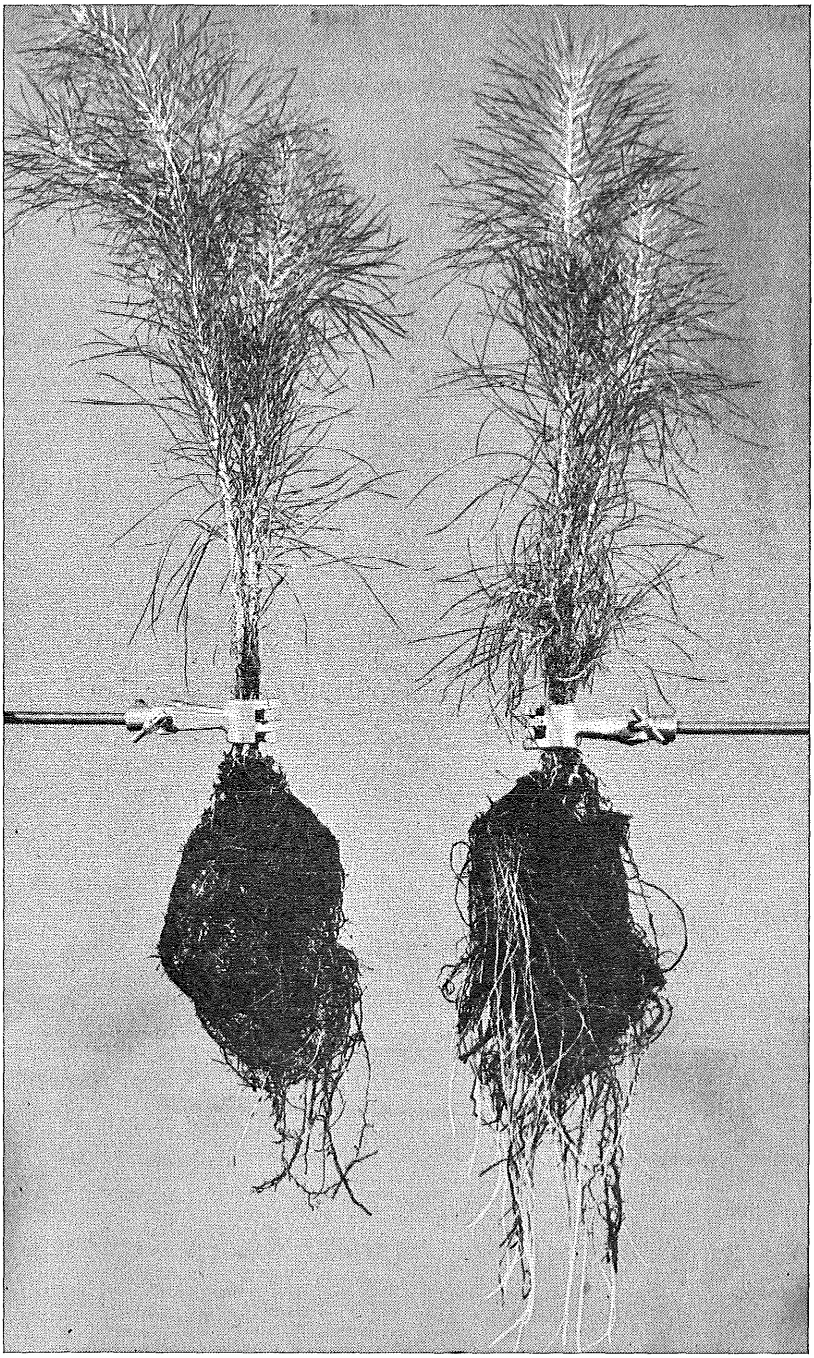

Fig. 3.—*Pinus taeda* plants on left inoculated with *P. cinnamomi* in liquid culture. The foliage is still healthy and some new roots are being produced. Uninoculated plants on right.

