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The Distribution of *Phytophthora cinnamomi* in Forests of Eastern Gippsland, Victoria

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Abstract

Soil surveys of the distribution of *Phytopthora cinnamomi* in eastern Victorian eucalypt forests showed it to be widely distributed in flat, poorly drained coastal forests extending from Wilson's Promontory to the New South Wales border and from 15 to 25 km from the coast.

P. cinnamomi was scattered in the foothill forests up to an altitude of about 800 m. It was sometimes found in high altitude forests, at sites where recent logging, clearing and road construction had occurred. Its frequency of occurrence was related to the intensity of forestry activity, to internal soil drainage and to the occurrence of warm soil temperatures.

Data are provided on a number of factors affecting soil populations of *P. cinnamomi*, and its possible origin is discussed.

Introduction

In December 1968, *Phytophthora cinnamomi* Rands was isolated for the first time in a Victorian *Eucalyptus sieberi* L. Johnson forest, in eastern Gippsland. The fungus was associated with a severe die-back disease closely resembling 'jarrah die-back' (Podger *et al.* 1965; Podger 1968) in Western Australia. Initial greenhouse pathogenicity tests with juvenile- and intermediate-aged seedlings, field tests (Marks *et al.* 1972), and reports from Western Australia (Batini, personal communication) showed that *P. cinnamomi* produced severe root rot in *E. sieberi*, a forest dominant and one of the most useful commercial hardwoods in eastern Gippsland. Eastern Gippsland forests supply about 42% of the sawn timber used in Victoria, and the discovery of a serious root rot pathogen in this valuable forest ecosystem has caused considerable concern.

Surveys of the distribution of organisms associated with die-back disease are costly and time-consuming and, prior to undertaking any search, it is essential to ascertain the pathogenicity of the organisms being surveyed. In the eastern States of Australia there is some uncertainty whether *P. cinnamomi* is the causal agent of die-back. Stahl and Jehne (1971) and Pratt and Heather (1973*a*) stated that many potentially pathogenic *Pythium* and *Phytophthora* spp. are found in forest soils and, although no pathogenicity tests were reported, Pratt and Heather surmised that die-back disease is caused either wholly or partly by *Pythium* and other *Phytophthora* spp. acting with or without *P. cinnamomi*. Pathogenicity tests carried out in Victoria under optimal conditions for disease development showed that none of the oomycetous soil organisms tested were as pathogenic to the stringybark type of eucalypts as *P. cinnamomi* (Marks and Kassaby 1972). The *Pythium* species isolated from forest soils of eastern Gippsland, unlike *P. cinnamomi*, were non-pathogenic. *P. drechsleri*, which is frequently reported in forest soils, was unable to kill or injure intermediate-aged *E. sieberi* seedlings.

The distribution and survival of *P. cinnamomi* depend on its behaviour in soil, its ability to parasitize tree roots and the environmental factors which influence the process of root infection. Surveys recording only the presence or absence of the fungus provide meagre information on its behaviour and are unsatisfactory for the purpose of formulating disease control measures in forests. A number of ancillary experiments was carried out in an attempt to uncover the behaviour of *P. cinnamomi* and a resumé of the more important findings is given here.

Materials and Methods

Initially, half-ripe Packham Triumph pears (P. T. Jenkins, personal communication) and blue lupins (Chee and Newhook 1965) were used to bait the fungus from soil. Supply problems arose with the pears and during the middle part of the survey (1969–70) blue lupins were used. Since it is desirable from a phytopathological viewpoint to use host tissue as bait, a cotyledon baiting method was developed (Marks and Kassaby 1974) which proved convenient and sensitive and was adopted for all work after 1971.

P. cinnamomi was identified by culture methods when pear and lupin baits were used and directly from cotyledons where possible. In cases of uncertainty, the cotyledons were subcultured on antibiotic agar for identification.

Soil samples were collected from around the root masses of trees and shrubs because preliminary results (Marks *et al.* 1972) had shown that fungal inoculum was most abundant in this zone. Usually a 'set' of four or five 150–200-g samples was collected within an area of about 100 m^2. The soils were mixed, stored in plastic bags and transported to Melbourne in an insulated container. (It was found that unsatisfactory results were obtained with chilled soils (<5°C) or soils subjected to prolonged exposure to temperatures above 35°C.)

