CROWN DIEBACK IN EUCALYPT FORESTS

A GENERAL REVIEW

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1. Introduction

This review is prepared as an introduction to the seminar on eucalypt crown dieback to be convened by the Forestry Council Standing Committee, sub committee on Pests and Diseases. The seminar is scheduled to take place at Lakes Entrance, Victoria, during the period November 12 to 16, 1973.

From submissions provided by participants in the symposium the review is intended to provide coherent background information on the following aspects of the problem area.

1.1. Extent and location of the problem.
1.2. History and symptoms.
1.3. Causal agencies and methods of identification.
1.4. Possible economic implications.

In context it must be read and discussed largely as an introduction to further review sessions which will cater for detailed examination of specific topics as follows:

1.5. Detection of dieback diseases.
1.6. Causal agencies.
1.7. Economic impact.
1.8. Control potential.
1.9. Management of dieback forest.
1.10. Research direction for management of dieback forests.

The review hence aims to define the problem area only and should not be expected to exhaustively develop any one of the above study areas.

2. Definition

In approaching this symposium, "Crown Dieback in Eucalypt Forest" must be viewed initially as a delineation to develop understanding within a problem field currently of concern in Australia. The title cannot be accepted as a working definition of value to the precise communication required for research and operational efficiency. A major objective of the seminar must be to re-define or categorise the subject field to the extent that in future we all know what the other is talking about when referring to crown disorders in eucalypt forests. For the occasion, the definition has been made sufficiently fluid (or vague if you prefer) to ensure that all relevant viewpoints may be represented and evaluated within the proceedings.

Initial drafting for this review was based on the concept that crown dieback in eucalypts is the condition where the primary crown is disordered to be replaced by a secondary crown. The condition can be progressive, leading to the ultimate death of the tree or group of trees.

To the forest manager, the significant feature of crown dieback is a change in the health or growth potential of the trees involved. It can be detected by ground inspection or from air photo interpretation and represents a potential disorder which may adversely influence forest production, protection or amenity values.

The significance of crown damage once detected (and obviously detection is the first requisite for significance) depends on its extent in area and time and its influence on forest values. Survey and mapping will assist to assess the level of significance. The final assessment however, requires knowledge of the process of the disorder and the causal agencies.

It is only at this process and causal stage that strict definition of crown disorders is essential. Damage to the primary crown may result from physical defoliating agencies such as fire scorch, unseasonal frost, hail or cyclonic winds. Although such agencies and their process are readily explained and of a transitory nature (the cause of which generally requires no detailed research or control effort) this is not always the case with external, direct defoliation. Chemical pollution causing direct leaf kill, extreme attacks by leaf-eating insects and animals or drought damage are not necessarily the result of random occurrences due to natural sequence. The importance of direct defoliation lies in its time of occurrence, specificity, area basis and repetition.

There is a tendency to consider direct defoliation as separate to the "crown dieback" which is of current concern in Western Australia, Southern Victoria and Tasmania. These conditions, described in the following section, often result from gradual crown mortality due to upsets in the physiology of the tree. In review however, it is difficult to separate destruction of the primary crown and its effects on forest values: whether it results from root damage by _Phytophthora cinnamomi_ (Podger, 1972) vascular disorder by _Armilleria mellia_ (Kile, 1973a) or direct defoliation by _Didymuria violescens_ (Mazanec, 1966) or _Perthida glyphopa_ (Wallace, 1970). The confusion resulting from attempts at precise definition of crown dieback is furthered on considering so-called drought effects which may result in a crown disorder due to excessive transpiration (increased exposure), decreased root absorption, a combination of both (i.e. seed trees) or vascular impairment due to stem damage.

It is obvious that crown damage must be considered as an analogy to heart disease in humans. It can result from almost any environmental agency which is out of balance and the effects of both conditions, once developed, influence the entire organism.

As a working definition it is recommended that crown dieback in eucalypts is considered as the development of a secondary crown due to a temporary or permanent imbalance in the environment. This is a functional definition which caters for detection of possible disasters. Detection is the prime requirement and influence on forest values is the significant criterion.

Lack of development of a secondary crown distinguishes outright tree mortality from progressive crown dieback disorders. Further categorization required for communication and research in crown dieback problems is also probably simplest on the basis of control requirements. Causal agencies could be separated as atmospheric, soil borne, internal and complex. Further subdivision could be on the basis of whether the causal agent is physical, chemical or biological.

The preamble and preoccupation with definition is essential to this review, and the symposium. Preliminary work has suggested that we know too little of the cause, extent and evaluation of eucalypt disorders in Australia to devote too much time, at present, on detailed definition of the problem area. What is required however, is a working separation which will lead to co-ordination and communication in detection, survey, appraisal, and control approaches.

3. Recorded Problems

As a practical approach, recorded instances of conditions relevant to the seminar have been reported separately on a State or geographic basis. Varying amounts of information for separate disorders also make it necessary to group history, symptoms, location and extent in a single brief review.

3.1. Crown dieback disorders reported in Western Australia concern:

3.1.1 Crown deterioration in jarrah.

3.1.2 Jarrah dieback.

3.1.3 Jarrah leaf miner.

3.1.4 Karri dieback.

3.1.5 Lurp damage to flooded gum.

3.1.1 Crown deterioration - Prior to 1952 foresters expressed concern at progressive crown deterioration in cut over mature jarrah (Eucalyptus marginata Sm) forest in the northern sector of its range (Wallace and Hatch, 1953). In certain areas the dense primary crowns of mature to overmature trees left following selection cutting were observed to thin, tend to replacement by a secondary crown and leave much dead wood exposed.

The condition was never adequately explained and has been largely ignored following the association of a jarrah dieback with Phytophthora cinnamomi (Podger, Doepel and Zentmyer, 1965). There is evidence to indicate however, that even in the absence of P. cinnamomi in W.A., certain areas of selectively logged or disturbed jarrah forest have experienced crown breakdown. This situation was believed to be associated with disturbance due to logging resulting in fluctuations in the surface hydrology.