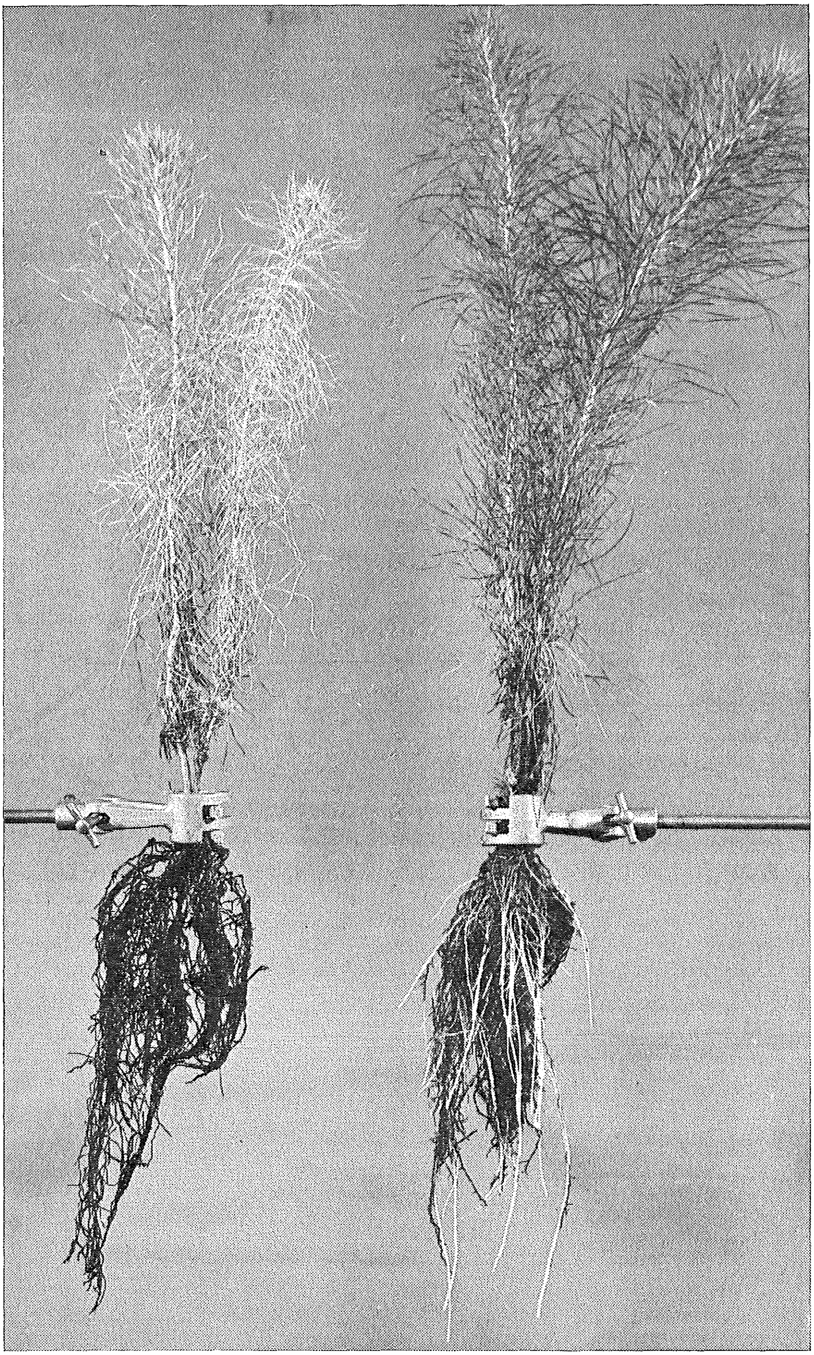

Fig. 4.—*Pinus radiata* plants on left inoculated with *P. cinnamomi* in liquid culture. Note complete root death and wilting of foliage. Uninoculated plants on right.

