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FOREST RESEARCH INSTITUTE

WESTERN REGIONAL STATION.

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RESEARCH PROJECT W.A.4 - THE CAUSE OF JARRAH DIEBACK.

PROGRESS REPORT NUMBER 3 - WATERLOGGING AS A POSSIBLE CAUSE.

This report is the third in a series which examines hypotheses of cause advanced by earlier workers to explain jarrah dieback. Earlier reports examined and rejected hypotheses of decline of nutrient availability, accumulation of toxic concentrations of ions, and drought.

This report examines waterlogging as a possible cause.

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Waterlogging as a possible cause of jarrah dieback.

Loneragan (1962) has suggested that dieback may be due to winter flooding of water gaining situations in the landscape. This, he suggested, could have come about through the increased mass drainage following removal of forest cover during "trade cutting" operations. Increased run-off and greater sub-surface flow have been consistently associated with reductions in plant cover (Kittredge 1948). This reduction may be due to harvesting or to the removal of canopy by other agencies such as fire. McArthur (1964), for example, reported an immediate and substantial increase of stream flow on small catchments in jarrah forest defoliated by fire during January 1961.

Where run-off accumulates in slowly draining situations at lower levels in the landscape the soil may remain saturated for a considerable period. In these conditions gases contained in the soil are displaced by water. Effective soil aeration is essential for maintenance of normal aerobic respiration of plant roots and many soil organisms. Waterlogging results in reduction in the availability of oxygen and accumulation of respired carbon dioxide. These conditions may have profound morphologic and physiologic effects on the plant. These include a conversion to anaerobic respiration with consequent production and accumulation of toxic by-products in the plant, associated rhizosphere micro-organisms and in the chemical status of inorganic constituents of the soil (Daubenmire 1959). Plant species differ widely with respect to their requirements for aeration (Daubenmire 1959 and Kramer and Kozlowski 1960) and thus in their relative abilities to tolerate sub-optimal aeration. Such differences in species have been shown for coniferous species (Zak 1961), for American hardwood species (Hosner and Boyce 1962) and for Eucalyptus(Boden 1962).

Evidence consistent with waterlogging as a cause of dieback.

The field occurrence of the seven most common eucalypts in the jarrah forest region indicates a wide range of variation in adaptation to environments which are seasonally waterlogged. E. rudis occurs on seasonally flooded soils of low relief on the Swan Coastal Plain, particularly in the vicinity of Dardanup, but is typically riparian. E. wandoo and grows well on soils which are subject to short periods of flooding in winter, but also on better drained soils where clay subsoil is within several feet of the surface. E. patens and E. calophylla extent on to poorly drained sites but usually only as scattered and unhealthy specimens. E. marginata is almost entirely restricted to well drained soils in the northern jarrah forest but occurs on the winter flooded soils in the south. Its growth on ill-drained soil is invariably poor. E. megacarpa is restricted to relatively well drained, but water gaining, sites in proximity to semi-permanent streams. Boden (1962) points out that there are no species of Eucalyptus which grow on permanently water-logged soil. He considers that many species which are apparently adapted to waterlogged environments are restricted to slightly better drained microsites. "Their position in the field is determined more by a high water requirement in summer than an ability to withstand water-logging in winter."

The earlier workers' observation that dieback did not occur on deeper soils or on steep slopes was consistent with an hypothesis that the disease developed only on shallow soils of impeded drainage in water-gaining situations. The strong association of the disease with cutting was also consistent with the claim that the losses were due to an increase in height of water tables. Evidence of a climatic trend to increased winter rainfall (Gentilli 1952) also favoured this interpretation. The few exceptions to the pattern of association of dieback with cutting might be due to mass drainage effects on the small residual areas of virgin forest from which dieback had been reported, although these had not been directly affected by cutting. The occasional dieback area in a typical topographic situation might be explained by localised subsoil ponding. Such ponding was observed on Frollets formation in 1960 in an area pattern drilled by a mining exploration company.

The observed failure of jarrah to regenerate on dieback sites is consistent with the hypothesis since death of the stand would tend to increase the period of waterlogging.

Test of the hypothesis.

E. marginata is the only species of the seven main eucalypts which occur in the jarrah forest which has shown marked sensitivity to dieback in the field. If it was found to be less sensitive to water-logging than any one of the dieback resistant species the hypothesis, that waterlogging per se is the cause of jarrah dieback, should be rejected. This hypothesis was tested in two experiments numbers 2 and 3.

Experiment 2.

The seven species were grown on soil from the location described in detail in Experiment 1 (See Progress Report No.2), potted in one-gallon metal cans. In February 1963 seed was sown directly into the pots of sieved and mixed soil. On 7/6/63 when most plants were 1.5" - 4" tall, six replications of each species was thinned to one plant per pot and immersed to soil level in a waterlogging tank. A similar number of paired controls were placed in an adjacent unfilled tank. Positions in the tanks were randomly assigned.