This is highly probable. Jarrah has been shown to be very sensitive to waterlogging (Podger, 1967; Batini, 1968) and environmental disturbance in the jarrah forest can cause soil moisture and water table levels to fluctuate considerably (Peck and Hurle, 1972). Crown deterioration following selective logging can be observed to a lesser extent in the karri (E. diversicolor F. Muell) forest and is a common feature with seed trees in karri, jarrah and the ash eucalypts. The degrade of crowns due to exposure following disturbance (Hayes and Buell, 1955) is worthy of further investigation, particularly with respect to ecosystems believed to be relic or delicately balanced climaxes. This is a common view for the jarrah forest.

Jarrah also suffers a severe crown thinning during seed years which occur generally on a four year basis. Loss of crown due to this association resulted in a decrease in basal area increment of 40 per cent, during the 1965-67 flowering and seeding cycle.[1] The crown thinning is temporary and refers to all age classes. Normally, the "crown deterioration" consideration applies only to mature to overmature trees.

3.1.2 Jarrah dieback - This condition refers to the die-back of the crown and eventual mortality of jarrah in virtually all ecologic situations within its natural range (Podger, 1972; Batini and Hopkins, 1972). Initial records in 1921 of unexplained deaths of jarrah refer to small, discrete patches of dead jarrah near Karragullen in the northern forest. Further small pockets of dead and dying jarrah were observed in 1928 some 80 km further south. The disease had reached sufficient magnitude by 1948 to be considered an important problem and resulted in the initiation of a joint State-Commonwealth venture to investigate the disease.

The first symptoms of the disease are usually yellowing and deaths of bull banksia (*Banksia grandis* Willd.) blackboys (*Xanthorrhoea pressii* Endl.) and zamia palms (*Macrozamia reidlei* C.A. Gardn.) in the understorey. Other less conspicuous members of the understorey and shrub layers are similarly affected. The jarrah trees show the effect at a later stage, often after all

1 Forests Department W.A., Annual Report, 1967

the understorey has died. The symptoms are a thinning of the foliage and a dying back of the branches. This dieback becomes progressively more severe until the tree succumbs. Deaths in the jarrah overstorey appear to be random and sporadic. Some individuals or small groups may survive for many years and then succumb quite rapidly.

Diseased areas usually spread slowly, though the rate of movement is quite variable depending on the site, the forest type and the season. Some mature trees, notably marri (E. calophylla R. Br.), blackbutt (E. patens Benth.), bullich (E. megacarpa F. Muell), wandoo (E. wandoo Blakely) and karri (E. diversicolor F. Muell) are tolerant to the disease.

Mapping of 0.7M ha of the northern jarrah forest has revealed that 36,800 ha or 5 per cent of the area is affected by the disease. (Batini and Hopkins, 1972). It is however, not possible to map dieback in southern forests from air photographs accurately at this stage. Allowing for dieback in southern areas and increases at the measured rate of 4 per cent of the diseased area per annum (Batini, 1973) the current area infected is estimated to be in the order of 80,000 ha.

The more severely affected areas are located in the northern and western margin of the jarrah forest concentrated in a belt from Mundaring to Collie parallel with the Darling Scarp. Here up to 30 per cent of the forest may be affected to some degree. Proceeding inland, the extent of infection gradually decreases and is less than one per cent in the eastern section of the State

Forest (Batini and Hopkins, 1972).

Batini (1973) has shown that the disease is most closely associated with watercourses with strong relationships existing between disease and roads, disease and soil type, disease and cutting history and disease and rainfall. Development was affected by a large number of ecologic factors considered: with the individual factors also proving to be inter-related.

3.1.3 Jarrah leaf miner - The jarrah leaf miner (Perthida glyphopa Common) infests flooded gum (E. rudis Endl.) and jarrah in the south-west of the State (Wallace, 1970). Flooded gum is attacked by the leaf miner throughout the south-west, except on the Darling Range. The tree is confined to watercourses and other moist situations and is not an important forest species.

Newman and Clark (1926) first described outbreaks of leaf miner in jarrah around the ports and coastal townships in the early 1920's and recorded an infestation near Perth as early as 1914. In the late 1950's outbreaks of the leaf miner were noted in jarrah forest east of Manjimup and these spread rapidly. In 1971 moderate to heavy infestation covered approximately 1.4 M ha of which approximately 0.4 M ha were in State Forest, the remainder in partly cleared farmland (Mazanec, 1973, pers. comm.). Surveys (Wallace, 1970) have revealed that the prime jarrah forest still remains relatively free from the disease and the major damage is associated with cleared, farmed areas.

The moths emerge in April-May from the soil and deposit their eggs singly under the lower epidermis of the leaves. The larvae excavate blotch mines within the leaves and, on maturation in September-October, each constructs a cell. The cell is cut out leaving an oval hole in the leaf. The encased larva drops to the ground and aestivates in the soil until the following April. Up to 30 larvae may reach maturity in one leaf of jarrah (Wallace, 1970).

Infested leaves become discoloured early in September and many of those in which the tissue has been destroyed are shed. The less damaged leaves are retained longer, but many drop off during January-March in the following year.

Some 23 per cent of trees are resistant to leaf miner attack. The annual loss in girth increment has been assessed by Mazanec (pers. comm.) to be in the order of 70 per cent in the forest and 40 per cent on the coastal plain.

It is suspected that parasitism and bird activity may control numbers of leaf miners in certain areas (Wallace, 1970). Controlled burning and tree density are aspects, mentioned by Wallace, which may have relevance in the control of the disorder.

3.1.4 Karri dieback - To date there has been little cause for concern with respect to crown dieback in this important commercial eucalypt. Several years ago however, an isolated patch of virgin karri in Warren Block was found to be dead, apparently as a result of association with *Armillaria mellea*[1]. No further occurrences have been reported and in fact it is unusual to find a karri tree whose death cannot be simply explained. Although the fungus is present in the southern forest, actual known instances of attack on eucalypts are rare.

