STUDIES

ON PROBLEMS OF REGENERATION

OF

EUCALYPTUS REGNANS

IN TASMANIA

By

K. W. CREMER

Master of Science Thesis

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Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Tasmania.

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(Paper presented to "Australian Forestry" 1962)

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PART A

INTRODUCTION

CHAPTERS I AND II

CHAPTER I

IMPORTANCE AND ENVIRONMENT OF THE E. REGNANS FOREST

A. IMPORTANCE AND DISTRIBUTION OF THE E.REGNANS FORESTS

E. regnans is confined to Tasmania and Victoria. It is one of the three or four most important timber species in these two states. In 1958, *E. regnans* produced the fifth largest volume of sawn eucalypt timber in Australia (Hanson, 1961).

E. regnans grows best under fairly cool conditions at 100 ft. to 2,000 ft. in Tasmania and at 600 ft. to 4,000 ft. in Victoria, on a variety of soils of medium to high fertility under a fairly evenly distributed rainfall of at least 45 inches per year. The tree frequently exceeds 200 ft. in height (up to 322') and usually grows in pure stands of one age, sometimes with 10,000 cubic feet of merchantable wood per acre. Its most common associates are *E. delegatensis* and *E. obliqua*. *E. Regnans* is "spar aged" at 150 years and "mature" at 250 years. It rarely exceeds 400 years. In dense stands on good sites it may grow an average of 100 cubic feet of merchantable timber per acre per year during the first 100 years. Its intended rotation is 60 to 90 years.

E. regnans is the most important single timber species on the 330,000 acre pulpwood Concession area of the Australian Newsprint Mills Ltd. Most of this area is contained by the basin of the Florentine River. Next in importance are *E. delegatensis* and *E. obliqua*. These species commonly mix with *E. regnans* especially at the

