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CONTROL OF Phytophthora cinnamomi RANDS IN AUSTRALIAN FORESTS

by

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ABSTRACT

Control of damage by P. cinnamomi in Australian forests involves minimizing economic loss by prompt salvage of diseased or threatened trees, restriction of spread of inoculum into healthy, susceptible forest and, where practicable, rehabilitation of diseased, cut over areas with resistant species. No procedure offers to permanently safeguard susceptible biological systems but wise use of a number of partial control measures and minimal disturbance should maintain at least some threatened ecosystems for a relatively long term. The efficiency of control is dependent on prompt application of quarantine and thorough follow up. Factors complicating effective control are the virulence of the pathogen, an inability of management to fully evaluate natural forest systems, a lack of knowledge of the disease potential and the inability to economically assess the benefits of quarantine and hygiene practices. In Western Australia, it has proved necessary to redirect forest management into a control programme.

INTRODUCTION

Eucalypt dieback associated with the presence of Phytophthora cinnamomi is recognised as a serious problem in the jarrah (Eucalyptus marginata) forests of Western Australia (Podger, Doepel and Zentmeyer, 1965), in open sclerophyll forest of the Brisbane Ranges in Victoria (Weste and Taylor, 1971) in mixed species eucalypt forest with E. sieberi as a dominant in both eastern Victoria (Marks, Kassaby and Fagg 1972) and north eastern Tasmania (Felton, 1972) and possibly in regrowth wet sclerophyll eucalypts (E. obliqua, E. regnans) in south eastern Tasmania (Felton, 1972). In these instances it is believed that P. cinnamomi is a recent introduction and spread of the fungus is associated with loss of increment and mortality of commercial eucalypts.

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The fungus is also known to be present in coastal eucalypt forests of New South Wales and Queensland where it has been suggested that it is indigenous and poses a potential for damage with continued forestry development (Pratt, Heather and Shepherd, 1972).

Estimates in 1971 indicate that about 300,000 acres of eucalypt forest in Australia are affected by P. cinnamomi dieback. The longest record and greatest damage for the disease situation is in Western Australia where isolated dieback patches have been observed since the 1920's. The disease presence in a forest generally consists of discrete, scattered points of infection or localized infections particularly concentrated along watercourses and roads. Even severely diseased forest blocks in Western Australia contain 70 percent or more of the land area in healthy forest. Spread is achieved by slow expansion in perimeters of existing diseased patches or, more rapidly, from the establishment of new disease points from disjunct dispersal of inoculum into healthy forest zones.

Initial concern for dieback has focused onto losses in wood production through decreased increment, tree mortality and the failure of regeneration of major commercial eucalypts. Phytophthora cinnamomi however, affects most elements of the forest structure in susceptible communities (Podger, 1972; Weste and Taylor, 1971) and losses in wood production are not necessarily more relevant than the influence of the disease on watershed, aesthetic, recreation and biological values.

Management of diseased forest will vary with State objectives and types of forest involved. This dissertation, concerning the practicability of controlling damage by P. cinnamomi in Australian forests, draws heavily on Western Australian experience (Anon. 1971). Where attempts are made to evaluate application to other forest areas, these comments are the author's and only the basis of discussion.

THE NECESSITY FOR CONTROL

To decide whether control measures are required for P. cinnamomi in Australia involves answering two questions: (a) What expenditure is warranted (b) Within economic limits, are practical effective control procedures available? Accurate evaluation of present and potential financial loss in a disease situation which is unprecendented in eucalypt management is an improbable if not impossible objective. Most forest amenity values (aesthetic, recreation, biology) have no price within our current economic system and research, at this stage of development, can only vaguely guess at the actual course of the disease in Australia. Eastern states have however, the precedent of *P. cinnamomi* disease development in Western Australia and the example set by the *P. lateralis* invasion of *Chamaecyparis lawsoniana* stands in Oregon (Roth, 1963). In Western Australia the actual and the potential for damage caused by *P. cinnamomi* in the jarrah forest is adequately appreciated to resolve that control is desirable and that measures could carry quite a high expenditure; if effective.

The basis of this paper hence centres on the practicability of control measures, bearing in mind that an economical evaluation of the disease situation is not available.