1 Forests Department W.A. unpublished report

3.1.5 Lurp damage to flooded gum - In certain seasons extensive lurp attack is found on E. rudis. Attack can lead to complete defoliation and, in association with leaf miner activity, result in tree mortality. This attack appears to be identical to that reported for E. camaldulensis in South Australia and Victoria. No adequate references to either the local or Eastern States situation is available.

3.2. Victoria

Recent reports have documented accounts of eucalypt crown dieback in

3.2.1 Eastern Victoria (Marks, Kassaby and Reynolds, 1972; Marks, Kassaby and Fagg, 1973).

3.2.2 Dry sclerophyll forest in the Brisbane Ranges (Podger and Ashton, 1970; Weste and Taylor, 1971; Weste, Cooke and Taylor, 1973).

3.2.3 Dry sclerophyll woodlands at Wilsons Promontory (Weste and Law, 1973).

All three occurrences are related to the presence of Phytophthora cinnamomi as a recent introduction and symptoms are similar to that reported for jarrah dieback in Western Australia. Different forest types and economic impacts are concerned and it is desirable to review the three situations as separate entities.

3.2.1 Dieback in mixed hardwood forests of eastern Victoria - Lee (1962) described a rapid decline and dieback of patches of several eucalypt species in eastern Victoria. It appears that the disease may have originated in the late 1930's but was first recorded soon after the heavy rains of 1952-53 and increased further during the wet summer of 1956. Lee's inspections in 1958-59 recorded that the largest patches did not exceed 2 ha and that a total area of approximately 25 ha was observed. The disease was associated with road construction and heavy logging on sites with impeded drainage. During the past 13 years the disease has expanded rapidly and been associated with the presence of P. cinnamomi (Marks, Kassaby and Reynolds, 1972).

Observations made in 1971 based on ground survey and aerial reconnaissance show that the larger dieback patches exceed 40 ha in area. Patches of dieback extend from the far east coast of Victoria to Yarram and into the low foothills of the central highlands. A total of 800 ha shows severe dieback and about 4900 ha in eastern Victoria is lightly affected. All damaged areas are either close to roads or have been logged in the past. Identification of the disease is often complicated by past fire damage.

The disease appears to be worst on relatively infertile soils where drainage is impeded. However, damage has been observed in well drained soils subject to occasional periods of excessive moisture.

All dominance classes of trees are affected by dieback. Macrantherous species show resistance while the renantherous species are susceptible. Lightly affected stands usually show poor crown development with dieback in a few of the major limbs. In severe cases a considerable part of the crown is lost and there are many dead limbs. On severely affected sites most trees are killed. Natural regeneration in affected stands is stunted and spindly, with thin, chlorotic flat-topped crowns. When dieback assumes epiphytotic proportions the foliage of trees of all sizes suddenly loses its sheen and begins to wilt. The leaves turn yellow, then brown, and the tree dies within 2-3 months of the onset of the first symptoms.

Crown dieback in east Gippsland is similar to jarrah dieback in that both understorey and overstorey plants are affected. Understorey species showing symptoms in Victoria include Stypandra glauca, Banksia marginata, Daviesia latifolia, Xanthorrhoea australis and Bedfordia salicina (Marks et al, 1972). The symptoms develop more rapidly than those seen in the overstorey and are more severe. Most of the affected plants show severe drought symptoms, the foliage wilts and turns yellow and the plants died within a few weeks. In the initial stages of infection, damage in the understorey preceded dieback in the overstorey, spreading several metres in advance of the damage to the forest canopy.

Neither crown dieback nor the causal associate, P. cinnamomi, has been found in the forests of the central highlands or in the high altitude forests of east Gippsland.

3.2.2 The Brisbane Ranges - Podger and Ashton (1970) were the first to record a disorder in understorey species and shrubs in the Brisbane Ranges in Victoria which has since been associated with a eucalypt crown dieback (Weste and Taylor, 1971).

The original workers, on observing the understorey symptoms in 1969, correlated the situation with that of jarrah dieback in Western Australia. They were able to associate P. cinnamomi with the presence of the understorey deaths. Original infections were located along Marshall's Road in the Brisbane Ranges, some 72 km south-west of Melbourne. The woodland occurs on a gently undulating plateau with a mean annual rainfall of 630 mm. Soils are lateritic, gravelly, grey and yellow sands overlying dense mottled clays at shallow depth. Eucalyptus obliqua, E. macrorhyncha and E. baxteri are the main overstorey species. There is a dense shrub cover of evergreens in which Xanthorrhoea australis is prominent.

Podger and Ashton recorded four areas seen to be diseased in the ranges to be or recent origin and all less than 0.5 ha in extent. Weste and Taylor (1971) and Weste, Cooke and Taylor (1973) have studied the disease development in detail. The total affected area mapped in 1970 was in excess of 60 ha, consisting of small patches scattered over a wide area. All diseased sites showed appreciable increase in area over a 5 month study interval (Weste and Taylor, 1971). In poorly drained soils the linear extension of the disease symptoms was at twice the rate laterally (10.4m) and three times the rate downhill (29.4m) as in moderately drained soils (5.2m and 10.2m respectively). Lateral spread on well drained sites was zero, while uphill spread was less than 1.5m, even on waterlogged sites.

Two years later (Weste, Cooke and Taylor, 1973) the rate of spread for these sites over a period of three years along the verge of ridge roads was measured at 171m per year. Extension of disease by run-off measured over the same period was 400m per year. The extension of disease always occurred from originally infected sites. No disease developed on disturbed sites with the same topography, soil and flora, when P. cinnamomi was absent.

Visual symptoms appear first in the understorey and the grass tree (X. australis) is a useful indicator. The leaves turn yellow (the outermost first), then a rich cinnamon brown, and finally the umbrella shaped top collapses and the grass tree dies; over a period of 2-5 months. Symptoms in eucalypts depend on the extent of droughting and of fine root destruction. The crown thins, followed by leaf abcission and dieback of the branchlets. Epicormic buds may develop then die with the death of the tree gradually occurring over a period of twelve months. More rapid death may follow leaves losing their shine, the foliage appearing grey-green. The veins project to form prominent ridges. The crown then rapidly dries out, the leaves becoming a pale-grey-green and brittle. Finally the foliage turns brown and remains attached long after death. Trees were usually dead within four weeks from the appearance of initial symptoms.