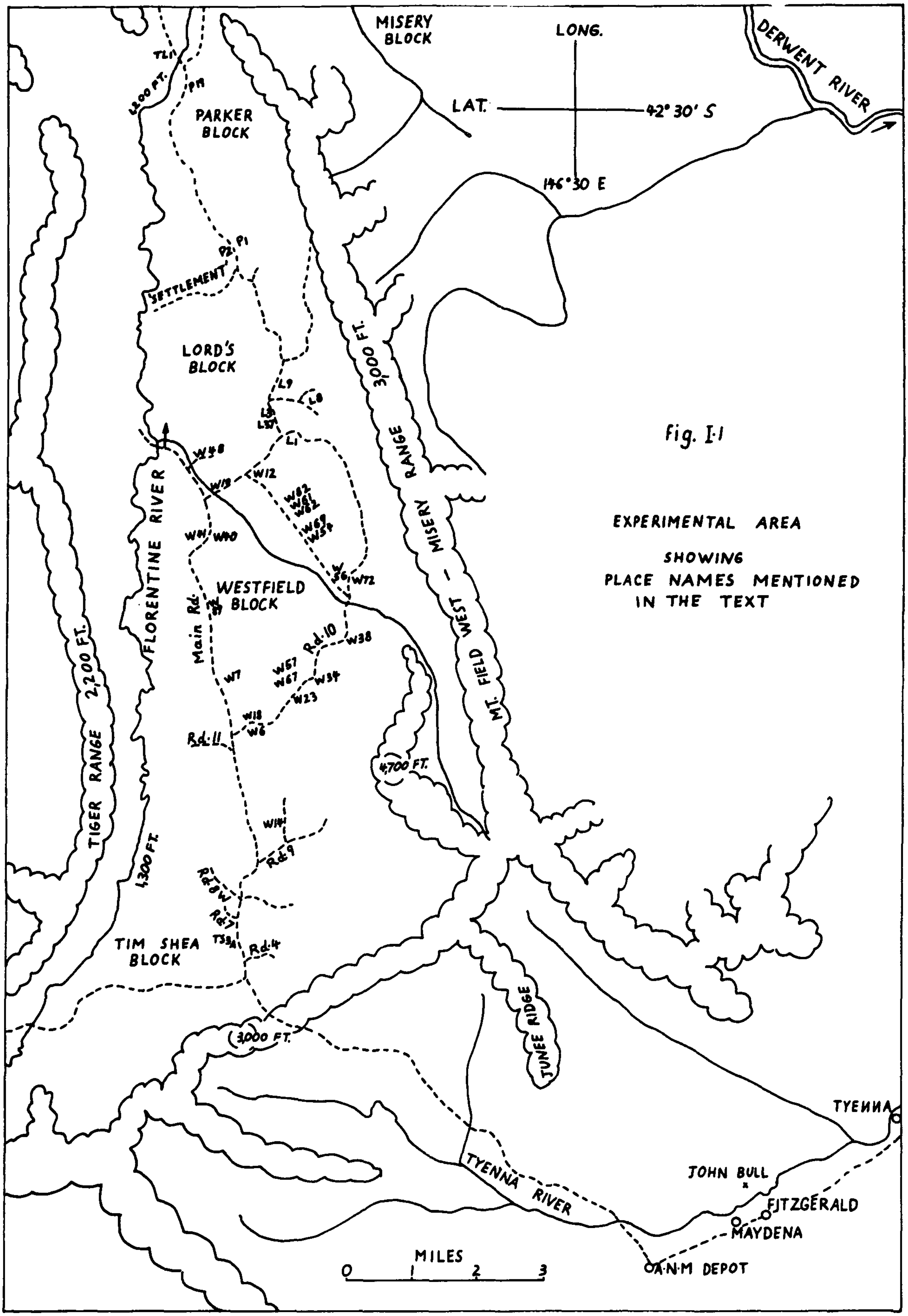


Fig. I·1

EXPERIMENTAL AREA
SHOWING
PLACE NAMES MENTIONED
IN THE TEXT

latter's limit in range of altitude and dryness respectively. The ecology and regeneration requirements of these closely related species when associated with a dense understorey are similar to those of E. regnans. Most of the findings for E. regnans would, therefore, apply equally well to these species when grown in a wet climate.

I. Geography

The Floretine Valley is near the centre of Tasmania, an island about 200 miles in diameter. The geographical features referred to in the text are shown in figure I.1. A coupe is an area of forest which is felled as one unit. The coupes are numbered in the approximate order of felling within the forest block where they occur and whose initials they carry, e.g.W.56. Roads are numbered. Some areas may be referred to by the road which serves them, e.g. Road 8W, Road 11.

II. Topography.

The main part of the Florentine Valley is about 1,200 ft. high and rises at a gentle gradient from N. to S. The bottom of the valley is 2 - 3 miles wide, is steeply flanked on the eastern side by the 2,000 to 4,700 ft. high Misery-Field West range and on the western side by the 2,000 - 2,500 ft. high Tiger Range (see figure I.1).

III. Geology and Soils.

Inside the Florentine Valley, the occurrence of E. regnans is limited by altitude and soils, which are both largely determined by geology.

The soils which carry good E. regnans are characterized by medium to high fertility, by good drainage but high moisture holding capacity and by a rather heavy texture. They are easily puddled by tractors and snigged logs at most times of the year.

A large accumulation of peaty humus on the surface of the ground is a common and outstanding characteristic of these soils. The humus varies in depth from little or nothing where the understorey is wet sclerophyll scrub to several feet depth at the butt of mature eucalypts and Nothofagus where the understorey is rainforest.

A close study of the soils has not been made. The individual soil types are referred to by their parent materials. Within such a soil type, the soils appear to be relatively uniform except under conditions of extremely good or extremely poor drainage, or extreme altitude and exposure.

The broad valley floor consists of cavernous limestone. Except on the occasional rises and knolls where the limestone rock frequently outcrops, the derived soil is a deep, yellow clay loam. Both are well drained and support good E. regnans forests.