Waterlogging was commenced on 7/6/63. Fresh water was piped into the tanks once a week.

Results.

There were no deaths of plants before 60 days. The first symptoms of distress were in E.marginata; the large leaves became flaccid yellow brown in colour and marginal necrosis and slightly curling of the leaf lamina developed. E. rudis grew well and developed aerenchyma at the stem base and cladogenous roots which grew out several feet through the water. E. rudis was the only species which made strong terminal growth during the experiment. The death of all foliage occurred in plants of most species at various times during the experiment. The number of days waterlogging until the plant tops died was recorded for each pot. The data is summarised in table 1.

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Table 1. Number of days before death of foliage.

	Replications						
	1	2	3	4	5	6	Mean
E.marginata	60	70	84	99	106	196	102
E.megacarpa	29	99	154	168	179	208	139
E.patens	106	179	208	252	263	263	212
E.accedens	99	204	215	252	279	332	230
E.wandoo	200	204	236	246	252	260	233
E.calophylla	196	232	246	260	263	333	255
E.rudis	291	350+	350+	350+	350+	350+	340

There were no deaths in the control series during the period of the experiment.

The effects of waterlogging in the field are determined, not only by the ability of a species to tolerate waterlogging, but also by the ability of the plant to recover once waterlogging ceases. It is possible that the plants may have suffered root damage which, though not expressed in top response, under the conditions of the experiment might be lethal when aeration returned to normal. A second experiment was made to determine the relative response of the same seven species to several periods of waterlogging and return to well aerated conditions.

Experiment 3.

For each of seven species eighteen 6" plastic pots with openings at the base were filled with screened soil from the same area as for experiments 1 and 2. Pregerminated seed was sown on to the pots on several occasions from 10/7/64 to 20/10/64. On 19/8/65 the pots were randomly assigned to three replications of six treatments for each species and thinned to five seedlings per pot. The pots were then placed in larger pots so that the surface plane of the two pots coincided. The outside pot was then filled with water for multiples of ten days up to 50 days. Deaths of the seedlings in each treatment were determined six weeks after the close of the longest waterlogging treatment (see table 2.).

Table 2. Mean plant mortality of seedlings of seven Eucalypts after variable periods of waterlogging.

Species	Treatments					
	0	10	20	30	40	50
E.marginata	7	7	27	33	53	53
E.megacarpa	0	0	0	0	0	0
E.accedens	0	0	0	0	0	0
E.patens	0	0	0	0	0	0
E.wandoo	0	0	0	0	0	0
E.calophylla	0	0	0	0	0	0
E.rudis	0	0	0	0	0	0

Conclusion.

E.marginata is substantially less tolerant of waterlogging than any of the other species. The experiment provides no basis for the rejection of the hypothesis. More recent developments, however, throw doubt on this hypothesis. Dieback has recently developed in extensive areas of essentially undisturbed forest in the low plateau west of Nannup, and has also been recently recorded in several locations on well drained soils on steep slopes (up to 28°). These occurrences require some other explanation. In the first instance it is difficult to envisage how the stands west of Nannup have suddenly become very sensitive to conditions which they appear to have tolerated for at least half a century. It is possible that the climatic changes reported by Gentilli (1952) may have a bearing on this development. Their effects, however, might be expected to have been more widespread and gradual, and without a pattern of spread, rather than sudden and localised.

A further inconsistency was revealed once the significance of deaths of ground species was recognised. Plants which are apparently adapted to poorly drained environments, e.g. Swamp Banksia (Banksia littoralis), Banksia quercifolia, Leptospermum ellipticum, Adenanthos obovata, Aotus ericoides and Xanthorrhoea spp. may be dead and dying a few feet distant from healthy patches of the same species growing on apparently identical sites. In some of these situations B.grandis or E.marginata co-occur and show similar responses, e.g. dead and dying jarrah and B.grandis among dead and dying B.littoralis, and healthy B.grandis and jarrah among healthy B.littoralis a few feet away in apparently identical sites. Such circumstances are usually temporary and may exist for only a year or two before the whole area of the swamp community is affected. Such situations may be seen to develop in one swampy site but not in other nearby swamps, despite the apparent similarity of both the sites and the condition of the surrounding forest. The disease often develops in some of these other sites several or many years later.

Finally, the hypothesis that waterlogging per se causes jarrah dieback is not consistent with the very restricted occurrence of dieback in the wetter southern forests in those areas cut over many years ago in the vicinity of Manjimup, Pemberton and Walpole.

Although the marked sensitivity of jarrah to waterlogging is consistent with the hypothesis that waterlogging is a cause of jarrah dieback, the evidence of other aspects of the syndrome suggests that waterlogging alone is not an adequate explanation of the cause of jarrah dieback.

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