3.2.3 Wilsons Promontory - Diseased vegetation was first reported from the northern slopes of the Vereker Range at Wilsons Promontory National Park in September, 1970 (Weste and Law, 1973). The park is situated 240 km south-west of Melbourne and consists of rugged granite mountains with quaternary deposits around the coast.

The pathogen (P. cinnamomi) and disease has since invaded three types of plant community - dry sclerophyll woodland, heaths and swamps. Dominants of both tree and shrub strata are susceptible and have been killed. Highly susceptible shrubs of the understorey such as X. australis and Isopogan cerato-phyllus are destroyed first. These are followed 6-12 months later by less susceptible shrubs and at least 12 months later symptoms appear in the trees. In 1973 it is estimated that 400 ha of a total of 60,000 ha is diseased. The area and extent of each disease site have been accurately mapped by Helen Veitch (pers. comm.). Spread along the contour is very much slower (18m per year) compared with rates in the Brisbane Ranges (171m per year). Spread by water run off occurred at the same rate i.e. 400m per year (Weste, pers. comm.).

The disease evidently originated from tracked vehicles brought from infected forests near Yarram in 1962 to assist in fire control on the Vereker Range. The symptoms in both understorey and overstorey are similar to those described for the Brisbane Ranges. However, the dominant tree in the shrubby woodland Banksia serrata exhibits marked chlorosis. Death usually occurred within two months from the onset of symptoms. Associated trees of E. obliqua turned brown and died within one or two months. In the understorey the extreme susceptibility of the swamp-heath, Sprengelia incarnata was useful in delineating disease sites (Weste and Law, 1973).

3.3. Tasmania

Four eucalypt crown diebacks are currently recognised in Tasmania.

3.3.1 High altitude dieback of E. delegatensis.
3.3.2 Regrowth dieback.
3.3.3 Gully dieback.
3.3.4 East coast dieback.

A fifth crown disorder resulting in severe defoliation of eucalypts in central Tasmania is included for review.

3.3.1 <u>High altitude dieback of E. delegatensis</u> R.T. Baker - This condition studied in detail by Ellis (1964, 1971) consists of a decline in vigour and mortality of mature dominant trees of <u>E. delegatensis</u>.

The disorder can be seen on aerial photographs of the Camden Plateau taken in 1932. It has been recorded for the Surrey Hills, on Maggs Mountain and is most important on the Camden Plateau where Ellis (1964) estimated that in 1962 some 1,800 ha of 5000 ha of eucalypt forest was affected. The dieback is most severe on this high plateau enclosed roughly within the triangle, Trenah, Ben Nevis, and Mt. Scott. It is restricted to altitudes above 760m and becomes severe above 900m. A general estimate of the total area involved by the disorder is 2,500 ha (Felton, pers. comm.)

The severity of the dieback, found to increase with altitude, was related to the degree of development of rainforest understoreys; it thus being related to the time since the stands were burned (Ellis, 1964).

Dieback symptoms are a general thinning of the foliage followed by the death of the smaller branchlets and the inhibition of normal new growth; leaves not appearing to wilt or shrivel prior to falling. Some development of epicormic shoots occurs, but is not generally vigorous except after scrub removal by road making or logging. Trees of all age classes and canopy positions are affected. <u>Eucalyptus dalrympleana</u> Maiden which occurs as an admixture in some stands is not affected by dieback.

In some areas individual trees of E.delegatensis have died amongst others which are apparently healthy, elsewhere death has been general over a hectare or so in area, but the overstorey of some stands is composed entirely of healthy eucalypts. The forests do not show the symptoms where the understorey has been maintained in an open nature by repeated burning. Deaths occur in neighbouring areas with older and denser understoreys (Felton, 1972).

Ellis (1972) considers that this dieback, which is restricted to the trees, is due to microclimatic changes of the soil following the invasion of the stands by rainforest understoreys.

3.3.2 Regrowth dieback - Dieback as such was first recognised in the south of Tasmania in 1964 when the first unexplained death of a co-dominant eucalypt on permanent yield plots occurred. An earlier record of declining trees dates from 1956 when descriptions were made of crown dieback symptoms in E. obliqua on two temporary assessment plots in a stand of regrowth which now has severe dieback. Between 1956 and 1964 regrowth dieback existed in the south at a much lower level than it does now, for since 1964 the dieback has noticeably increased in amount and severity (Felton, 1972).

In the north east of Tasmania regrowth dieback was first noticed in 1956, in E. obliqua L'Herit and E. regnans F. Muell, after a very wet summer. Some of the patches that appeared then have since increased only very slightly. The same is true for a path of about 40 ha in the north west, first noticed in 1945. By 1947 many trees were dead, but the patch did not enlarge and in 1970, still contained live trees which had epicormic crowns, (Felton, 1972).

Regrowth dieback has been most studied in southern Tasmania where there are appreciable areas of regrowth resulting from wildfires associated with logging in virgin old growth forests which began at the end of the last century. The important eucalypts in regrowth stands are E. obliqua, E. regnans and E. globulus Labill. Eucalyptus globulus appears to be relatively tolerant of dieback when compared with E. obliqua or E. regnans but trees dead due to dieback can be found. The understorey below the eucalypts is dense, usually of the wet sclerophyll type but tending to become rain forest in the moister habitats. The understorey has not been seen to die except when very young as regeneration on burnt areas or roadside fringes (Felton, 1972).

South of Hobart, regrowth dieback is common on the main island within an area of about 16,000 ha of regrowth bounded on the south by the D'Entrecasteaux River and on the north by the southern watershed of the middle reaches of the Huon River. A few patches are known in the catchment of the Huon but here regeneration is generally healthy as it is on Bruny Island, Tasmans Peninsula and in the Concession of Australian Newsprint Mills (Felton, 1972).