FIGURE 1

POSSIBILITIES FOR CONTROL

Disease control in native forests is hampered by the fact that we are working with extensive, perennial crops with low economic value per acre and with relatively few facilities for intensive working on an average acre basis.

Phytophthora cinnamomi is one of the most virulent pathogens known and there is no known procedure for eradicating the fungus from the forest. Control, in eucalypt forests, must be viewed as a multi-stage operation of minimizing losses and reorganizing the community. No single practice will provide a completely satisfactory solution.

(1) Chemical and Microbiological Measures.

Chemical fungicides have limited effects on *P. cinnamomi* and effective procedures involving steam sterilization and soil improvement (Baker, 1957), soil fumigation and fungicidal drenching can only be considered for use in high value or strategic areas such as nurseries, gardens or vehicle washing points. Microbiological antagonism has been recorded for the fungus (Marx and Davey, 1969; Gilpatrick, 1969; Pratt, 1971) and the presence of mycorrhiza in exotic pine plantations is considered to be a major factor conferring field resistance to the species involved. Manipulation of forest soils to favour antagonism as an effective means of control for eucalypts does not, at present, offer practical promise.

(2) Species Resistance.

Replacement of susceptible dominant eucalypts with resistant species is the only completely effective control measure offering (Weste and Taylor, 1971). Such replacement must be viewed within the perspective of site suitability for alternative species and the economics of the replacement crop. Replacement would normally follow logging in which timber from diseased or threatened stands is salvaged.

Within the littleleaf situation of south east U.S.A. (Campbell and Copeland, 1954) sound economical control is provided on fertile sites by replacing the diseased Pinus echinata with P. taeda. On severely eroded sites where soil fertility and structure are impoverished, neither species is economical with or without fertilizer additions.

FIGURE 2

Many areas in the jarrah forest are too infertile to grow economical replacement tree crops. These are carrying the naturally resistant E. calophylla and, as open park land, will have amenity value if not wood production value. The wetter and more fertile sites are being planted with high value resistant eucalypts such as E. microcorys, E. saligna, E. resinfera and E. globulus. Pinus pinaster and Pinus radiata are used as replacement species where soils and climate are appropriate.

Within infected mixed species forests in Gippsland and north east Tasmania it is possible that suitable naturally resistant components of the stand will return the site to productivity. Following large scale logging such as wood chip operations, damaged or threatened stands might be direct seeded to advantage with at least a proportion of species of known resistance.

Replacement of susceptible eucalypts with resistant species on areas devastated by P. cinnamomi is perhaps a rehabilitation rather than a control measure. In Western Australia however, resistant species are being planted on healthy sites surrounding diseased patches to restrict rate of natural spread of the fungus from the infection point. Sites known to be highly susceptible to infection and strategically located within areas of healthy forest are also cleared and planted to resistant species. Here the objective is to reduce the chance of infection from random or uncontrolled soil movement. These latter uses combine both sanitation and quarantine functions with an upgrading of forest productivity and must be viewed as vital control measures.

Limited initial promise in research and the time factor involved, preclude the prospect of breeding resistant forms of the susceptible high value eucalypts.

TABLE 1

3. Cultural Manipulation

(a) Canopy maintenance. The activity of *P. cinnamomi* has been associated with critical ranges of soil moisture and soil temperature (Kuhlman, 1964; Roth and Kuhlman, 1966). Ecologic studies within the jarrah forest delineate a range of site conditions which suggest varying degrees of resistance to the fungus (Figs. 1 and 2). Sites can be grouped into areas of decreasing disease hazard and quarantine and hygiene measures weighted accordingly. Encouragement of dense canopy cover and a thick litter layer (Fig.3), will decrease fungal activity and the potential for damage on the most productive sites.

(b) Host Reduction. It is believed that the high susceptibility of the jarrah forest to infection by *P. cinnamomi* is partly associated with the abundance of highly susceptible host material (Roth, 1963) present in the understorey and ground flora. In particular the *Proteaceae* appear to offer a critical infection and survival vehicle on the productive, well drained sites. Reduction of the density of such species by prescribed burning, chemical weedicides or physical removal, warrants consideration. Burning techniques and canopy closure could be applicable to large areas of forest, cheaply. Weedicide removal is more pertinent to strategic and high value sites.