The location of each set of samples was marked on a map of the area, a grid notation from the relevant 1 : 250,000 scale map providing the identification number of the set. The baiting tests were carried out on three subsamples from each set sample.

Usually, during the initial stages of the survey in the coastal and foothill forests, one sample set was taken from an area that looked diseased and another from adjacent healthy-looking vegetation clear of the diseased vegetation. Results soon showed that infection boundaries often could not be detected (cf. Weste and Taylor 1971), especially in soils where heavy thunderstorms could cause temporary waterlogging and where there was much movement of surface water. In subsequent surveys no attempts were made to detect infection zones.

In the initial stages of the survey in the high altitude forests, samples were collected from both obviously diseased areas and adjacent undisturbed, healthy-looking vegetation. The results soon showed that *P. cinnamomi* was found only in the diseased areas and did not occur among the healthy flora. Consequently, all subsequent sampling in these regions was confined to sites with diseased vegetation and locations where moisture accumulated.

Vavilov's hypothesis* (see Leppik 1970) was examined under controlled environmental conditions by raising seedlings from mixtures of seeds of die-back-tolerant and sensitive eucalypt trees found in Gippsland. The tests were carried out in 0·5-l. pots containing soil naturally infected with *P. cinnamomi*. Approximately equal numbers of seeds were densely sown in each pot, and during the test the soils were subjected to alternate periods of saturation (2 days) and desiccation (5 days). All tests were carried out in a ventilated phytotron at 24/20°C day/night temperatures.

The soils used were either steamed for 45 min or steamed and re-infected with 10 g of naturally infected soil. An unsteamed, naturally infected soil was used as the control.

The population density index (PDI) of *P. cinnamomi* (Marks *et al.* 1972) was measured at quarterly intervals from 1 March 1972, under four planted species of fertilized and unfertilized eucalypts and fertilized and unfertilized *Pinus radiata* D. Don growing in forest areas rated as of high, moderate and low die-back hazard (Marks *et al.* 1973). Samples were collected from five fixed points on each plot, and the soil temperature and moisture content were measured with thermistors and gypsum blocks placed at 7 and 25 cm from the soil surface. Samples were not collected on 1 June 1972 from the high and low hazard sites.

Results

Distribution of P. cinnamomi

During the survey 720 sites were sampled in Victoria mainly in eastern and southern Gippsland with a few scattered throughout the rest of the State. Of these, 380 were infected with *P. cinnamomi*, 273 (mostly from high altitude forests) were uninfected, and 67 were infected only with unidentified *Pythium* spp. This last result must be considered inconclusive since the fast-growing *Pythium* spp., sometimes associated with *P. cinnamomi*, may have masked the latter. About half the samples yielding *P. cinnamomi* were also infected with *Pythium* spp.

Most positive isolations of *P. cinnamomi* were made from poorly drained coastal forests (Fig. 1) between Wilson's Promontory and the New South Wales border. It occurred less frequently in the better-drained foothill forests, where uninfected sites were encountered frequently. In the high altitude, wet sclerophyll forests *P. cinnamomi* was found only in association with machine-made clearings, drains and log storage areas. Distribution even in the flat, poorly drained soils was not uniform and occasional pockets of uninfected soil were encountered.

It is very difficult to make any generalization as to what type of soil or habitat favours *P. cinnamomi*, as Pratt and Heather (1973*b*) have noted. For example, the fungus was isolated from dry ridge soils supporting highly disease-tolerant *E. maculata* Hook., from mid-slope positions and from moist gullies.

Use was also made of the severe die-back epidemic of autumn 1971 that occurred in Victoria after above-average summer rainfall over most of the State (Marks *et al.* 1972). A number of forest trees and the understorey flora showed severe damage, associated consistently with root infection by *P. cinnamomi*. Areas with die-back

* Vavilov stated that in situations where host and parasite have been associated over a long period in the centres of their origin, every new and more virulent race of parasite must have necessarily eliminated most of the susceptible species in the local population.