Regrowth dieback is typically a diffuse phenomenon. Dead trees occur as individuals or in very small groups associated with trees with defective crowns. Trees with defective crowns not accompanied by dead trees are common. In a stand there is a pappering of dieback patches. Early symptoms of the dieback are death in the primary crown of the eucalypt, which is usually accompanied or may be preceded by the development of a secondary epicormic crown. Death is usually the result of non replacement of abscissed leaves, but sudden deaths where large parts of the crown are retained as dead leaves may be seen.

Dead seedlings have occurred in three situations, where the previous regrowth had dieback, scattered amongst the apparently healthy seedlings, on roadside fringes and in small definite patches on shallow soils. These patches were first seen in the late summer of 1969 in two year old regeneration. They increased slightly in size the next summer but have not expanded since and occupy a completely negligible proportion of the large areas of regeneration in southern forests (Felton, 1972). Were it not for the fact that P. cinnamomi was recovered from the soil and roots of the dead and dying seedlings, death would have been attributed solely to drought. Regeneration seven years old nearby is not affected. This and the general health of regeneration on dieback sites, now up to 11 years of age, suggest that deaths will be restricted to very young eucalypts, to presumably reappear as the stands of regeneration become very much older (Felton, 1972).

Within the southern area, severe dieback is generally associated with flat sites liable to waterlogging in winter.

3.3.3 Gully dieback - Gully dieback was first recognised as a problem in 1969 following a major upsurge in eastern Tasmania of dead and dying forest which was co-incident with locally high populations of leaf-eating larvae of the seedling gum moth Roselia sp. These populations crashed after heavy rains in February 1969 that also broke a severe drought. The gum moth and drought must have had some effect on the expression of the disease, but the fact that other agencies were involved is clearly shown by deaths which have continued when rainfall has been high and gum moth populations low, since 1969 (Felton, 1972).

Gully dieback is found in eastern Tasmania where annual rainfall is less than 1000 mm and summers are drier than within the regrowth and high altitudinal dieback areas. It is known to occur from near Buckland in the south to west of St. Helens in the north. In the southern part of its range, in the Eastern Tiers, it is relatively infrequent, the area most severely affected being on the lower eastern slopes of the North Eastern Highlands. Here dry sclerophyll forest types predominate, tending to wet sclerophyll in most gullies. Typically, the topography of the forest is well defined ridges and gullies. _Eucalyptus sieberi_ L. Johnson is characteristic of the drier ridge tops and upper north facing slopes and _E. amygdalina_ Labill and _E. obliqua_ of gully bottoms and south facing slopes, the latter being the only renantherous species found. _Eucalyptus viminalis_ is scattered through the moister situations, with _E. globulus_ in similar situations within its zone of occurrence. Soil drainage is good in all topographic positions (Felton, 1972.)

Of 60,000 ha assessed to date by air photographic interpretation approximately 2,400 ha were found to be affected by dieback; most of this occuring within the western section of the Upper Scamander map sheet (Felton, 1972). Palzer (1973) reports

2,800 ha total affected by gully dieback. Comparisons of photos taken in 1950 and 1969 clearly show that both the area affected by the disease and the intensity within affected patches substantially increased in this period (Felton, 1972). Palzer (1973) reports the up-stream extension involved to be up to a rate of 63m per year.

The recognition of early signs of the dieback is made difficult by crown defects due to periodic fires. In the most developed dieback patches all older trees are dead leaving a few acacias as the only live tall trees. Healthy eucalypts occur upslope, the change from dead to healthy trees usually being well defined and, on the north facing slopes, often co-incident with the sharp change from _E. obliqua_ to _E. sieberi_. _Eucalyptus amygdalina_, _E. delegatensis_, _E. obliqua_ and _E. viminalis_ are killed by the dieback, though the last species shows some tolerance. _Eucalyptus ovata_ shows great tolerance, living in gullies where trees of the other species are dead. _E. sieberi_ rarely occurs in gully bottoms but where it does it may be killed.

In less developed patches, trees with dead or dying primary crowns but apparently healthy epi-cormic shoots are common. Rapid deaths are more frequent than with regrowth dieback. Deaths are common and patchy in the dry sclerophyll under-storey which is dominated by plants of the fami-lies _Papilionateae_ and _Epacridaceae_. Wet sclerophyll understorey is unaffected.

Healthy eucalypt regeneration about 4 years old may be found below the dead trees in gullies where the understorey is not dense. Seeding deaths occurred in autumn 1971 in an artificial regeneration trial established in 1969. *Phytophthora cinnamomi* has been recovered from these dead seedlings (Felton, 1972).

3.3.4 East Coast dieback - Along the east coast, especially around Scamander and Coles Bay, there is an extensive decline in *E. sieberi* and *E. amygdalina* and many understorey plants susceptible to *P. cinnamomi*. There are also some poorly drained river flats and plateaux where *E. amygdalina* and sometimes *E. obliqua* and understorey plants are declining.

It is considered that *P. cinnamomi*, as a recent introduction, is the likely pathogen.

3.3.5 Insect defoliation - Greaves (1966) has reported sporadic defoliations to regrowth eucalypts of height 2 to 8m in central Tasmania. The damage is caused by a leaf beetle *Chrysoptharta bimaculata*, principally to young regrowth of *E. regnans* and *E. viminalis*. *E. delegatensis* is also readily attacked while *E. obliqua* and *E. simmondsii* appear to be resistant under natural conditions.

Outbreaks could be associated with years having above average temperatures for December and January and the availability of host eucalypts within a critical height range. Kile (1973b) however, reports that this insect destroyed more than 40 per cent of the foliage in some areas of 60 year old *E. obliqua* and *E. regnans* in the 1972-73 growing season. He suggests that such damage may influence the growth and health of large trees. *E. globulus* was much less affected.