(c) Fertilizer Addition. The application of nitrogenous fertilizers to littleleaf stands in the U.S.A. has improved health of trees but is regarded as an uneconomical control measure (Campbell and Copeland, 1954). Studies in Western Australia with fertilizers increased the resistance of seedlings of *P. pinaster* to *P. cinnamomi* but gave negative results with seedlings of *E. marginata*. Current work suggests however, that fertilizer additions to high value, non infected jarrah stands will economically accelerate growth and decrease the risk of value loss from future, chance infection. Here the objective is to achieve maximum value increment in minimum time as an insurance against future infection. This has long been the attitude in pine plantation management with respect to potential fire damage.

TABLE 2

4. Physical Measures.

(a) Quarantine Extensive field sampling and direct inoculation trials (Roth and Kuhlman, 1963; Podger, 1972) will determine whether dieback spread or mortality loss is directly associated with movement of inoculum of *P. cinnamomi*. This is the case in the jarrah forest and appears to apply to dieback in the Brisbane Ranges (Weste and Taylor, 1971), in Gippsland (Marks, Kassaby and Fagg, 1972) and in parts of Tasmania (Felton, 1972). In Western Australia it has also been demonstrated by direct inoculation that the karri (E. diversicolor) forest and pine plantations are resistant to the fungus. Other studies in the jarrah forest reveal that well drained prime jarrah sites have moisture and temperature conditions favourable to resistance (Figs. 1 and 2), that survival of inoculum is much greater in wet gully sites than on well drained true jarrah sites and is poorer in summer than in winter (Table 1). The probability of infection is also related to the inoculum level and soil type (Table 2).

FIGURE 3

Coupled with the relatively isolated locations of P. cinnamomi infection and the knowledge that major spread of P. cinnamomi in jarrah dieback results from transmission of inoculum by logging machinery, road grading, road gravel, exploration drilling and other human agencies, these facts provide confidence in quarantine as an effective means of control. Quarantine to minimize movement of machinery in healthy forest and the assurance that equipment is clean before it is operated (Roth and Kuhlman, 1963) provides the most positive procedure for control offering (Table 3).

In Western Australia a system of quarantine and sanitation has been implemented to

(i) Define and demark healthy and diseased zones in the forest.

(ii) Obtain log quotas by concentrating logging operations on clean cutting diseased areas.

(iii) Restrict logging in healthy areas to silvicultural requirements, removed in summer.

(iv) Prohibit the use of gravel from infected sites, restrict road construction and restrict road grading.

(v) Ensure that all vehicles moving out of infected areas are washed clean of soil.

(vi) Limit the number of access routes into healthy forest and upgrade major road surfaces to control surface wash and minimize mud collection by vehicles.

(vii) Ensure that all users of the forest contact local forestry officers prior to undertaking new operations within the forest.

Current knowledge of the disease situation in Victoria and Tasmania suggests that quarantine and hygiene would be effective in these situations also. Even in N.S.W. where it is suspected that the disease is endemic in the gullies, cleanliness of equipment, restricted access, concentrated forest operations and upgrading of road surfaces to prevent wash, should be applicable.

TABLE 3

(b) Ditching, draining, fallowing and windrowing. Ditches to restrict lateral spread through wash and root transmission, ploughing and fallowing to reduce fungal populations in cut over diseased areas and the burning of windrows on active infection edges all should have a minor, positive control effect. Such techniques can only be considered for strategic areas, or where convenient, following clear falling. Highly susceptible sites adjacent to healthy, high value jarrah forest are also drained prior to planting with resistant species.

(c) Salvage logging. Control of economic loss in the disease situation is affected by prompt salvage of infected or threatened trees and milling before drying can result in checking and degrade. Efficient salvage requires detailed knowledge of the situation in the field and the commissioning of special rubber tyred units and marketing arrangements. Salvage operations in the jarrah forest are arranged so that clean equipment works in from healthy forest into the diseased patch. A buffer formed by clear cutting healthy forest in a swath around the perimeter of the infection reduces the need for further, early salvage and possibly, by forming a relatively host free buffer, reduces the rate of spread of the diseased patch.

MANAGEMENT STRATEGY

Management of eucalypt forest infected with P.cinnamomi cannot expect to eradicate the fungus or to completely halt rate of spread and intensification of the fungus. Control avenues summarized promise only to slow the rate of spread into susceptible forest, minimize log value loss through effective salvage and replace susceptible species with resistant species where it is economical to do so. The question which managers must ask of this control concept is how effective will quarantine and hygiene practices be and what expenditure do they warrant.