The foliage of all uninoculated plants was healthy at completion of the experiment. The tops of *P. taeda* and *P. elliottii* plants showed no effect of inoculation. One of the 10 inoculated *P. echinata* plants died back from the tip. Three of the *P. caribaea* were chlorotic and one died. Eight of the *P. radiata* were severely wilted or dead.

A close examination of the inoculated root systems revealed pronounced differences between species. With *P. taeda* (Figure 3) and *P. elliottii* the white root tips and smaller fibrous roots were largely decayed but the more woody roots were alive and producing new root tips. The *P. taeda* roots were in slightly better condition than the *P. elliottii* at the completion of the experiment. The relatively low average rating of 3·2 for *P. elliottii* after nine days was caused by slow development of root rot in two of the pots.

The larger woody roots of *P. echinata* were also still alive but the rate of new root-tip production was much slower than with the two species mentioned.

The butts of the main roots of *P. caribaea* were alive and shooting above water level but the remainder of the root system was completely decayed. *P. radiata* was in the worst condition of all, with the roots mainly rotten and in most cases even the butts of the trees affected, resulting in wilting or death of the tops (Figure 4).

Newhook (1961) has drawn attention to what he termed "non-lethal pathological infection of roots" when *Pinus* roots are inoculated with *Phytophthora.* This condition was obvious in the inoculated *P. elliottii* and *P. taeda* roots in the above experiment. On examination most of the larger roots were showing pronounced symptoms of infection in the cortical tissue but such roots were still producing new root tips. These were retarded and did not reach any great length and hence the "nil" count for root tips over 1 in. Nevertheless, there is an indication that these two species have the capacity for root regeneration in the presence of severe *P. cinnamomi* infection and perhaps could be expected to show more tolerance to infection in the field than species such as *P. radiata* and *P. caribaea.*

### (c) Experiment 3

A further experiment was conducted in 1962 to test the pathogenicity of *P. cinnamomi* to *P. patula. P. radiata* and *P. taeda* were included for comparison purposes. The procedure was the same as in Experiment 1. The plants were four months old at transplanting. For each species three pots each containing two plants were inoculated and three kept as controls. The ratings were carried out as before but counts of healthy root tips over 1 in. in length were made both before and after inoculation. Sporangia of *P. cinnamomi* developed on excised, washed root tips of inoculated plants of the three species. Results are given in Table 3.

TABLE 3

RESULTS OF ROOT-ROT INOCULATIONS IN LIQUID CULTURE—EXPERIMENT 3

| Species | Treatment | Average No. of Healthy Root Tips | | Average Root-rot Rating | |
|---|---|---|---|---|---|
| | | Before Inoculation | 6 Days After Inoculation | After 6 Days | After 4 Weeks |
| *P. radiata* .. | Inoculated | 121 | 6 | 4·7 | 5 |
| | Control | 97 | 115 | 0 | 0 |
| *P. taeda* .. | Inoculated | 59 | 6 | 4·3 | 2 |
| | Control | 67 | 70 | 0 | 0 |
| *P. patula* .. | Inoculated | 40 | 4 | 4·7 | 3·3 |
| | Control | 58 | 86 | 0 | 1* |

* Not caused by *Phytophthora* infection; no pathogen isolated; occurring in one pot only

The foliage of all control plants and the inoculated *P. taeda* and *P. patula* were quite healthy in appearance at completion of the experiment. Four of the six *P. radiata* plants were wilted.

The root condition of the inoculated *P. radiata* and *P. taeda* plants was somewhat similar to that found in the previous experiment. Rotting of the root tips occurred initially in both species but there was a pronounced recovery phase in the case of *P. taeda*. Complete root death occurred with *P. radiata*. *P. patula* appeared to be intermediate between the other two in root-rot susceptibility under the conditions of the experiment.

### (d) Experiment 4

Using similar plants and inoculation technique as in Experiment 3, the three *Pinus* species were tested for susceptibility to infection with *P. boehmeriae*.

