

KEYNOTE ADDRESS

INDIGENOUS FOREST HEALTH IN THE SOUTH PACIFIC — A PLANT PATHOLOGIST'S VIEW

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ABSTRACT

Worldwide we could be said to be in the middle of a "dieback decade". The term is relatively new but evidence is accumulating which indicates that periodic recurrence of many dieback epidemics, with intervals of decades or centuries, is not uncommon. Canopy dieback, starting with gradual defoliation and twig death, occurs over a wide spectrum of forest types in indigenous forests of the Pacific region. Stress in some form or other is commonly recognised as a contributory factor, e.g., drought, excess water, insect infestation, competition, and combinations of these. Gross divergence from "normal extremes" is often the critical feature and the decline set in motion may be irreversible, even if deterioration takes several years.

Primary foliage pathogens appear to be relatively innocuous in our zone. Primary insect infestation of leaves and twigs does cause concern although manifestation may be irregular. Analogous, but more devastating, is browsing by possums. Amongst other effects, possums have changed the dominance pattern of rata-kamahi in several regions of New Zealand.

A group of less spectacular but nevertheless widespread lethal influences includes damping-off and root-rot fungi, browsing mammals, predators of seed, and feral pigs, as transporters of soil-borne pathogens. Between them, these factors can change the whole course of regeneration.

Various physical aspects of the environment have direct and indirect impacts on forest health: gross disturbance by storm, roadworks, logging; changes in hydrology of a site (e.g., podocarp dieback); passive introduction of a pathogen (e.g., *Phytophthora*); increase in inoculum food base (e.g., *Armillaria*); soil compaction; increased insolation causing a rise in soil temperature with consequent influence on disease severity (*Phytophthora*).

Keywords: damping-off; root rots; stem rots; dieback; forest decline; foliage diseases; forest health.

INTRODUCTION

Johann Forster, visiting Dusky Sound on Cook's second voyage to New Zealand, wrote in his diary of 28 March 1773 that he was tired from "walking between felled rotten trees . . . where I frequently fell in with my legs up to my knees and above." In the light of modern knowledge we can conjecture that debris resulting from an earlier mass dieback of beech (*Nothofagus* spp.) caused Forster's discomfort. Despite our recent interest in forest decline and dieback, the phenomenon itself is almost certainly not new. For example, Wylie & Johnston (1984) pointed out that as early as the fourth century B.C. Greeks and Romans were writing about the adverse effects of such things as excessive tree clearing, overgrazing, and fire, with consequent effects on erosion, siltation, salinity, and flooding — the recipe for "rural dieback", as Australians know it today, in residual trees of former native forest now exploited for grazing.

Such historical allusions are not inappropriate in a context where forest diebacks dominate the research and management scenes in many parts of the world, and where there is a tendency for diebacks to be regarded as "new" diseases.

In Australia, White (1986), for example, summarised other notable diebacks which occurred at least a century ago. He quoted Norton's (1886) report on an epidemic of eucalypt dieback between 1852 and 1857 that affected 3000–4000 acres in some parts of New South Wales and MacPherson's (1886) report on extensive dieback in parts of Victoria. A century later the same species were involved, on the same sites and in the same localities. In New Zealand, analyses of tree ring data and pollen (Jane & Green 1983; McGlone 1983) indicate that similar widespread losses of trees have occurred periodically in past centuries and have exerted a major influence, again on stands of the same species as are affected by mass dieback today. Exceptions to the recurrent aspect would include, notably, those where *Phytophthora cinnamomi* Rands has undoubtedly been introduced to parts of Western Australia and Victoria in historic times (Newhook 1978; Podger 1972; Weste 1974), causing serious loss of canopy and understorey species. Inevitably, then, any review of the forest health situation in our region will be dominated by discussion of dieback syndromes. Not only is this because of the spectacular nature of the losses and the similarity in extent, but also because, in a large number of these events, the syndromes can be seen as complexes in which various biotic factors that might otherwise claim individual attention are now recognised as contributing in a much broader context.

Before embarking on the main part of this address, a few comments are warranted that might explain any bias in my interpretation of the title.