It is unfortunate that there is no known way to evaluate the effectiveness of imposed quarantine and hygiene prescriptions. Comparison of spread and damage on a quarantined area, with that on a non quarantined area, is considered to be impracticable under field conditions. In the absence of an effective checking system, the imposition of quarantine and hygiene measures must rest on management's faith in research information, knowledge of forest values and community requirements and professional intuition - if the latter is permitted. We can, from Western Australian data, model a simple system which can aid decision making.

Fifty years after the detection of jarrah dieback and, presumably of the presence of P. cinnamomi in Western Australia, less than 5 percent of the forest is infected and rate of spread of the diseased area, over the past decade, has been around 4 percent per annum. Most spread, in this instance is through transmission by mechanical equipment. If we assume that the whole forest would be infected, under previous conditions for spread, in say 50 years it is realistic to suggest that rigid quarantine and hygiene measures restricting both mechanical transmission of the pathogen and intensification of existing infections, could extend the critical infection time to 200 years. In practice early attention to quarantine and hygiene could be perhaps even more beneficial as it is expected that rate of disease progression is based on an exponental rather than a linear model. This conceptual basis probably only is acceptable when infection of a forest area is in early stages of development and localized. Practicability of control measures against P. cinnamomi to restrict spread is dependent on prompt application and faithful follow up (Roth and Kuhlman, 1963).

The economics of control can be partially overcome by salvage operations and initial concentration on protecting the uninfected, high value areas which represent maximum productive and biological value to the future, Quarantine measures, road improvement, hygiene planting of resistant species and intensive silviculture have present economic validity in the productive, high quality eucalypt stands. In Western Australia it is anticipated that in the order of 1 million acres of high quality jarrah forest warrants attention as intensive management control units. Within these there are reasonable expectations that jarrah will be retained as an important element of the community for at least a further planned rotation. This is not so for approximately 1 million acres of high quality forest which is infected to the extent that management to continue a current rotation, or a future rotation of jarrah to fulfilment, is probably not realistic. From this area the timber is mined, providing for a replacement crop of resistant eucalypts where this is economically feasible.

The term "timber mining" is used here to indicate that sustained yield management of the existing resource no longer applies in a P. cinnamomi disease situation. Under control, the economics of salvage, conducive with minimizing log extraction from the intensive management unit, should determine the allowable cut.

Finally, it is necessary to re-iterate that many of the control measures summarized have limited control value. There is however, no single satisfactory procedure for control of P. cinnamomi in Australian forests. Effective control will be achieved only by evaluating and developing all possible methods offering and incorporating each into the control system as appropriate. Even a small measure of control, projected over several million acres, can be significant.

Control, as reported, will minimize damage due to P. cinnamomi and buy time to allow the establishment of appropriate rehabilitation measures. Full advantage depends on prompt action.

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Table 1

Percentage recovery of *P. cinnamomi*, by lupin baiting, from small clods of diseased soil placed in different ecological situations for varying lengths of time.

Time		Ecological Situation				
Placed	Baited	Road Surface	Ridge Top (Soil Surface)	Valley Bottom (Soil Surface)	Ridge Top (Buried at 3in)	Valley Bottom (Buried at 3in)
November	June	0	0	0	25	25
January	June	0	0	25	50	75
May	June	100	50	75	75	75

Table 2

Mortality of *Banksia grandis* seedlings associated with variation in potting soil, watering levels and inoculum levels of *P. cinnamomi*. Twenty four plants were used in each treatment combination and mortalities under low moisture conditions were mainly due to drought effects.

Inoculation Procedure	Potting Medium				Total
	Silt	Sand	Gravel	Loam	
Low Moisture Treatments					
Control	0	0	0	1	1
5ml Sand Mycelium	0	2	3	1	6
100 ml Sand Mycelium	0	6	0	0	6
2 Infected Lupin Roots	0	1	0	1	2
10 Infected Lupin Roots	0	0	6	2	8
Total	0	9	9	5	23
High Moisture Treatments					
Control	0	0	5	4	9
5ml Sand Mycelium	0	0	1	0	1
100ml Sand Mycelium	0	0	0	6	6
2 Infected Lupin Roots	21	9	8	0	38
10 Infected Lupin Roots	21	22	24	24	91
Total	42	31	38	34	145

Table 3

Effectiveness of washing machines with a high pressure hose in reducing spread of soil by prime mover units.