Six days after inoculation, *P. radiata* root tips showed symptoms of infection but a further three weeks later the root system had entered a recovery phase and there was little visible infection. Only occasional root tips of *P. taeda* were infected, most of the root system remaining intact. Most *P. patula* root tips exhibited infection after six days and over three-quarters of the root system had rotted in a further three weeks. Sporangia typical of *P. boehmeriae* developed on excised infected root tips of the three host species.

Under the conditions of this small experiment *P. patula* could be considered more susceptible to infection than *P. radiata,* which in turn appeared more susceptible than *P. taeda.*

## V. DISCUSSION

The investigations detailed above and experience overseas indicate that *P. cinnamomi* is a root pathogen of considerable present and potential importance in *Pinus* plantations in southern Queensland. The implications of nursery infection have been outlined and it is axiomatic that every effort should be made to produce healthy trees for field planting. Most of the areas currently being planted by the Queensland Department of Forestry consist of cleared virgin forest. Whether the pathogen occurs naturally in such areas is at present unknown, although a limited number of soil isolations have failed to detect its presence.

Forest nursery practice in Queensland has been very intensive, with at the most one year and often no interval between pine plantings in the same soil. This has allowed rapid build-up of the disease in infested soils. The shifting of nursery sites from infested localities to more isolated virgin areas is advisable. Also, there is need for the cultivation of larger areas which would permit a wide interval between successive pine plantings. Local practice involves the growing of *Pinus* plants in the nursery for nearly 12 months. Soil sterilization of areas in existing infested nurseries prior to planting may not be the answer, as re-infection could occur during such a period. The use of irrigation water which has drained from pine or pineapple plantations could also present problems. It may be necessary to chemically treat such water if other supplies are not available.

Losses of infected transplants in the field have already occurred in several localities and this has been the most spectacular exhibition of the disease outside the nurseries. Deaths of older trees have been relatively rare and have been associated with severe environmental conditions. Whether chronic root rot may be causing decreased growth is so far unknown. Certainly this has been illustrated with similar diseases of tree crops such as citrus.

Newhook (1959) pointed out that *P. radiata* is most susceptible in New Zealand during the very early years in the field and then when the mature growth phase is reached after 20-30 years. Most *Pinus* plantations in Queensland are younger than 30 years, so the effects of the disease on older trees here are as yet unknown.

Phytophthora root rots are usually more severe in poorly drained than in well-drained soils. Soil surveys are carried out by the Department of Forestry prior to plantation establishment and plantings are now largely restricted to the deeper and better drained soil types. However, many of these, particularly in the coastal higher rainfall belt, could still be expected to support *Phytophthora* infection in wet seasons. If cycles of wet years occur, or if *Phytophthora* population reaches high levels, damage could occur even in the best soils. Such happenings are not uncommon in pineapple plantations in these coastal areas.

There are indications from the greenhouse inoculation tests that *P. taeda* and *P. elliottii* are more resistant to *P. cinnamomi* infection than the other *Pinus* species tested. *P. elliottii* is the main species at present planted in the southern coastal areas. *P. radiata* is mainly restricted to inland drier areas, although heavy rains do sometimes occur in these regions. *P. caribaea* is chiefly planted in coastal areas further north, where, as experience with pineapples indicates, higher temperatures may not favour *P. cinnamomi* infection so much. *P. patula* and *P. taeda* are no longer planted in any quantity, but existing plantations are located in inland and coastal areas respectively.

With the exception of the one record of *P. boehmeriae, P. cinnamomi* is the only *Phytophthora* species which has been associated with pine root rot in southern Queensland. Of the other *Phytophthora* species recorded by Newhook (1959) from conifer plantations in New Zealand, *P. cryptogea* is known to infect lucerne in Queensland, but *P. citricola, P. syringae* and *P. cactorum* have not been recorded here.

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