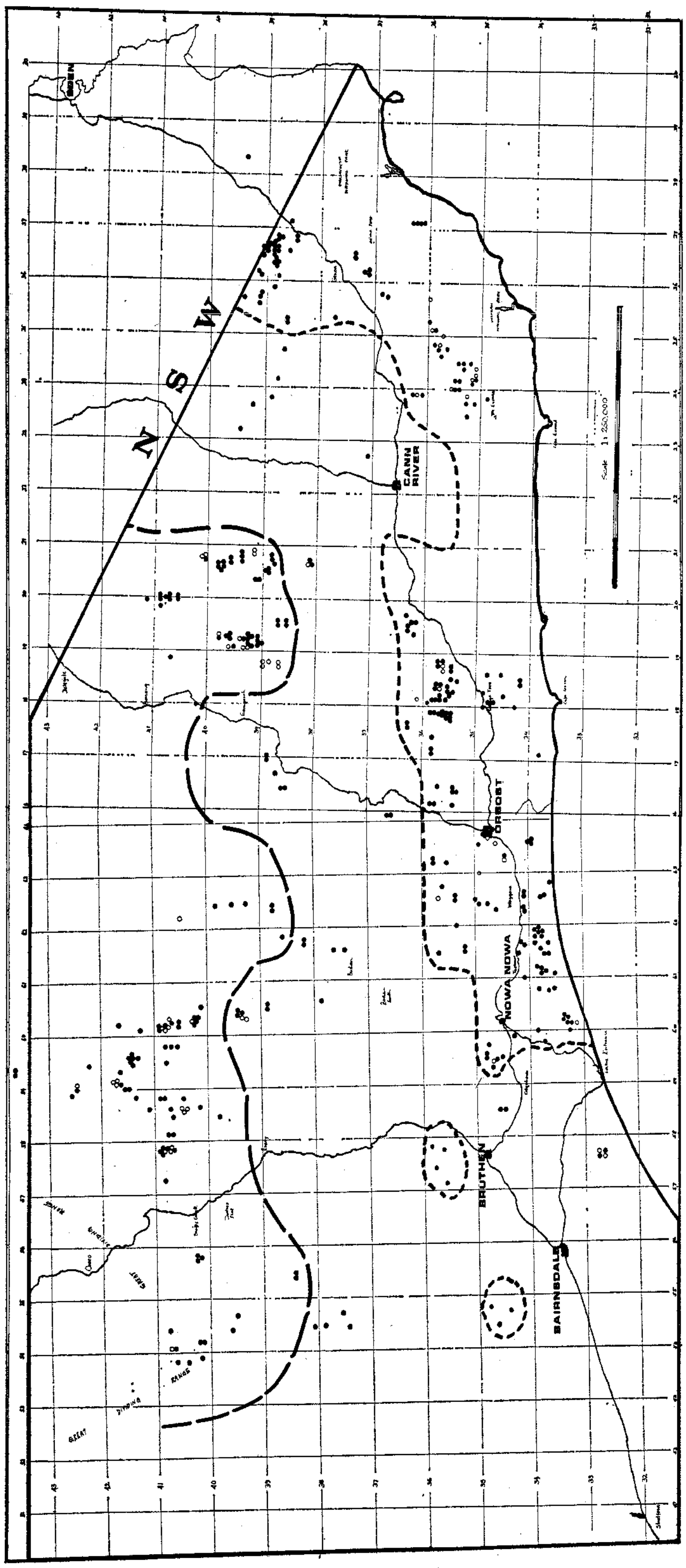

Fig. 1. Sites where soil sampling was carried out: *c.* 417 are marked but in many cases those close together could not be marked separately. Areas north of the heavy broken line were uninfected except by some roadsides and in some recent clearings. Areas south of and within the dashed line were heavily infected.

were reported throughout Victoria by Forests Commission staff, but most occurrences were in the south-east. Bruthen, Cann River, Geelong, Nowa Nowa, Orbost and Yarram had serious outbreaks, i.e. many areas with numerous die-back patches ranging from 0·5 to 100 ha; Heyfield and Maffra had moderate outbreaks, i.e. infection widely scattered with few die-back patches; Daylesford, the eastern Otways, Gellibrand, Stawell and Trentham had small pockets of infection with very few die-back patches. The northern areas did not experience any wide-spread damage in native forests and none was recorded in any of the mountain forests, except in recently cleared and regenerated areas, in tractor landings and alongside roads.

