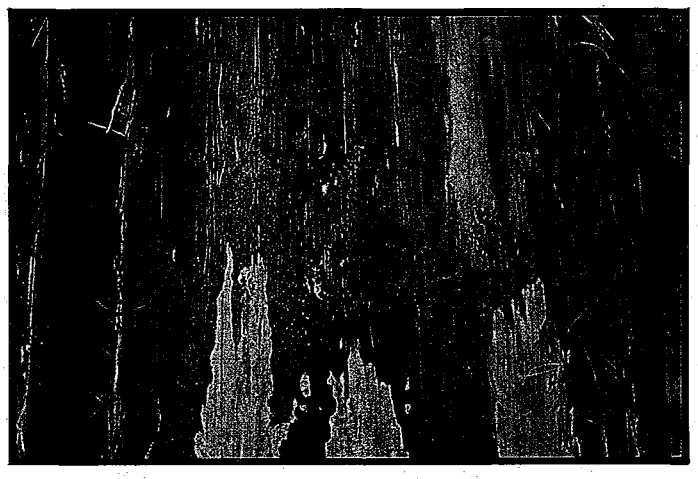


White rot produced by *Armillaria* on a mountain ash tree in a regrowth dieback area in Tasmania.

The colourful fruiting bodies are one sign that this eucalypt stump is under *Armillaria* attack.

More trouble for gum trees

Forests are home for many types of fungus, but undoubtedly the most familiar are the ones that produce mushroom-like fruiting bodies. Among these are species of *Armillaria*, which in some of Australia's moister eucalypt forests play an important role in breaking down dead plant material and returning it to the soil.

In many timber-producing forests they attack the dead stumps of felled trees, often producing colourful clusters of fruiting bodies around decaying stumps. Sometimes they also attack living trees, and an unidentified species of *Armillaria* has recently been implicated as almost certainly the prime cause of serious dieback problems in forest areas in central Victoria.

The main area affected is the 11 000-ha Mount Cole State Forest near Beaufort, west of Ballarat. This is a forest with a history. Timber-getting began in the 1840 s, and the area was very heavily cut over during the gold-mining years beginning in 1851 . Its timber was used for lining underground mines, building construction, and fuel.

Because of the damage done, the forest was closed to timber-getting in 1904 , and exploitation on a significant scale did not begin again until 1947 . Since then the management procedure has been selection cutting — the removal of single trees or small groups.

Spread followed drought

Several small patches of dieback were known when significant timber-getting resumed in the forest in 1947 , but the situation seemed fairly static until the late 1960 s. The dieback began to spread noticeably after a record dry spell in 1966–69 , and the spread has since continued at a rate that is causing increasing concern. The Victorian Forests Commission estimates that severe dieback covered 1000 ha (nearly 10% of the forest) by July 1976 , and that light to moderate dieback affected another 400 ha.

In the severely affected patches, which range in size from 0·2 to 20 ha, all the eucalypts are dead or dying. Nine eucalypt species grow in the forest, the most widespread being messmate stringybark (*Eucalyptus obliqua*), a peppermint (*E. radiata*), and manna gum (*E. viminalis*). All are susceptible, and so are some of the forest's acacias. Other forest plants appear to be unaffected.

Sometimes the trees die quickly, but more often death does not occur until 2–8 years after the foliage begins to show signs of deterioration. In the parts of the forest that are lightly affected, scattered individual trees, or small groups, are dead or dying.

Preliminary investigations of dieback in the Mount Cole forest, and of similar but less severe disease in the Wombat and Macedon forests to the east, were carried out between 1974 and 1976 by Dr Jim Edgar and Mr Colin Almond, of the Forests Commission, and Dr Glen Kile of the CSIRO Division of Forest Research. Dr Kile had earlier studied the possible role of *Armillaria* fungi in some forest dieback in Tasmania.