Unit	Unwashed	Washed
	Soil wt. lost between 0 and 7.5chns (lbs)	Soil wt. lost between 0 and 7chns (lbs)
Caterpillar D7	172	6
Caterpillar D4	357	9
Michigan Loader	45	0.1
Bedford 7-ton truck	260	0.1
Chevrolet 15cwt truck	19	0.0
Land Rover	3	0.0

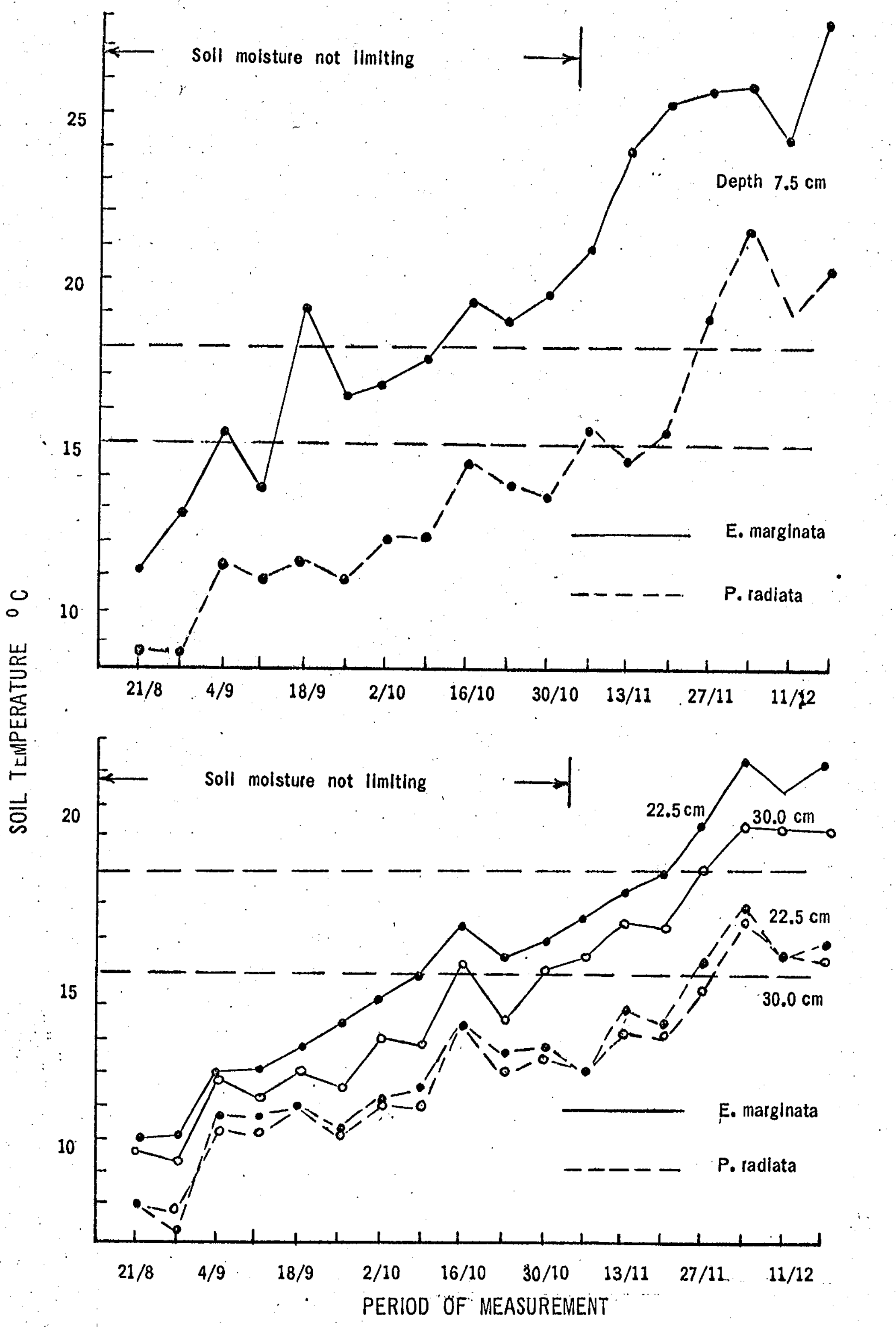

FIGURE 3. The effect of dense canopy cover (Pinus radiata) and open cut over forest (E. marginata) on soil temperature in the jarrah forest. Limits for soil moisture and temperature threshholds for P. cinnamomi activity (15° C and 18° C) are indicated.