- (1) The South Pacific region is a wide and diverse area where most research to date has been centred on Australia, New Zealand, and, to some extent, Papua-New Guinea.
- (2) Since my invitation was to provide "A Plant Pathologist's View", it is possible that some degree of bias might be discernible, although I hope that I have done justice to my belief that the discipline of plant pathology, which naturally embraces forest pathology, draws widely on the expertise of scientists and practitioners in many other disciplines.
- (3) A temptation to draw analogies or lessons from the genus *Phytophthora*, which I know most intimately, may call for a small degree of tolerance!

Using "disease" in a broad sense, I will focus first on the impact of what are, or seem to be, primary causes before contributing to the main debate on forest dieback syndromes.

PRIMARY ATTACK ON FOLIAGE

Numerous rusts have been recorded on forest trees in our region, but relatively little is known of their impact. Likewise, leaf spot, twig dieback, and stem canker fungi, and at least one bacterial foliage pathogen, *Pseudomonas dysoxylis* Hutchinson (Hutchinson 1949), are present but not subjected to serious ongoing investigation. The situation might change dramatically, however, should an aggressive pathogen such as the rust fungus *Puccinia psidii* Wint., which is endemic on members of the Myrtaceae in central portions of America, be accidentally introduced to our region, where

myrtaceous species are common and physiognomically important in canopy and understorey, e.g., *Eucalyptus*, *Metrosideros*, *Leptospermum*.

Analogous in impact to foliage pathogens, are the insects that chew or burrow into leaves or twigs, and the herbivores such as possums (*Trichosurus vulpecula* Kerr). Possums, originally introduced from Australia, probably account for more loss, both in terms of numbers of trees and area affected, than any other cause of tree death and decline in New Zealand. Through heavy browsing, they have already changed the dominance pattern of southern rata (*Metrosideros umbellata* Cav.), they are contributing at an alarming rate to disappearance of the physiognomically important pohutukawa (*M. excelsa* Sol. ex Gaertn.) from the northern New Zealand coastline, and, with wallabies (*Petrogale penicillata penicillata* Griffith), they have virtually eliminated several species such as *Urostemon* (*Senecio*) *kirkii* Hook f. ex Kirk from Rangitoto Island, a volcanic cone in Auckland Harbour 200 (± 50) years old.

Introduced browsing animals such as goats, deer, and rabbits, along with seed-feeders such as rats and mice, have become rife and represent a non-indigenous threat to what would have been a natural indigenous forest succession after the death, for one reason or another, of overstorey trees. Together, the foregoing pests are capable of changing the normal course of regeneration and because they have been introduced, by man, too recently for selective pressure for resistance to be effective, we can no longer assume that regeneration will automatically restore damaged forest communities to their original state.

SOIL-BORNE DISEASES

Seedling Diseases

There is another class of ground-level determinants of succession, or lack of it, that I think ecologists grossly overlook: damping-off fungi such as *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Phoma*, acting surreptitiously but effectively as pre-emergence or post-emergence pathogens, can repeatedly deny establishment of regenerating seedlings. There must be many examples, but one will suffice: regenerating seedlings are often conspicuously absent from kauri (*Agathis australis* Salisb.) forest in northern New Zealand where frequent heavy seed-fall is common and where (R.L. Bielecki pers. comm.) crucial factors such as light appear not to be limiting. In such areas *Phytophthora cinnamomi* can be isolated readily from soil (Newhook 1970). In this context we must not forget the importance of inoculum dispersal by animals such as feral pigs (Brown 1976).

Root and Stem Rots

Root rots caused by *Phellinus* spp. and related fungi are common in tropical plants of our region and there is no denying their primary role in many sites, including temperate areas in Australia and New Zealand. Entry of such fungi into trunks of many indigenous species can be enhanced by wounds at or near ground level, with internal spread causing heart rot. This address will not deal further with such "degrade" fungi.

While I can speak with little authority on forest health in other South Pacific countries, there are in Australia and New Zealand two common fungal genera that

include notorious soil-borne pathogens – *Armillaria* and *Phytophthora* (notably *P. cinnamomi*). Yet even with these organisms there are field situations that are far from understood. At one extreme, with *P. cinnamomi*, we have situations where, at least in the understorey, presence of disease symptoms closely coincides with presence of a pathogen, e.g., sudden death of *Xanthorrhoea* spp. in Brisbane Ranges, Victoria (Weste 1974; Weste *et al.* 1976) and *Banksia grandis* Willd. (Podger 1972) in jarrah (*Eucalyptus marginata* Donn. ex Smith) forest in Western Australia. At the other extreme, both *Phytophthora* spp. and *Armillaria* spp. can be found in some areas as natural constituents of genetically susceptible indigenous forests without exhibiting spectacular or even minor ill-effects until “the balance is tipped” by, say, climatic extremes or gross physical disturbance to a community. Further discussion of these organisms is best left to the section on dieback diseases.