Die-back showed a mosaic distribution in the flat coastal forests, usually being worst in areas where water had accumulated temporarily. In the more hilly forests it was usually associated with water flowing off roads or with flat cleared pockets of land where temporary soil saturation could occur.

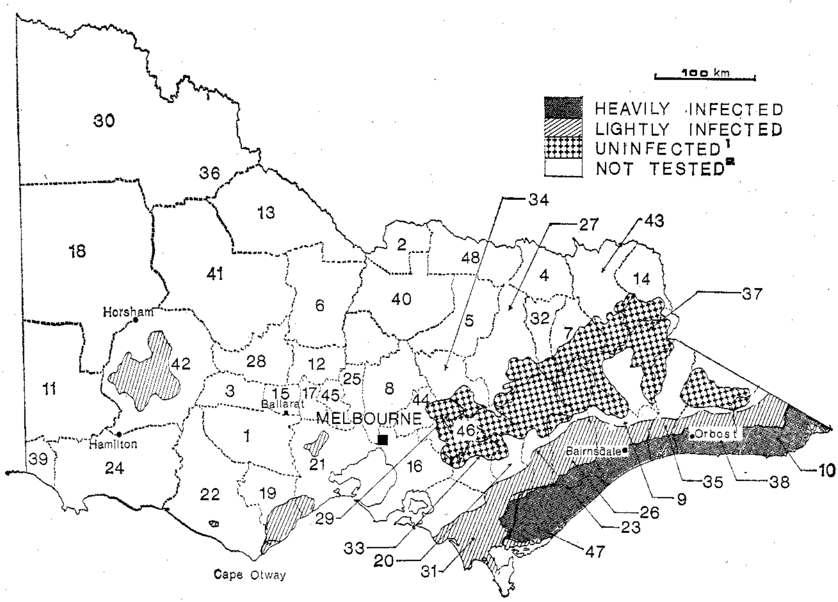

Fig. 2. Distribution of *P. cinnamomi* in forest areas determined by disease incidence in 1970–71 and soil surveys. (1) Uninfected area consists mainly of mountain forest types; the few infection points resulted from logging, road-making and earth moving. (2) 'Untested' region was not sampled systematically.

The general information of both surveys is summarized in Fig. 2. It was apparent immediately that although large areas of the State were infected by *P. cinnamomi* we could not confirm the view of Pratt *et al.* (1973) that it is a widespread and common component of the forest soil microflora in this part of south-eastern Australia. The frequency of isolations depended on soil temperatures, water accumulation and the intensity of man's activity in the forests. A wide range of trees and shrubs was affected (see Weste and Taylor 1971) but many factors affected the distribution and extent of damage, and some inexplicable situations were found. These are discussed below.

Long-distance Transmission

Batini and coworkers (personal communication) in Western Australia demonstrated very clearly that *P. cinnamomi* could be transported for long distances in soil adhering to tracked vehicles and spread widely in a forest by infected gravel used in road surfacing. Weste *et al.* (1973) showed that the fungus moved several hundreds of metres in water flowing from diseased areas and that the rate of spread depended in part on a soil's physical structure. In the Brisbane Ranges, under conditions in which spread is rapid, the zone of infection in the soil kept a considerable distance ahead of the above-ground symptoms of damage, and in areas where either the vegetation was disease-tolerant or drought stresses were minimal no above-ground damage was visible for a long time.

It is quite possible that similar situations could exist in eastern Gippsland. It was very difficult to find areas in the coastal forests which had not been logged previously. However, one small pocket of unlogged and completely undisturbed forest that showed moderate die-back was discovered in the Yerung forest block about 35 km east-south-east of Orbost. Soil samples taken from the area yielded *P. cinnamomi.* There were no man-made tracks, and no machinery had operated in that part of the forest, but during heavy rainstorms water could flow into the forest from infected areas 3–4 km away. Thus either very rapid movement of the fungus can occur in flat, poorly drained soils or the fungus is indigenous to this region. However, the extensive damage observed in the surrounding forest suggested a relatively recent introduction.

Infected nursery stock is an insidious yet easily controllled cause of long-distance transmission in non-forested areas. Rhododendrons and azaleas are sold in large numbers in Victoria and frequently come from infected nurseries. Recently, *P. cinnamomi* was discovered in some major forest tree nurseries, and there is evidence that infected planting stock may infect newly planted forest areas.