The Misery-Field West Range has a capping of dolerite. This rock, in situ on the Misery Plateau and transported by solifluction and creeks or glaciers down the eastern slopes of the valley (Gilbert, 1959) was the parent material for another important soil type. The soils derived from dolerite form a red brown clay-loam of very variable depth. The solifluction material where not on steep slopes produced often very deep and relatively moist soils even though the surface is commonly very rocky. Deep dolerite soils are often poorly drained where they occur on flats or in hollows. The extensive fluvio-glacial gravels tend to be deep and very well drained. On the Misery Plateau the dolerite soil is apparently very shallow and certainly very rocky. On drier sites such as the ridges and steep slopes of shallow rocky dolerite soil, *E. regnans* is usually replaced by *E. obliqua* and other species.

Mudstones produce deep, moist, yellow, clayey soils over considerable areas mainly along the eastern and northern portions of the valley.

The infertile, highly silicious soils on Tim Shea and on occasional low ridges along the valley bottom do not carry *E. regnans*.

IV. The Climate.

(1) Precipitation and Evaporation.

Table I.1:

Rainfall recorded at Maydena 1945-1960.

The potential evapotranspiration is calculated from mean monthly temperatures according to Thornthwaite's method (1948).

	Inches				
	Rainfall			Potential Evapotranspiration (Mean)	Water Balance (Mean)
	Min.	Max.	Mean		
January	.89	3.90	2.42	3.85	-1.43
February	1.37	5.60	2.65	2.91	-0.26
March	1.06	5.93	3.04	2.49	+0.55
April	1.03	9.76	4.23	1.67	+2.56
May	1.49	18.16	4.94	1.26	+3.68
June	.09	15.46	4.74	.91	+3.83
July	1.01	9.42	4.58	.74	+3.84
August	1.43	12.33	5.51	1.09	+4.42
September	1.23	7.36	4.12	1.50	+2.62
October	2.46	7.86	5.07	2.09	+2.98
November	2.18	8.10	4.45	2.56	+1.89
December	.39	5.81	3.68	3.55	+0.13
Year	29.03	63.17	49.43	24.52	24.91

These figures put the climate of Maydena just within the most humid climatic type recognized by Thornthwaite (1948). In the United States, similar climatic regions occur on the north-west coast and in some mountainous areas near the east and west coasts.

Table I.1 shows that January is normally the driest month of the year and that the summer is very much drier than the winter.

This is due mostly to the much higher rate of potential evapotranspiration in summer. The relative dryness of <u>different</u> summers is nevertheless controlled by the relative rates of rainfall and differences in temperature have a comparatively small effect. Thus the relatively very dry summer of 1960/61 received 13 inches of rain in six months and would have avaporated 19 inches, while the very wet summer of 1957/58 received 24 inches and evaporated 16 inches of rain.

The annual rainfall in the Florentine Valley is 5 to 10 inches higher than in Maydena. Within the Florentine Valley, the rainfall increases towards the south and towards higher altitudes. Very dry summers are unusual. The top soil dries out to several inches depth only in dry years. The litter underneath a plant canopy is almost continuously moist during the winter half of the year.

Snow falls several times each winter but does not usually last more than two days. Fogs are frequent. Dew precipitation may be important at the higher altitudes.

(2) <u>Temperatures</u>

See table I.2

Table I.2:

Temperatures measured in a Stevenson Screen at Maydena during 1952 to 1960 (Mount, 1961):

Photo No.1 : Mature *E. obliqua* ermergent over dense rainforest understorey of *Atherosperma moschata, Nothofagus cunninghami,* and *Eucryphia lucida.*