3.4. New South Wales and Australian Capital Territory

Extensive defoliation of alpine ash by phasmatids has posed the single greatest crown dieback problem in N.S.W. Crown dieback is common in woodland formations but is relatively rare in coastal sclerophyll formations.

3.4.1 Eden district - This is regarded as a key area because of its close proximity to dieback areas in Victoria. Crowns have been extensively fire damaged but no sign of deterioration of the understorey, and no damage to the overstorey has been detected, except in a very few wet conditions. Occasional scattered deaths in seedling regeneration have been associated with the presence of P. cinnamomi which is known to be widely distributed in the area (Forest Commission, N.S.W., 1973, pers. comm.)

Pratt and Heather (1973) report recovering P. cinnamomi from eucalypt forest in N.S.W. with disease symptoms in the overstorey at the following locations - Green Cape, Eden, Bega, east Batemans Bay, Penrose, Ourimbah, Coffs Harbour and Orara.

3.4.2 Newcastle district - At Ourimbah, some 80 km from Sydney, severe crown dieback has occurred in mixed eucalypt forest. This dieback appeared to be due chiefly to psyllid attack (Moore, 1962). P. cinnamomi and other fungi have been found in association with the dying trees. Similar psyllid induced deaths have been recorded in the Glen Innes, Wauchope, Coffs Harbour and Taree districts.

Hartigan (1969) reported that the dieback described by Moore in Wyong forestry sub-district developed in an insidious manner, the symptoms being masked by seasonal variations in forest cover. Species involved were E. saligna, E. deenei, E. microcorys, E. propinqua, E. peniculata and Syncarpia laurifolia. It was possible in 1969 to detect the disorder with a fair degree of accuracy and indications on the apparent spread had been 6 km in 10 years. The affected area covers about 30 km^2 between Wyong and Gosford. The forests have been exploited heavily for timber, contain a lot of land development and small farms and has been damaged by fire. There has been no spread of the disorder to the better areas of Ourimbah State Forest.

The disorder appears in patches of approximately 100 ha in extent originating from about half way up a hill to the ridge itself and then spreading along the ridge. It is assumed this pattern is due to distribution of susceptible species which is in turn a reflection of soil conditions. It would appear that the disorder is of complex causation in which soil condition, psyllids and Phytophthora all play a part.

3.4.3 Other areas - All such areas in which P. cinnamoni have been located (Pratt and Heather, 1973) are being investigated by the New South Wales Commission (pers. comm.). The present situation appears to be that very little serious damage has occurred. Crown dieback of eucalypts in N.S.W. is regarded however, as the single most important threat to the forest estate.

3.4.4 Australian Capital Territory - Some dead-top or dieback conditions are found throughout the wet and dry sclerophyll eucalypt forests of the A.C.T. These are most likely to be caused by drought, insects and wood rotting fungi (McArthur, 1973; pers. comm.)

Jehne (1970) sampled areas of disordered trees throughout the A.C.T. In general the selection of sampling site was guided by some visible symptoms of tree dieback, although these symptoms were mainly confined to individual trees and no cases of complete death of vegetation on any appreciable area were encountered. Phytophthora cinnamomi was found in half the eucalypt sites with dieback symptoms. Most dieback patches were found on waterlogged soils and after high seasonal rainfall. No area where either the understorey or the overstorey of the vegetation has been totally killed has yet been found in the A.C.T.

Jehne (1972) reports on scattered trees and patches of mature E. dives exhibiting crown dieback and death in dry sclerophyll forest at Blue Range. Eucalyptus dalrympleana was also occasionally affected. The dieback patches of up to one hectare in extent were on a steep, rocky slope with an easterly aspect at an elevation of 1000m. Most of the crown dieback appeared to be less than 2 years old although isolated dead trees showed that there had been earlier deaths. He suggested that the disorder must be largely due to a high level of root parasitism by Exocarpos cupressiformis.

Numerous deaths of recently established plants in the Botanical Gardens on Black Hill have been attributed to P. cinnamomi activity by Weste (1972).

3.4.5 Phasmatid defoliation of alpine ash - Since the early 1950's a phasmatid Didymuria violescens Leach has become a principle defoliator of eucalypts in the mountain forests of south-eastern Australia (Readshaw, 1965). The first outbreak was noted in Bago State Forest in 1952-53 and subsequently other outbreaks appeared further and further south of this with each successive generation of D. violescens. Initially its favoured habitat appeared to be the peppermint-gum association of the E. delegatensis - E. dalrympleana Maiden alliance, but later alpine and mountain ash associations were also heavily infested. The least favoured habitats were dry sclerophyll forests and snow gum communities. Approximately 1700 km^2 of forest were defoliated in 1962-63 and further defoliation occurred in 1964-65 (Mazanec, 1966). The most characteristic feature of the phasmatid outbreaks has been the synchronized occurrence of defoliation in the odd calendar years (1955, 1957, 1959, etc.) with no defoliation in the even years (Readshaw, 1965). This corresponds with the two year life cycle of the insect.

The effect of defoliation on the growth and survival of the mountain eucalypts varies considerably according to the species of the host tree. Eucalyptus radiata Sieb, E. dives Schauer, E. dalrympleana, E. viminalis and E. maculosa R.T. Baker can survive repeated defoliation mainly by producing large numbers of epicormic shoots. Eucalyptus delegatensis and E. regnans are more sensitive to damage and both species have suffered considerable mortality after only one complete defoliation. Shepherd (1957) described the effects of severe defoliation of alpine ash at Bago State Forest and showed that serious mortality and depression of diameter increment occurred. Mortality of mountain ash defoliated by phasmatids during 1960-61 and again in 1962-63 reached 83 per cent within two years of the second defoliation (Mazanec, 1967). The effect of successive defoliation on current annual radial increment ranged from an estimated reduction of one per cent in 1951 to 56 per cent in 1962 and averaged 20 per cent over the outbreak period of 16 years (Readshaw and Mazanec, 1969).