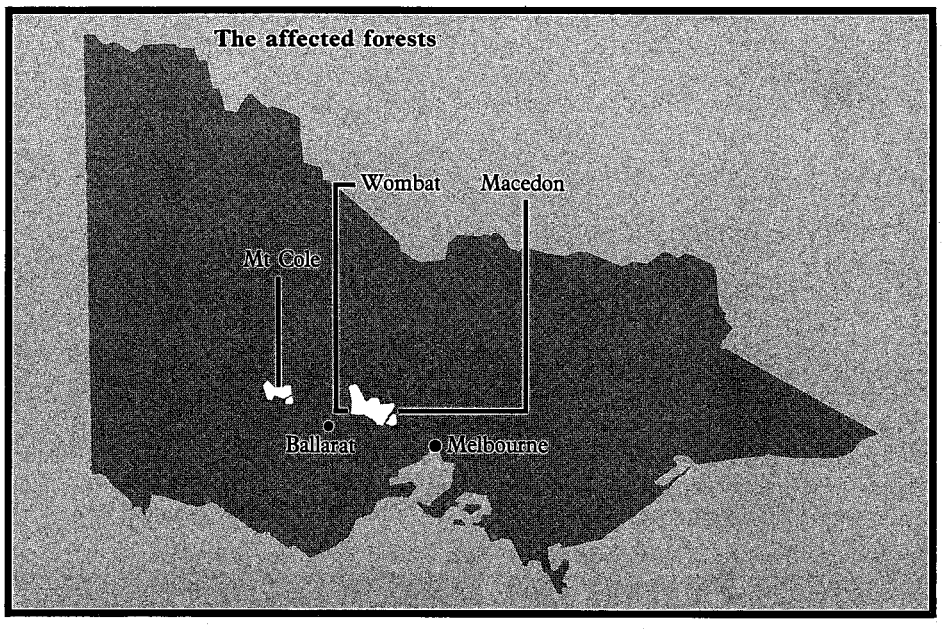
The scientists found that *Armillaria* was consistently associated with dieback-affected trees, while all attempts to find the microscopic root-rotting fungus *Phytophthora cinnamomi*, another possible cause of the problem, failed in the Mount Cole and Macedon forests. In the Wombat forest, the scientists found *Phytophthora* in some dieback areas, but *Armillaria* was more widespread. They concluded that *Armillaria* was probably the main cause of dieback there, but that *Phytophthora* was the chief problem in some areas with shallow, poorly drained soils.

How it attacks

Attack by *Armillaria* is a much more obvious business than attack by *P. cinnamomi*. Fungal material first penetrates woody roots, and then moves up inside the bark, spreading around the base of the tree. It kills the vascular cambium, the growing area of the roots and stem— in effect ring-barking the tree. Visible signs of attack include strands of whitish material on the trunk near the ground, dark brown stains in infected bark, and, in autumn, fruiting bodies growing around the tree.

An important aspect of *Armillaria*-associated dieback is the role played by tree stumps. Apparently, when a tree is felled, the stump becomes more susceptible to attack by the fungus. It serves as a large food base, allowing the fungus to spread, in an energetic and destructive manner, to the roots of surrounding trees.

Dr Kile and Mr Frank Podger of the Division of Forest Research recently studied the destructive operations of a species identified as *A. luteobubalina* around an infected acacia stump in a plantation of mountain ash (*E. regnans*) near Traralgon, Vic. Dead and dying trees surrounded the stump, and the scientists calculated that the fungus was spreading outwards — growing along roots, and from root to root — at a rate averaging about 2·5 m per year. *Armillaria* appears to be able to spread at a similar rate in the Mount Cole, Wombat, and Macedon forests.



Jumping-off stumps

From their study in those forests, Dr Edgar, Dr Kile, and Mr Almond concluded that logging appeared to initiate the dieback, by providing stumps on which *Armillaria* could multiply. But they could find no clear link between the intensity of logging operations and disease development. Severe dieback exists in lightly as well as heavily cut stands, while the trees in some heavily cut areas remain healthy.

An important unanswered question is why dieback did not become a significant problem in these forests until the late 1960s. Dr Kile suggests that the gradual increase in the scale of forest operations, producing a gradual increase in the stump food base, probably provided the necessary conditions.

But what those conditions are remains to be determined. *Armillaria* is found virtually throughout Victoria's mountain forests, but appears to cause no more than minor localized damage. Generally, it lives in apparent equilibrium with the trees.

Differences between species of the fungus are probably important. Dr Kile believes that there may be at least five species in eucalypt forest and, in collaboration with Dr Roy Watling of the Royal Botanic Garden, Edinburgh, has recently begun the laborious task of producing scientific descriptions of them. Little is known about their distribution, or about differences in their ability to injure trees.

Removing their food

While much remains to be found out about the fungi and their habits, an obvious approach exists for controlling the dieback they cause — reducing the food base by removing stumps and dead roots from the affected forest. The Forests Commission is looking at possible methods. One is 'whole-tree logging', using bulldozers to push trees over. Stumps would then be cut off and removed from the forest. Another approach is to fell trees in the usual way and then push the stumps out and rip the ground to get rid of as much stump and root material as possible. Either approach would increase the costs of timber-getting.