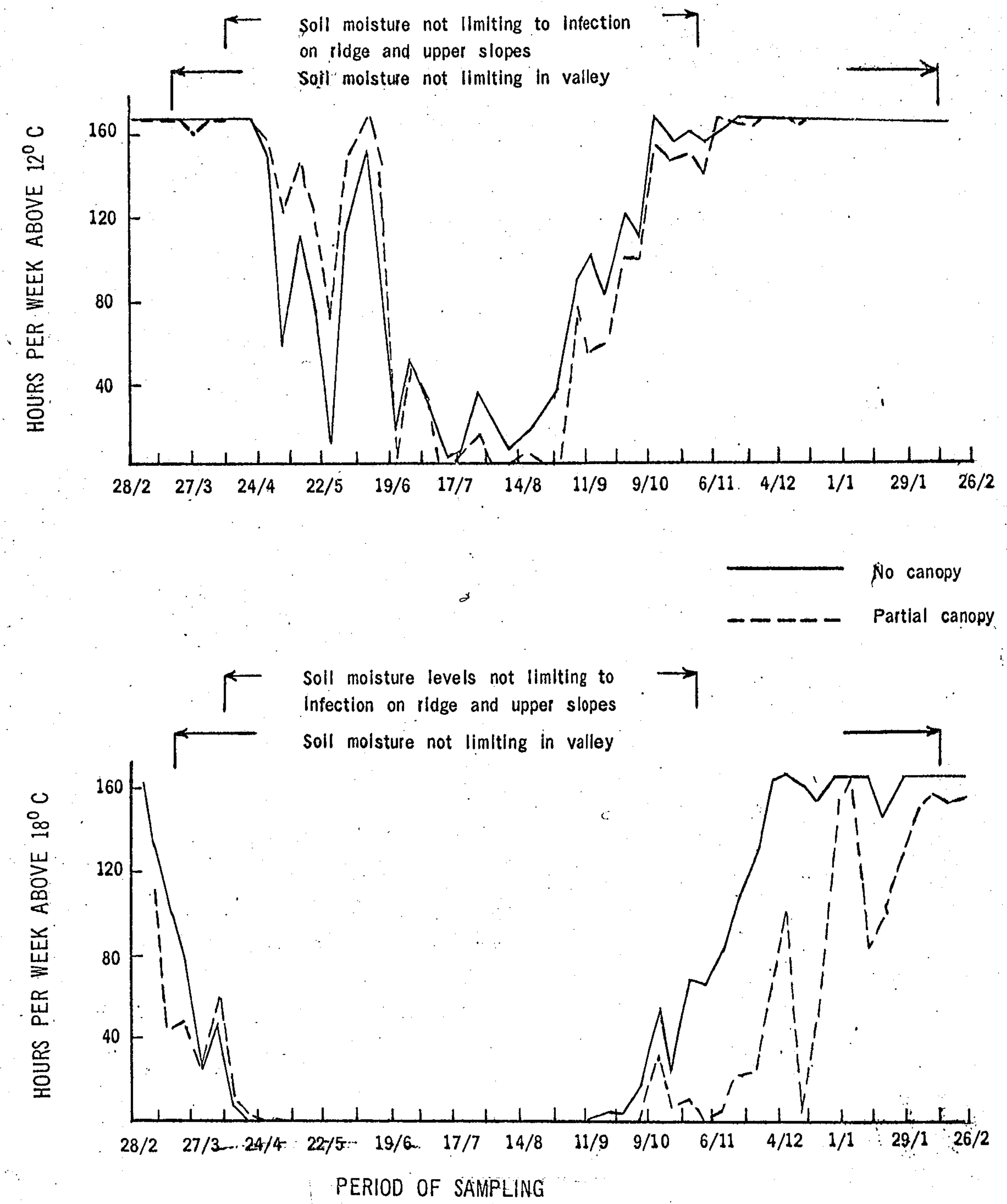

FIGURE 2. Interaction between soil and temperature conditions which favour development of P. cinnamomi and site and canopy conditions in the jarrah forest. Surface temperatures do not vary significantly with topographic position on similar aspects.