3.4.6 Crown dieback of eucalypts in woodlands and plantations - For many years research has been carried out on insects which defoliate eucalypts in south-eastern Australia by Carne. Biennial surveys during the past 8 years have studied insect infestation of trees bordering a route of some 100 km extending from Canberra to Euroa in Victoria (Carne, 1965). Most dieback observed in the survey appears to have resulted from insect attack:

(i) Saw-flies (*Perga* spp.) are among the most important defoliators of woodland eucalypts and are often present in numbers sufficient to destroy the entire foliage of host trees. These include *E. melliodora* A. Cunn., *E. blakelyi* Maiden and *E. camaldulensis* Dehn. *Perga affinis* is one of several species likely to prevent the growth or successful establishment of plantations of these and several other eucalypt species. Related saw-flies are responsible for severe and repeated damage to eucalypts dominant in alpine or sub-alpine catchment areas.

The principal area occupied by the species lies between the 540 mm and 760 mm isohyets where these delineate a 50-100 km wide corridor from Seymour in Victoria, north-east to Coolac in New South Wales. To the east of Coolac, the insect becomes progressively less abundant and has not been found east of Gunning. The wetter and colder limit is defined with remarkable precision from Seymour to Canberra by the Hume Highway (Carne, 1962).

The saw-fly is an inhabitant of river valley woodland, rarely becoming abundant in other situations and being absent from sclerophyll forest formations. The susceptibility of trees to infestation is influenced by seasonal production of new foliage. Those growing in sites where the water table is high, and whose leaf production is to a large extent independent of rainfall patterns, may be subject to chronic attack (Carne, 1965).

(ii) Christmas beetles of the species Anoplognathus montanus seriously damage E. albens in the Cootamundra district. Extensive dieback and mortality followed a series of seasons with very high beetle populations. This insect also causes extensive dieback of roadside or ornamental plantings of E. rubida, E. lindleyana and other species in the Australian Capital Territory (Carne, 1973, pers. comm.)

The species Anoplognathus porosus and A. chloropyrus defoliate plantations of E. grandis Hill in the Coffs Harbour region, (Carne, Greaves and McInnes, 1973). Severe defoliation is limited to young trees planted on old grasslands. Leaf beetles (Paropsis and Chrysophtharta spp.), a sap sucking bug (Eurymelia sp.) and psyllids also attack these plantations.

(iii) Psyllids have resulted in dieback of E. blakelyi, E. camaldulensis and E. melliodora in many parts of southern New South Wales and northern Victoria (Carne, 1973, pers. comm.)

(iv) Paropsine beetles and their larvae are prominent among the insects that defoliate woodland eucalypts in south eastern mainland Australia. They are active from late spring until early winter and can cause dieback or even death to eucalypts (Carne, 1966). One of the most abundant paropsines is *Paropsis atomaria* Ol. In the Australian Capital Territory the eucalypts most commonly attacked are *E. blakelyi*, *E. melliodora*, *E. polyanthemos* Schau and *E. fastigata* F. Muell. In the A.C.T. and N.S.W. *P. atomaria* was abundant only on young trees or on coppice growth, both in savannah woodland and in disturbed sclerophyll forest. Mature trees never supported numbers of the insect sufficient to cause appreciable defoliation (Carne, 1966). However, in extensively cleared areas in Victoria, severe defoliation of well-grown shelter belts of *E. cladocalyx* has been caused occasionally by this insect (C.J. Irvine, pers. comm.)

3.5. Queensland

To date there have been few reports of any economic effects of dieback in eucalypts. Of particular interest in recent years is a decline of *E. drepanophylla* (grey ironbark). This has been noted around Brisbane, Nambour, Gympie and Jimna.

In areas where damage occurs, death is widespread on sites ranging from gullies to ridge tops and grey ironbark is the only species affected. Death appears to be mainly of trees of the larger girth classes. Incidence of top crown dieback is fairly frequent.

In the Mackay region reports have been received of the death of patches of trees ranging up to 2 ha in extent. *E. carnea* has shown the greatest resistance to the disorder. Species mainly affected were *E. tereticornis*, *E. intermedia*, *E. creba*, *Tristania sauveolens* and *Glochidion ferdinandi*. No pathogens have been recovered from these areas on the several occasions isolation work has been undertaken. Features of these deaths were that there were proportionately more trees dead in the gullies than on ridges and that most of the deaths appeared to have occurred over a relatively short period of time. These forests were not regarded as suitable for hardwood management.

In general, stag headed eucalypts are evident through many commercial forests but it is impossible to say whether this is due to overmaturity, competition, droughts, mistletoe, insects, fires or fungi. Though increments may be affected, the incidence has no material effect on selection of trees in forest management (Queensland Dept. Forestry 1973, pers. comm.)

Phytophthora cinnamomi has been found associated with dieback in a number of instances. In North Queensland in a survey undertaken with the Australian National University the organism was found associated with a slight decline of *Eucalyptus* species near Kennedy on the coast. On the Atherton Tableland, it occurred in two separate locations near Ravenshoe with *E. acmenioides* and *E. eugenioides* suffering dieback. Few deaths had occurred in the areas. (Queensland Dept. Forestry, 1973, pers. comm.)

3.6. South Australia and Northern Territory

No factual reports concerning eucalypt crown dieback from these States has been received, with the exception of sporadic defoliation of *E. camaldulensis* in South Australia by psyllids.

3.7. Miscellaneous

3.7.1. Fire

3.7.1. Fire - Under modern management methods it is usual these days to omit reference to the serious effect that uncontrolled fire has or has had on promoting crown dieback in eucalypt forest. For the purpose of this seminar such an omission is unacceptable. Within Western Australia at least, uncontrolled fires have devastated several National Parks and water catchments in dry sclerophyll forest within the past few years. Mortality and crown dieback resulting from the relatively recent Dwellingup, Dandenong, Hobart and Blue Mountain fires represent greater changes in forest values than can be accredited to the numerous instances of crown dieback summarised previously. Fires represent a direct loss in wood values, increment and aesthetics but may also be precursors of future disease conditions (McArthur, 1973. pers. comm.).