The Forests Commission is also looking at the possibility that changing the forest management practice from selection cutting to clear-felling may help control the dieback problem. Some evidence suggests that young trees are less susceptible to *Armillaria* attack than older ones, and it may be possible to re-establish forest after clear-felling despite the presence of large food reserves for the fungus. If this does not prove to be so, the stumps could be removed, heaped into windrows, and burnt.

Other approaches to control being considered included treating stumps with chemicals that would encourage invasion by other fungi, which would compete with *Armillaria* for the food reserves. Alternatively, stumps could be inoculated with other fungi. Both these methods are used successfully in some similar disease situations overseas.

Tasmania

While *Armillaria* is almost certainly the main cause of dieback in the central Victorian forests, its role in dieback in other eucalypt forests where it is present appears to be much less important. In Tasmania, for example, it is found widely in forests affected by dieback, but in all cases the evidence indicates that its role is a secondary one — accelerating the decline of already dying trees or killing trees weakened by other agencies.

The State's most serious dieback problem, known locally as regrowth dieback, was first noticed in 1964. Since then it has spread over 16 000–20 000 ha of forest south of Geeveston, 50 km south-west of Hobart, and over smaller areas on Bruny Island, on the Tasman Peninsula, and near Mt Maurice in the north-east of the State.

Attack by Armillaria *is a much more obvious business than attack by* P. cinnamomi.

The dieback occurs mainly in stands of forest that have regenerated after being logged between 1880 and 1940. Intriguingly, the disease only appears to attack stands that are more than 30 years old. The trees most severely affected are messmate stringybark (*E. obliqua*) and mountain ash (*E. regnans*), which are the main species in these forests. The disease occasionally affects some other eucalypt species, but the understorey apparently remains untouched.

Dead and dying trees are scattered through the forests, with no clear boundaries between healthy and diseased stands. Trees generally take between 3 and 10 years to die after the first signs of deterioration appear in the foliage.

A mystery

Mr Trevor Bird of the CSIRO Division of Forest Research and Dr Kile and Mr Podger have been studying this dieback problem since 1972. They have ex-

amined a number of possible causes of the tree deaths, including attack by *Armillaria*, and have had to reject them all. In the words of Dr Kile, it is an 'exceedingly mystifying problem'.

Armillaria grows on the roots of something like three-quarters of the trees aged between 30 and 100 years — in both healthy stands and those affected by dieback. It rapidly colonizes the cambium of most stumps left after logging, and that of many dieback-affected trees. However, it does not appear to initiate decline in the health of trees; instead it moves into the cambium when dieback is well under way. The existence of some trees in advanced decline but apparently free of infection provides further evidence that *Armillaria* is not a primary factor in the disease.

The possibility that *P. cinnamomi* is the main culprit has also been examined and rejected. Attempts by the scientists to find it in affected stands have failed in all but a very few areas.

Another fungus that can rot the fine feeder roots of trees, a species of *Cylindrocarpon*, was recently put forward by Mr Walter Jehne, a research student at the University of Tasmania, as a possible cause of the dieback. This ubiquitous native fungus is a weak pathogen, but the theory is that it may kill trees after drought or other environmental stress has weakened them. The CSIRO scientists think this theory is unlikely to prove correct, but are planning experiments to test it.

The onset of regrowth dieback followed a protracted dry period: from 1959 to 1963 average summer rainfall at Southport, the nearest meteorological station to the main affected area, was nearly 60% below the long-term average. But dieback has spread continually since then, suggesting that stress of this kind is not needed to initiate tree deaths. In one experiment, the scientists are studying growth rings of 400-year-old celery-top pines in an attempt to find out whether droughts as severe as that experienced between 1959 and 1963 are very rare or relatively common events.

The apparently random distribution of affected trees and the sudden development of the disease support another theory that has been put forward — that a pollen-borne virus is the tree-killer. The absence of the disease in stands of trees that have not yet reached sexual maturity also fits in with this theory. But the affected trees show none of the foliage symptoms usually associated with virus infection, and no viruses that attack messmate stringybark and mountain ash are known. This theory remains to be researched in detail.

More Tasmanian dieback

Armillaria seems to play a secondary role in two more of Tasmania's dieback problems.