Factors causing Variation in Distribution

The simple yes-or-no type of answer provided by baiting soils indicates neither whether nor why fluctuations occur in soil populations of *P. cinnamomi.* To reach any understanding of the epidemiology of disease in forests, knowledge of the factors affecting such fluctuations is essential. The information given below was obtained as part of a continuing study, and only aspects related directly to the survey are reported.

Temperature and soil drainage. The quality of the internal soil drainage and the magnitude of the population density index (PDI) in the sites rated as 'high', 'moderate' and 'low' hazard were consistent with the disease rating for a water-borne root pathogen. The PDI attained highest values on the most poorly drained site and lowest on the best-drained (Fig. 3). On the last-named site many pockets of uninfected soil remained uninfected over a 2-year observation period even though adjacent areas were infected.

There was a distinct seasonal fluctuation in PDI (Fig. 3), most marked on the poorly drained site and sometimes scarcely recordable on the well-drained site. The increase in PDI corresponded to the spring and summer rise in soil temperature, and as temperatures declined so did the PDI.

Species tolerance. The PDI of *P. cinnamomi* in soils occupied by unfertilized root rot-tolerant species was sometimes greater than in those occupied by unfertilized sensitive species (Fig. 4). The greater mass of surviving roots in plots occupied by tolerant species would encourage survival of *P. cinnamomi* (cf. effect of fertilizers).

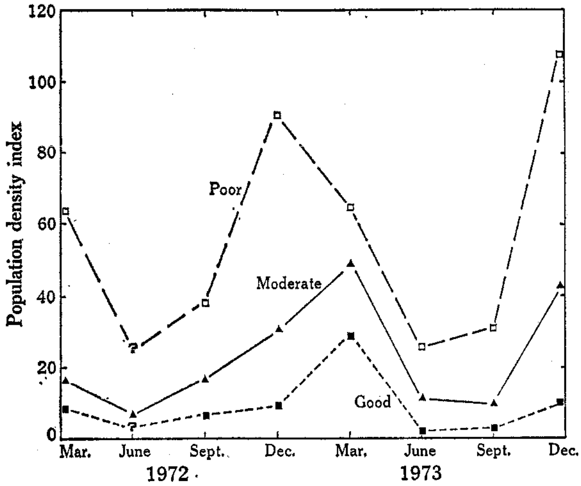

Fig. 3. Seasonal variation in PDI on a poor growth site with high die-back hazard, a moderate growth site with moderate die-back and a good growth site with little die-back (Marks *et al.* 1972). (Note. Mar.–Sept. 1972 was a very dry period with a prolonged drought.)

Fertilizers. A persistent reduction in PDI was observed in plots fertilized with Pivot 900 (10·7% NH_4, 6·0% urea, 7·0% PO_4, 9% K). This was probably the result of lower soil moisture levels caused by increased transpiration by the greatly enlarged crowns of the fertilized trees (Fig. 5). The effect was most noticeable on the low and moderate hazard sites among root rot-tolerant species. It is unlikely that fertilizer had any direct effect on the PDI because the difference was noticeable only after the canopy size had increased considerably.

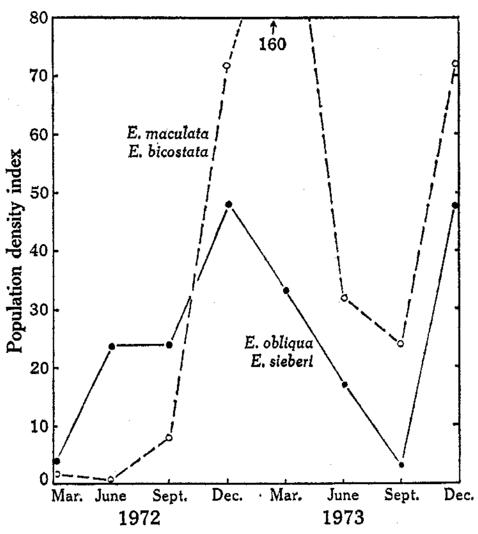

Fig. 4. Comparison of the seasonal variation in PDI of *P. cinnamomi* in plots of *E. maculata* and *E. bicostata* (disease-tolerant) and *E. obliqua* and *E. sieberi* (disease-sensitive) planted in July 1971 at Nowa Nowa, a moderate die-back hazard site.