3.7.2. Drought - Eucalypt crown dieback due to drought has been mentioned in conjunction with gully dieback in Tasmania, regrowth dieback and several insect problems. Drought alone must also be recorded as a major cause of eucalypt crown dieback in Australia.

Pook (1967) has reported effects of the 1965 drought on eucalypts in the Canberra district. Widespread wilting and death of eucalypts in native forests and woodland resulted. Water stress in eucalypts first became apparent at the end of February 1965, the first quarter of 1965 being the driest on record in the Canberra area. Wilting symptoms were initially obvious in trees of E. rossii Baker and Smith and E. macrorrhyncha F. Muell in circumstances where normal drainage through shallow soils had been interfered with, especially on warm slopes. By the end of March water stress was apparent in forests over a wide area. Stress in mature trees was first noticeable from the uniformly dull appearance of foliage. With increasing desiccation leaves gradually changed colour, became yellowish or chlorotic and in extreme cases turned brown and brittle as they died off. Leaves more than one year old were shed during a period of intense litter fall in the early stages of the drought.

On many sites, there was at first a tendency for the foliage of the exposed parts of tree crowns to be more desiccated than that afforded protection in the lower levels of tree canopies or on the cooler aspects of tree crowns. This meant that there was often a superficial "scorching" of crowns in forest stands having a more or less continuous canopy. Lateral "scorching" was apparent on the exposed sides of tree crowns on slopes of westerly to northerly aspect where desiccation was intensified by dry winds.

Desiccation of wood and bark and subsequent shrinkage caused splitting and decortication or bark shedding to varying degrees depending on the dryness of habitat, tree age and species characteristics. Progressive dehydration ultimately led to exposure and destruction of the cambium of droughted trees. This type of injury was frequently limited to the exposed sides of tree boles and main branches. Deterioration of trees under stress early in the drought facilitated invasion by bark beetles.

Maximum drought effect on eucalypts occurred in dry sclerophyll associations and occasionally extended into marginal savannah woodlands. The general pattern was for wilting of trees to occur on lighter textured, stonier and shallow soils, especially on steep sunny aspects. The most severe injury to foliage and bark, together with high mortality was found in scribbly gum. Stringy barks usually sustained severe wilting with less obvious bark injury and low mortality. Red box (E. polyanthemos Schau.) was rarely visibly affected and suffered least damage. Other minor species which wilted or died in some stands include E. goniocalyx, E. dives and E. bridgesiana. At some high mountain stations E. pauciflora E. stellulata and E. delegatensis suffered some degree of injury. All size classes of drought susceptible species from seedlings to overmature veterans were subjected to injury and mortality.

Most stands made rapid recovery after substantial rainfall of July and August 1965. In the following spring, shoots developed from epicormic buds on all but the most seriously decorticated trees. During the quite dry spell in January 1966 epicormic growth wilted on several damaged trees in areas where mortality had been high. Some of these trees finally died (Pook, 1967).

A series of drought years during the period 1968 and 1973 in the south-west of Western Australia has also resulted in crown dieback of some eucalypts in dry sclerophyll forest. This coincides with a record drought in the eastern goldfields woodlands in which many of these unique species are suffering extreme crown damage and mortality (Forests Dept. W.A. unpublished).

4. Discussion

Few of the disorders reported have been detailed to the extent that useful comments concerning causal agencies, methods of identification and possible economic implications can be developed at this stage. It must be obvious to the reader, however, that in total, economic implications of eucalypt crown dieback are considerable and that this seminar is well warranted.

To some extent, discussion of the set of disorders can be simplified by an approach within the following broad groupings:

4.1. Known soil pathogen - Jarrah dieback (Podger, 1972), the Victorian diebacks (Marks et al., 1972; Weste and Taylor, 1971; Weste and Law, 1973), potential diebacks in New South Wales (Pratt and Heather, 1973) and Tasmanian east-coast dieback (Palzer, 1973). These problems are not completely understood and control potentials and procedures need to be developed. <u>Phytophthora cinnamomi</u> is, however, expected to be a major causal agency.

4.2. Insect damage - Jarrah leaf miner (Wallace, 1970), phasmatid defoliation (Readshaw and Mazanec, 1969) and the various seedling and woodland defoliations (Greaves, 1966; Kile 1973b; Carne 1962; 1965; 1966; Carne et al. 1973) have identified causal agencies and, in some instances, acceptable partial control techniques. The environmental bases for the balance or imbalance of these natural agencies requires greater consideration.

4.3. Altered microclimate - Under this perhaps misleading heading I have grouped jarrah crown deterioration (Wallace and Hatch, 1953), high altitude dieback of <u>E. delegatensis</u> (Ellis, 1964), gully dieback (Felton, 1972), Ourimbah dieback (Hartigan, 1969) and regrowth dieback (Felton, 1972). At present the causal agencies of these diebacks are either not known or have apparently resulted from natural imbalances due to the process of forest management and exploitation. This latter factor could be associated with groups 4.1 and 4.2 and probably it is the complexity of natural factors which may be in imbalance which distinguishes the above group. It is suggested that the unknown potential threat posed by these disorders requires their thorough and early investigation in detail. Their existence demands the improvement of ecologic knowledge if future forestry in Australia is to be soundly based.

4.4. Fire and drought - damage by these two natural agencies is basic to natural eucalypt systems. The delicate balance of natural fire sequences with species presence and vigour, as indicated by high altitude dieback (Ellis, 1972), demands increased knowledge of fire ecology. Too little burning or too frequent burning may jeopardise the balance of entire ecosystems. The role of drought in disease expression as for instance in the case of mortality in P. cinnamomi problems and gully dieback (Felton, 1972) is poorly understood. The influences of major drought on eucalypt ecosystems (Pook, 1967) have not been adequately studied.

It is not intended that this grouping should do more than to assist the seminar participants to approach the detailed proceedings which follow with some initial screening of the various crown disorder conditions which could arise. This screening will be more efficient and practical with the development of successive reviews and sessions.

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