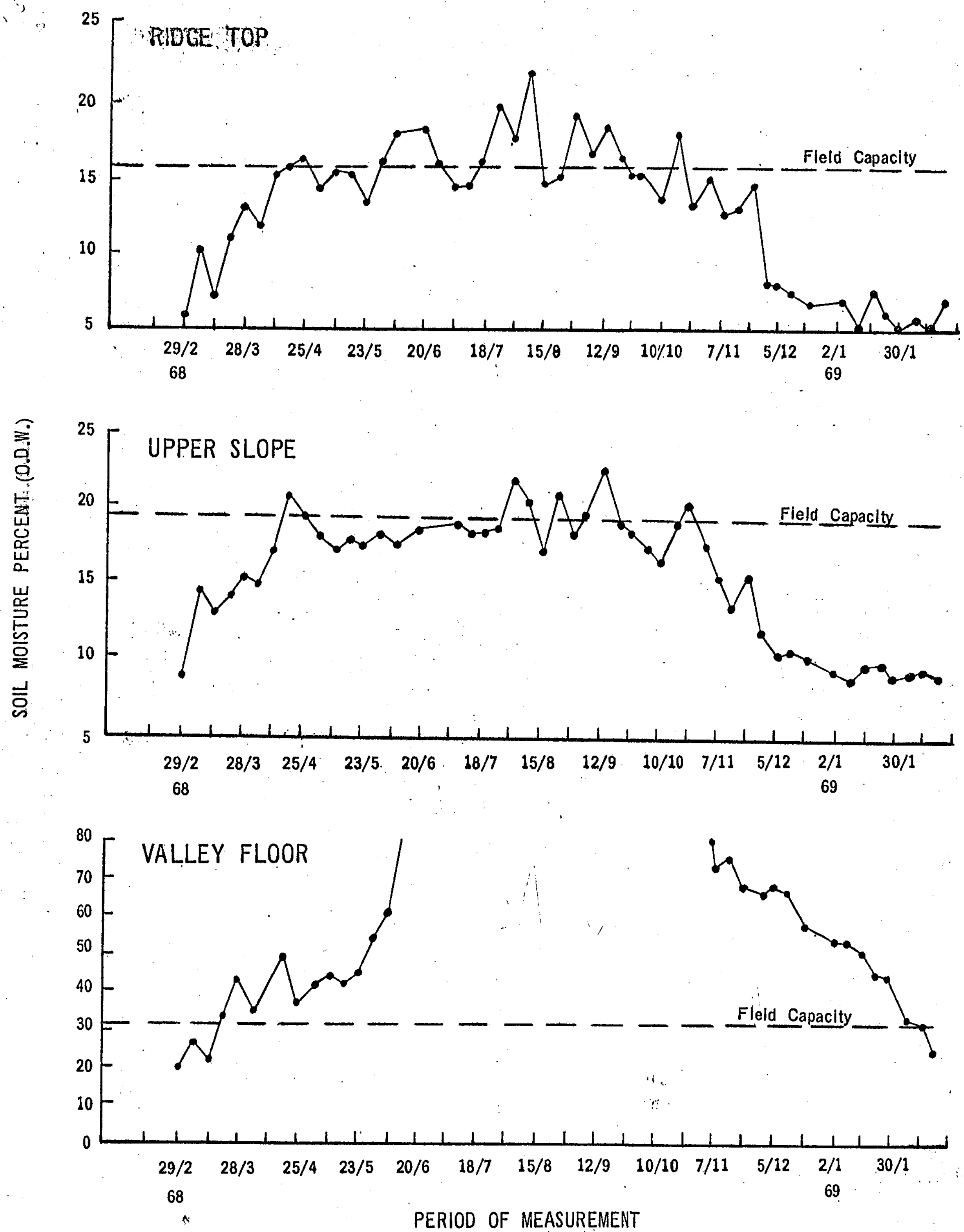

FIGURE 1. Variation in soil and moisture with topographic situation in the northern jarrah forest. Development of P. cinnamomi is favoured by soils at or above field capacity during the spring to autumn period.