Fire. The direct effect of heat from burning litter and low scrub would occur only in the uppermost 2–3 cm of soil. Tests showed that a gentle fire in the litter layer had no immediate effect on the frequency with which *P. cinnamomi* was isolated from the uppermost 15 cm of soil. However, a transient reduction in frequency, which lasted about 6 months, began about 30 days after the fire.

Soil texture. P. cinnamomi could be isolated from soils of varied texture and particle size provided they did not consist predominantly of compacted clay. It appeared that in densely compacted clay soil neither roots nor zoospores could penetrate, even though the soil remained saturated with water for long periods and the layers above were infected with *P. cinnamomi.*

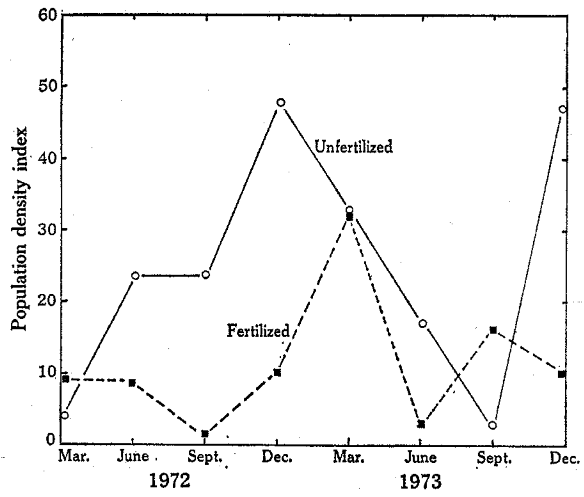

Fig. 5. Comparison of the seasonal variation in the PDI of *P. cinnamomi* on fertilized and unfertilized *E. sieberi* and *E. obliqua* (disease-sensitive) planted at Nowa Nowa (see Fig. 4) in July 1971.

Soil depth. P. cinnamomi was recovered at depths of 75 cm in freely drained sedimentary sands, but the PDI declined with depth, the fungus being barely detectable at 75 cm.

In some situations, especially during hot dry periods, the fungus could not be detected in the upper 10 cm of soil but was recovered below this level. This observation may explain the apparently spontaneous reappearance of *P. cinnamomi* in soil believed to be uninfected.

Variation in microhabitats. Intensive sampling in heavily infected forests on a 1·6-m^2 grid over an area of *c.* 100 m^2 failed to isolate *P. cinnamomi* from all points. The fungus appears to have a mosaic distribution pattern even in a heavily infected area, and the frequency of isolation is determined by unknown factors in the microsites.

Origin of P. cinnamomi

The competitive ability of gully-type, root rot-tolerant eucalypts (*E. bosistoana* F. Muell. and *E. viminalis* Labill.) was compared with that of typical colonists of dry slopes (*E. sieberi* and *E. globoidea* Blakely) which also grow extensively in poorly drained coastal soils. The same numbers of seed were mixed and sown in the same pot containing naturally infected soil. Germination was rapid and a dense crop of seedlings was produced initially; however, soon many began to wilt and die. The results (Tables 1, 2) after 30 days' growth showed that under conditions of strong competition the numbers of root rot-sensitive seedlings were greatly reduced both on naturally infected and on disinfected and reinoculated soils. The root rot-tolerant species rapidly became dominant. In striking contrast, the root rot-sensitive species

Table 1. Effect of intense competition under crowded conditions on survival of juvenile seedlings of *E. bosistoana* (tolerant) and *E. globoidea* (susceptible) growing in naturally infected soil from a die-back-affected forest

Soil treatment	Pot number	Total no. of seedlings	*E. bosistoana* No. of plants	*E. bosistoana* Mean height (mm)	*E. globoidea* No. of plants	*E. globoidea* Mean height (mm)
Steamed[A]	1	36	8	30	28	60
	2	22	3	53	19	55
	3	24	4	60	20	55
Steamed and inoculated	1	16	14	40	2	14
	2	15	12	34	3	14
	3	17	10	35	7	34
Untreated	1	18	15	15	3	15
	2	19	16	14	3	15
	3	27	20	16	7	15

[A] Soils free of *P. cinnamomi* and *Pythium* spp.

grew well and competed vigorously in soils *free* of pathogenic organisms, even though the soils were periodically saturated and conditions were not optimal for the species. On the basis of these results it appears that seedlings of *E. sieberi* and *E. globoidea* can eliminate competitors.