FOREST DECLINE AND DIEBACKS

In general, the terms “declines” and “diebacks” can be regarded as synonyms, with death of branches or whole trees the most serious outcome of a syndrome which begins as defoliation, twig death, and reduced annual increment. The terms are used widely throughout the world and most workers are agreed on at least one thing, that complex interactions are involved, with controversy attaching only to the question of which are the primary or most important factors. White (1986) has published a full and useful summary of the nature and knowledge of diebacks. Thus, I can rely heavily on that paper for the main details, reserving for myself what I hope will be some constructive contributions.

Firstly, however, let me list the main diebacks of our region.

Australia

- (a) Rural dieback/New England dieback in parts of New South Wales and Victoria, involving several species of *Eucalyptus* (Kile 1981; MacPherson 1886; Norton 1886; Richards 1984; Old *et al.* 1981; Parker *et al.* 1987; Wylie & Bevege 1980; White 1969, 1986).
- (b) Jarrah dieback in Western Australia involving not only jarrah (*E. marginata*) but over 90% of other species in many families; *Phytophthora cinnamomi* is recognised as a key factor in the disease but environmental factors are important, especially soil moisture (high for infection, low for pre-disposition and for subsequent moisture stress in hosts).
- (c) “Gully dieback” in Tasmania (Palzer 1981; West 1979) especially affecting *E. obliqua* L’Herit.
- (d) “Regrowth dieback” in Tasmania affecting *E. obliqua* and *E. regnans* F. Muell. (Palzer 1983; West 1979).
- (e) Diebacks of eucalypts in eastern Victoria affecting especially *E. sieberi* L. Johnson (Marks & Idczak 1973; Tregonning & Fagg 1984), generally accepted as being caused by *P. cinnamomi* after exceptionally heavy summer rainfall followed by a 3–4 month period of low rainfall.
- (f) Myrtle dieback in *Nothofagus* forests in Tasmania (Elliott *et al.* 1987).

Papua-New Guinea

Dieback of *Nothofagus* spp. (Arentz 1983, 1988).

New Zealand

- (a) Beech dieback affecting *Nothofagus* spp. in various high-altitude forests of both Islands (Hosking & Hutcheson 1986, 1988; Hosking & Kershaw 1985; Jane & Green 1983; Wardle & Allen 1983).
- (b) Rata/kamahi dieback affecting *Metrosideros umbellata* and *Weinmannia racemosa* Linn.f. in both Islands (Payton 1989; Stewart & Rose 1988; Stewart & Veblen 1983).

THEORIES FOR CAUSES OF DIEBACK DISEASES

Mueller-Dombois (1983) has analysed the cumulative results of investigation into the causes of dieback, recognising that the syndromes are complexes involving a number of interacting factors. He proposed that the primary and predisposing cause of dieback is synchronous senescence of a number of trees in one place — “cohort senescence”. A sudden trigger is needed to initiate decline, e.g., drought, flood, or wind, which places trees under stress. Recovery may occur if contributing (“tertiary”) factors such as insects or fungi do not play a subsequent major role. White (1986) accepted the Mueller-Dombois theory in general but preferred to regard excessively dry or excessively wet conditions (or both in succession) as the primary cause and placed these ahead of senescence in importance. In that regard, of course, factors such as dense stocking and unfavourable site quality can modify “ranking” of factors. In any case we must accept that, with such a diversity of forest communities involved, there will inevitably be many variations on a theme. Important contributions to the multiple factor approach are the models such as suggested by Landsberg & Wylie (1988) and Ogden (1988).

The remainder of my address will be devoted largely to improving understanding of the role of environmental factors.

ENVIRONMENTAL CONTRIBUTION

Physical Factors

Moisture

Moisture is perhaps the single most important environmental factor associated with forest ill-health. Abundance of free moisture, along with adequate temperature, is of obvious importance to phycomycetous pathogens. Timing of heavy rains can be critical, either within an annual cycle, e.g., jarrah forest (Podger 1972), or as rare, phenomenally heavy rainfall, e.g., North Auckland shelterbelts and *Agathis australis* regeneration (Newhook 1959).