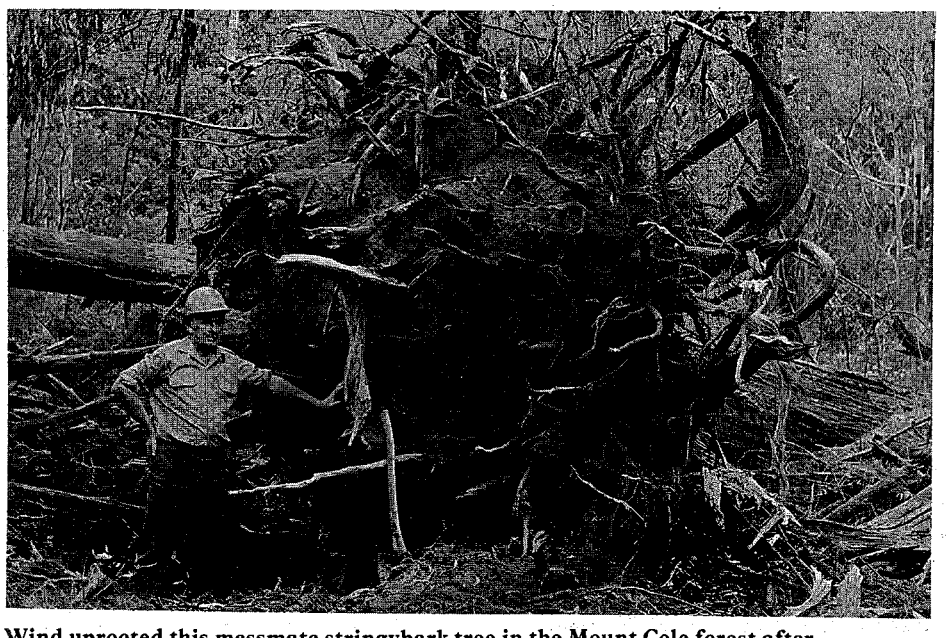
One, known as gully dieback and involving the death of messmate stringybark along gullies in the east of the island, appeared suddenly in 1967–68. It affects almost 2500 ha.

Research by Dr Chris Palzer of the Tasmanian Forestry Commission indicates that drought was the main cause of the problem. Rainfall between January and May 1968 in that part of Tasmania was about one-fifth of the average (by far the lowest on record), and the following year also was unusually dry. The fact that the trees died suddenly and that deaths have not continued supports the theory that drought was primarily responsible. Large numbers of leaf-eating insects were in the affected areas at the time, and probably joined with *Armillaria* in helping finish off drought-weakened trees.

The other dieback, referred to as high-altitude dieback, has killed high-quality alpine ash (*E. delegatensis*) in 2500–3000 ha of mountain forest in north-eastern and north-western Tasmania. Rainforest myrtle (*Nothofagus cunninghamii*) dominates the understorey of these forests, and *Armillaria* grows on roots of both ash and myrtle.

The trees in the dieback areas are more than 80 years old, and the understorey is dense. Dr Bob Ellis, formerly of the Tasmanian Forestry Commission, has attributed the deaths to effects on the tree roots of the soil cooling produced by the thickening myrtle cover. He believes this is a natural process leading to the replacement of eucalypt forest by rainforest — a process that fire normally interrupts before the eucalypts die. After fire, the eucalypts are able to regenerate on the uncovered warmer soil.

The Forestry Commission is looking into the possibility of preventing further dieback in these high cold areas by burning out the myrtle understorey. A program of experimental burns in small portions of forest has begun, to find out whether, and at what times of the year, fires can be lit that will destroy the understorey but leave the tall eucalypts unharmed.



Wind uprooted this messmate stringybark tree in the Mount Cole forest after *Armillaria* rotted its roots.

More about the topic

Tree decline and mortality in selectively logged eucalypt forests in central Victoria. J.G. Edgar, G.A. Kile, and C.A. Almond. *Australian Forestry*, 1976, **39**, 288–303.

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Dieback of alpine ash as related to changes in soil temperature. R.C. Ellis. *Australian Forestry*, 1971, **34**, 152–63.

Phytotoxins in *Cylindrocarpon* root-rot of *Eucalyptus obliqua* regrowth trees. W. Jehne. In 'Abstracts of Papers, Second National Plant Pathology Conference, Brisbane 1976', a supplement to *Australian Plant Pathology Society Newsletter*, 1976, **5**.