Table 2. Effect of natural soil infection on the survival of mixtures of juvenile seedlings of *E. viminalis*, *E. sieberi* and *E. globoidea*

Seedlings were raised for 30 days in soils subjected to intermittent flooding

Soil treatment	Pot number	Total no. of seedlings	Numbers of seedlings *E. viminalis*	*E. globoidea*	*E. sieberi*
Steamed[A]	1	57	39	6	12
	2	21	18	1	2
	3	51	21	6	24
	4	41	18	11	12
Naturally infected[B]	1	15	14	1	0
	2	6	4	2	0
	3	13	9	4	0
	4	15	8	3	4
Steamed reinoculated[B]	1	12	12	0	0
	2	19	17	0	2
	3	3	3	0	0
	4	4	4	0	0

[A] No *Phytophthora* or *Pythium* spp. detectable.

[B] Heavily infected with *Phytophthora* and *Pythium* at end of experiment.

Discussion

The pattern of movement of *P. cinnamomi* in the Brisbane Ranges of Victoria (Weste and Taylor 1971) is similar to that observed in Western Australian jarrah forests, and to the spread of *P. lateralis* in the *Chamaecyparis lawsoniana* (Murr.) Parl. forests of Oregon (Roth *et al.* 1957). In all cases movement was rapid, especially along well-travelled roads and watercourses, and severe damage was done to the forests.

In eastern Gippsland, studies of the distribution of *P. cinnamomi* began at least 30 years after the initial discovery of small patches of die-back (Elsey, personal communication). In the intervening period heavy logging, mining and road construction, together with the many fires that ravaged the region, have made it virtually impossible to find tracts of forest of any appreciable size that have not been disturbed by heavy machinery.

Forests in eastern Victoria supply about 42% of the total output of sawn hardwood logs from State forests, and have been logged since the early 1900s. Initially, railway sleepers and fencing timbers were cut by methods that caused little disruption of the vegetation. In post-World War II years, however, the forests have supplied most of Victoria's structural timber and operations in the late 1940s were conducted with heavy mechanical equipment. Shortly after this reports of die-back appeared, especially after heavy summer rainfall.

Most logging was confined originally to the forests around Yarram, Bairnsdale, Bruthen, Nowa Nowa, Orbost and, much later, Cann River. The easily accessible, flat coastal forests were cut first and as wood supplies dwindled operations moved eastwards and into the foothill forests. About 1965, logging commenced in the high altitude wet sclerophyll forests of *E. regnans* F. Muell., *E. delegatensis* R. T. Bak. and *E. nitens* Maiden.

Most coastal and intermediate foothill forests are now cut selectively and in the past the operation was often repeated. Very little partial or clear felling is carried out at present although this procedure is increasingly enforced. Heavy equipment is transported freely in all logging areas, usually on low loaders, and until 1973 no land hygiene was practised.

From present evidence, it appears that a large portion of the high altitude eucalypt forests (above 800 m) is not infected while most of the coastal forests are heavily contaminated and pockets of infected forests are found in the foothills. All infection detected above *c.* 800 m was associated with the movement of heavy machinery into the areas. No infection has yet been detected in unlogged gullies and lower slopes in this region or in areas that do not receive drainage from infected regions. Consequently, it is presumed that *P. cinnamomi* is not a native of the higher altitude ash-type forests, hence forest hygiene is justified, despite statements to the contrary (Pratt *et al.* 1972).

Because an indirect method was used to detect the presence of *P. cinnamomi* in soil, there is always a possibility that it is present in amounts too small to be detected, even though the baiting method is extremely sensitive. Experiments with re-baiting after raising eucalypt seedlings in the sample did not increase the frequency of detection, so it may be assumed that if the fungus was not found it did not exist in the sample (cf. Palzer 1969). Furthermore, the samples were collected from the root zone microhabitat that offered the best chance of survival for *P. cinnamomi.*

Thus it is possible to conclude that a negative result indicated absence of the fungus.