Preceding or subsequent exceptionally dry periods may be important in relation to physiological or real drought stress on hosts affected by root rot organisms such as *Phytophthora* spp. and *Armillaria* spp. When we examine environmental factors, however, we should interpret official meteorological data, especially annual means, with caution. In the early stages of research into jarrah dieback, overseas workers found it hard to accept that a disease caused by *P. cinnamomi* could be serious in a

750-mm (30-inch) low-rainfall region. Now that research has given us insight into the interaction of events, much of the controversy has disappeared.

Several workers have mooted that periods of more severe drought than normal are an important or critical predisposing factor in many major decline syndromes such as *Nothofagus* spp. dieback in Papua-New Guinea (Arentz 1988), beech (*Nothofagus* spp.) dieback in New Zealand (e.g., Hosking & Hutcheson 1986, 1988; Hosking & Kershaw 1985; Jane & Green 1983), myrtle (*Nothofagus* spp.) wilt in Australia (Elliott *et al.* 1987), and rural dieback of eucalypts and other components of residual pockets of indigenous forest in many parts of Australia (Wylie & Bevege 1980; Parker *et al.* 1987).

Temperature

Temperature ranks high as an environmental factor, influencing pathogen activity, directly or indirectly. Sporangial production and zoospore aggression by *P. cinnamomi* cease below 12 °C, thus precluding winter infection, despite adequate moisture. Lower-than-optimal temperatures in undisturbed forest may help to explain the innocuous presence in New Zealand of the important tropical pathogen, *Corticium salmonicolor* Berk. & Br. Opening of a forest canopy can create a crucial rise in soil and ambient temperature. Warming from the "greenhouse effect" will undoubtedly lead to an increase of activity by some pathogens. The effect may not be as much a direct effect on the pathogen as a stress-induced effect on the host that increases its vulnerability to tertiary factors such as insects and fungi.

Site disturbance

We should note that road building can not only introduce a pathogen such as *P. cinnamomi* (jarrah forest in Western Australia, Queensland rain forest, and Brisbane Ranges in Victoria are notable examples), but it can also adversely change the hydrology of valuable forest communities. Logging, both clearfelling and selective, frequently leads to a sudden upsurge of *Armillaria* spp. activity, which increases inoculum food base and stress, with subsequent mortality of regenerating seedlings and saplings and/or dieback of residual crop. Logging can have other serious adverse effects, for example, through compaction of soil or admission of sunlight with consequent rise in soil temperature, perhaps to the advantage of a soil-borne pathogen. I believe that, because logging increases the risk of serious disease, forests declared worthy of conservation cannot safely be selectively logged. However reassuring they may sound, claims that selective logging or sustained yield management are environmentally safe are dangerously fallible. Kellas *et al.* (1987) have pointed out that where *Armillaria luteobubalina* Watling & Kile infects and kills trees in mixed eucalypt stands of Victoria and Western Australia, the growth response from partial cutting may be negated. In short, commercial thinning leads too often to long-term loss.

Biotic Factors

While it is unrealistic to expect all factors to apply more or less equally in all dieback syndromes, it is interesting to note the extent to which close analogies exist. It would be tempting to group disease reactions into those that are associated with recognised pathogens or pests and those that represent host reactions. However, interactions make even this separation artificial.

Armillaria spp.

While *Armillaria* spp. are often “good” pathogens, their roles in large-scale deaths are often linked with environmental factors. Characteristically *Armillaria* spp. attack by means of rhizomorphs radiating from food bases such as major roots or trunks of previously infected trees. Effectiveness is proportional directly to the mass of the food base and inversely to the distance from the source of energy required for invasion. Hence, the creation of new food bases through harvesting, or through physical modification of the root environment, can lead to an increased incidence of dieback. Physical factors, especially those associated with moisture stress (climate, competition, soil conditions, transpiration demand in relation to root health or vigour), may influence the susceptibility of new hosts. *Armillaria* spp. commonly behave as a seemingly innocuous soil inhabitant of forests in which they cause sporadic loss, while at the other extreme they can respond spectacularly to major environmental changes, natural or man-made. Once launched, a massive attack produces enough food base for the mortality level to be self-maintaining, perhaps until a community is denuded, at least of its dominants.