A survey of the distribution of *P. cinnamomi* based on diseased vegetation only is inaccurate. The fungus moves rapidly and can colonize sites without causing visible disease in the above-ground parts of the trees. Consequently, in deep soils in the often mild climate of eastern Victoria, sharply demarcated disease boundaries (cf. Weste and Taylor 1971) are not often encountered. This situation is similar to that of the forests of southern Western Australia. On harsher sites where drought stresses are severe, the flora may have extended to their limits of colonization and plant communities are much less stable; disease then appears rapidly among root rot-sensitive species and the boundaries are clearly visible. Similar situations are seen in the northern jarrah forests of Western Australia and in the Brisbane Ranges in central Victoria.

The field evidence gathered in Victoria does not completely support the hypothesis that disturbances (Anon. 1971) are needed to alter an *existing* host–pathogen balance. Many examples of severe and extensive damage were seen on undisturbed sites and on sites where disturbance had occurred 10–20 years previously.

The factors which affect the activity and inoculum levels of *P. cinnamomi* in soil are of interest. The seasonal effect on the PDI of *P. cinnamomi* was marked (Fig. 3), and this suggests that the survival of the fungus in soil is strongly affected by temperature. Curiously enough, the PDI was lowest at a time when atmospheric moisture stresses were minimal and soil moisture levels consistently high. It appears that soil temperature has a predominant effect. It is reasonable to assume, however, that for PDI to increase, both soil temperature and moisture must be favourable. Past climatic records show that heavy summer rains fall periodically in south-eastern Australia close to the Pacific seaboard (Marks *et al.* 1972) and under such conditions the PDI could increase rapidly, with resulting epidemics of die-back on poorly drained sites. It is noteworthy that there are no records of die-back epidemics prior to 1940 even though the heaviest sustained summer rains occurred in those years.

Knowledge of the origin of *P. cinnamomi* will determine whether disease-sensitive forests should be protected by sanitation measures. In the United States Roth *et al.* (1957) were concerned with the possibility that aggressive root parasites might invade highly susceptible forests of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) and Port Orford cedar. Land hygiene measures were considered but not implemented, because in Douglas fir forests *P. cinnamomi* was found not to be a hazard (Roth and Kuhlman 1963) while Port Orford cedar forests were of very low economic value. In Australia, Pratt *et al.* (1972) deprecated the use of land hygiene measures in eastern Victoria because they considered that the fungus was indigenous. This viewpoint has been criticized severely (Routley and Routley 1974; Weste 1974) and, until the matter can be resolved satisfactorily, it is safest to protect the high-value, non-tolerant forest species with limited hygiene measures that do not seriously affect movement within the forest areas.

In Victoria the evidence, although not conclusive, suggests that the fungus is of recent origin. Marks *et al.* (1972, 1973), Weste and Taylor (1971), Weste *et al.* (1973), Weste (1974) and Weste and Marks (1974) based their conclusions on the origin of *P. cinnamomi* partly on Vavilov's rule (see Leppik 1970). Most of the forest dominants in central and eastern Victoria are sensitive to root rot caused by *P. cinnamomi*. *E. sieberi*, one of the most widespread dominants, has colonized about 300,000 ha of poorly drained, frequently saturated coastal soils. The heavy mortality which occurs today in the coastal forests after heavy summer rains is a post-World War II phenomenon associated with man's activities; there are no previous records of this type of damage. The damage is certainly spectacular: it resembles the after-effects of high intensity forest fires where the tree crowns are scorched. Furthermore, greenhouse and field experiments show quite clearly that *E. sieberi* can grow and compete with other eucalypt species under intermittently flooded conditions, provided the soils are free of *P. cinnamomi.* For these reasons it is assumed that the fungus was introduced relatively recently. Unfortunately, however, it is too widespread in the coastal and low foothill forests to permit the implementation of useful hygiene measures.

On the basis of the results presented and appraisal of published information, it can be concluded that *P. cinnamomi* is a serious root pathogen of many eucalypt species in eastern Victoria, and has the characteristics of an introduced (*sensu* Newhook and Podger 1972) soil organism. Serious consideration should be given to reducing its spread by contaminated nursery stock, infected gravel and mechanical equipment.

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