Phytophthora spp.

Phytophthora spp., especially *P. cinnamomi*, are sometimes aggressive primary pathogens, e.g., on *Banksia grandis* (Podger 1972) or *Xanthorrhoea* spp. (Weste 1973). However, in most diseases in which *Phytophthora* spp. are implicated, the fungus invades chiefly the white, unsuberised tips of feeder rootlets. Rootlet death may be followed by rootlet replacement (Fig. 1) and it is the balance between these opposing factors that will determine largely whether an infected host will die suddenly or after a period of decline, or whether it will recover or perhaps fail to show outward symptoms. The balance involves interactions with such environmental factors as soil moisture, temperature, nutrition, and age.

A striking illustration of host/pathogen behaviour is provided by *E. sieberi* on a tableland in East Gippsland, Victoria. Wholesale dieback associated with *P. cinnamomi* occurred in the late 1950s (Marks & Idczak 1973; Tregonning & Fagg 1984). The syndrome was comparable to that of a contemporaneous large-scale epidemic in pine shelterbelts and *Agathis australis* regeneration in northern New Zealand (Newhook 1959). When I was shown the East Gippsland block in 1970 there was considerable pole-sized regeneration of *E. sieberi*, outwardly healthy but plagued by sporadic sudden deaths. The healthy appearance of trees was misleading; root rot had limited their root systems to a small shallow plaque and trees could readily be pushed over by hand (Newhook 1978) (Fig. 2). The situation was a good illustration of the fact that trees can manage on a small fraction of their root systems in most seasons, until faced with an extremely stressful demand. Not surprisingly, the current situation in East Gippsland is such that the Victorian Department of Conservation, Forest and Lands has high hopes (Fagg 1987) for the regenerating *E. sieberi*. I must point out, however, that at some time in the near or distant future an exceptional summer rainfall may once again lead to a situation similar to that of 1956 and thus to devastation.

Herbivores and associated fungi

Like so many diebacks in other territories, defoliating insects, ambrosia beetles, and fungi such as *Ceratocystis* spp. are commonly found in association with dieback of

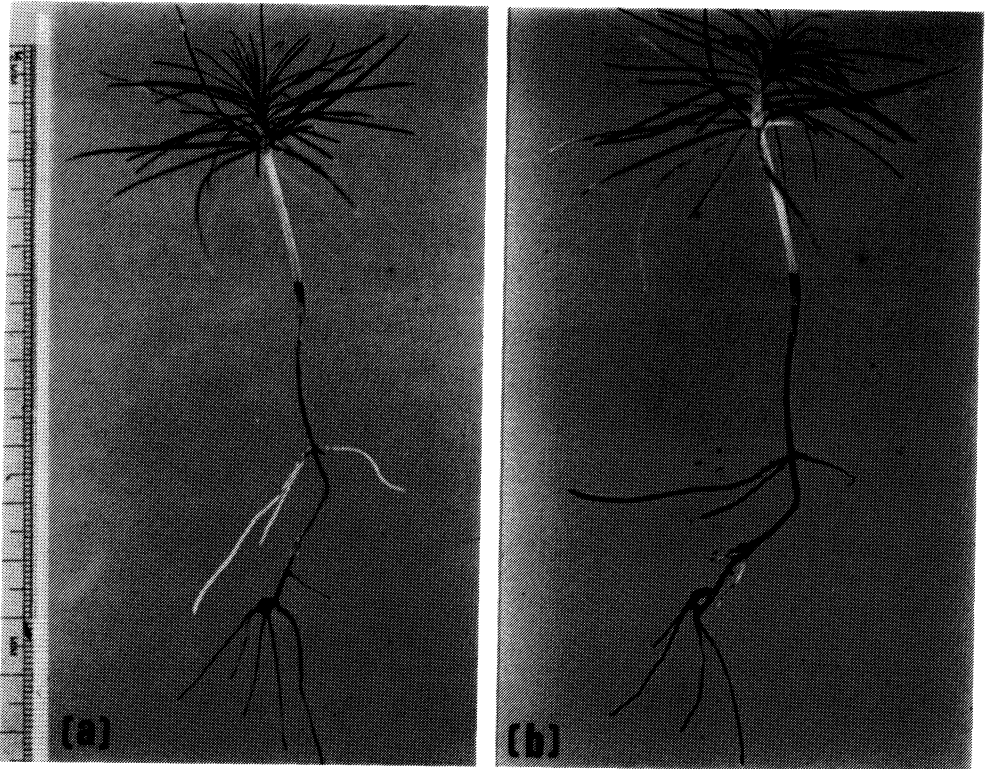


FIG. 1 — (a) Young *Pinus radiata* seedling in hydroponic culture to which *Phytophthora* sp. zoospores had been added 3 weeks earlier. Rootlet replacement has begun.
 (b) The same seedling, 3 weeks later. The new roots are now dead and a further attempt at regeneration has commenced.

Nothofagus, *Weinmannia*, and *Metrosideros*. White (1986) in Australia and Milligan (1974) in New Zealand have given good summaries of the contributory role of these organisms, including the impact of nutrient changes in leaves and twigs on incidence of crown pests and diseases. The importance of Fauld's (1977) positive results with *Platypus/Sporothrix* is underscored by the otherwise limited demonstrations of pathogenicity here or overseas. A key to the author's approach was his recognition of the importance of "aggregation of attack", i.e., heavy inoculum/infestation pressure. In the field, chemical attractants would play a major role in this regard.

CHANGE

We must recognise the importance of change where environmental factors are involved in disease development. To recognise change, however, we must have a knowledge of what is "normal" or "good health". An obvious example of change is the gradual decline and death of pole-sized kahikatea (*Dacrycarpus dacrydioides* (A. Rich.) Laubenf.) in natural rural copses near Auckland after drainage which dropped the ground watertable by 1–2 m. Conversely, on the fringes of Lake Monowai in the South Island of New Zealand, we have seen death of silver beech (*Nothofagus menziesii*



FIG. 2 — Readily pushed over and uprooted 12- to 14-year-old sapling of *Eucalyptus sieberi*, outwardly healthy but almost devoid of living roots. This site in east Gippsland was badly affected as a result of *P. cinnamomi* root rot after an exceptionally rainy season in 1956.

(Hook.f.) Oerst.) as a result of a permanent rise in the watertable of c. 2 m. Interestingly, the same species has re-established vigorously amongst the snags of the previous crop on flat areas of the shore where roots are growing in a non-stagnant surface watertable (Fig. 3).

Environmental change may come suddenly with massive wind-throw, waterlogging, or fire, or more insidiously when cattle cause soil compaction, when the logging of deep-rooted “waterpumps” increases salinity (Ive *et al.* 1988; Landsberg & Wylie 1988), when a prolonged drought reduces flushing of mangrove estuaries, or when logging or the alteration of a drainage pattern produces a rise in the watertable. Likewise, responses to change may be sudden or gradual, even over a period of 30 years (e.g., Tippet pers. comm.) or more (e.g., Shaw pers. comm.).

A change from absence to presence of *P. cinnamomi* is a major factor, especially on certain soils and with certain climatic regimes or incidents. Brown (1989) rightly asks why, if *P. cinnamomi* were *not* a recent introduction to areas of Queensland rainforest



FIG. 3 — Pole-sized beech (*Nothofagus menziesii*) regeneration. Trees are growing well on a saturated flat site on the shore of Lake Monowai, amongst derelict trunks of the same species killed by a 2-m rise in the level of the hydro lake about 30 years before.

that are experiencing patch mortality, excessively high rainfall in December–May 1973–74 (3757 mm compared with a mean of 1706 mm) should have “triggered” an existing disease condition, whereas in similarly wet seasons such as 1954–55 (3590 mm) or 1957–58 (3736 mm) it did not? Introduction of a root pathogen such as *P. cinnamomi* or of a voracious herbivore such as the possum creates major changes in successional patterns. These, and similar organisms — or even a prolonged climatic change such as may be brought about by the much-discussed greenhouse effect — must have an impact on our ability to accept many dieback syndromes as normal successional phenomena with an ancient history, rather than as diseases in the conventional sense.

CONCLUDING COMMENT

While there is a consensus amongst scientists, politicians, and the lay public that the impact of air-pollution, with its attendant acid rain and acid soil, poses a very real threat to the well-being of Northern Hemisphere forests, the presence of massive indigenous forest diebacks in the virtually air-pollution-free South Pacific region is a reminder that the dieback problem is still more complex than tends generally to be accepted.

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