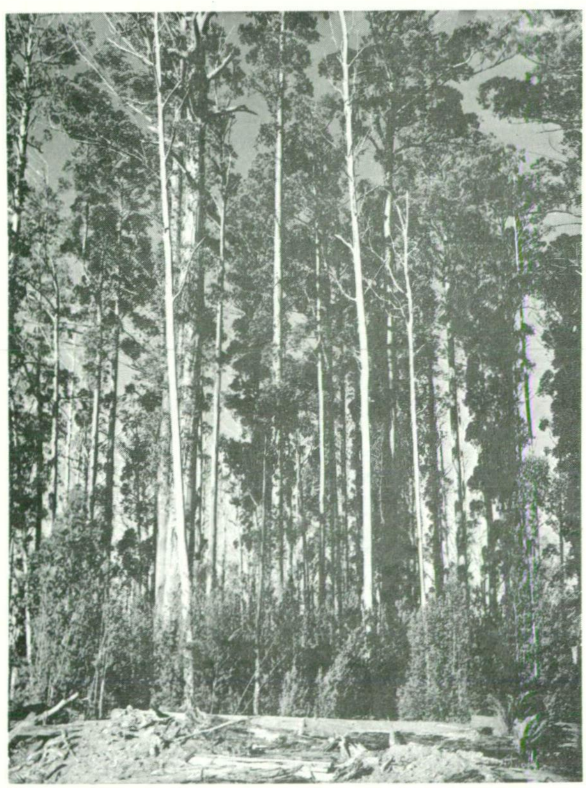


Photo No. 2 : Spur stand of *E. regnans* over wet sclerophyll understorey of *Pomaderris apetala.* Note same eucalypt regrowth of the same age as the under storey. Dead trees are due to suppression and fire.

° Fahrenheit

	Extreme Max.	Extreme Min.	Mean Max.	Mean Min.	Mean Daily
January	103	30	72	47	59
February	89	31	69	47	58
March	89	30	66	44	54
April	81	21	59	42	50
May	68	26	53	39	46
June	67	20	49	36	42
July	75	20	49	33	41
August	65	20	50	35	42
September	72	23	56	36	46
October	82	20	58	37	48
November	86	30	62	42	52
December	93	28	66	45	56

This table shows that the climate of Maydena is cool-mesothermal and insular. There are some hot days but no very cold days, even though frost may occur at any time during the year.

The temperature regime resembles that of the north-west coast of the U.S.A.

V. Vegetation and Ecology.

Eucalypt forests demand much light but permit most of it to pass through their canopy. In the moist temperate climate on soils which can grow *E. regnans* this excess light permits the growth of a dense understorey.

Because underneath this understorey light intensity at ground level is too low for the regeneration of the eucalypts and because eucalypt seed is dispersed effectively only within tree height distance and is not stored in the ground, the perpetuation of the eucalypts depends on the removal of the fire sensitive understorey by fire or by the axe at intervals shorter than the life span of the eucalypts (300-400 years) but at least as long as the age of seed production (10 to 20 years). The E. regnans tree is not much more fire resistant than the species of its understorey. Consequently it usually occurs in stands in which all trees are of one or two ages.

The understorey of the eucalypt forest may be dominated by wet sclerophyll species such as Pomaderris apetala, Acacia dealbata, Olearia argophylla, Prostanthera lasianthos and Zieria arborescens; or else it may be dominated by rainforest species such as Nothofagus cunninghamii and Atherosperma moschata.

Spar aged to mature eucalypts over a rainforest understorey are a late stage in the succession towards the climax of pure rainforest from a fire disturbance 150 to 350 years ago. The wet sclerophyll understorey is the result of a more recent fire (up to 40 years in the Florentine Valley) and is, at least in Tasmania, considered an earlier stage in the same succession towards a pure rainforest climax. (The above two paragraphs are largely based

Gilbert, 1959). Where spar to mature aged eucalypts are standing over a wet sclerophyll understorey, the understorey usually owes its origin to a fire which was much more recent than the fire which caused the regeneration of the eucalypts.

The wet sclerophyll scrub usually occurs on sites which are drier and subject to more frequent fires than the areas which carry rainforest with a eucalypt overstorey. In many cases the rainforest species are so rare amongst the wet sclerophyll scrub that the rainforest climax appears to be delayed indefinitely even in the absence of future fires, because the high fire frequency of the past has eliminated the seed sources for the rainforest species.

The vegetation and ecology are discussed in detail by Gilbert 1959 and Cremer 1960. The early succession following the burning of completely felled areas is described in Part D of this thesis.

VI. Fauna known to affect Eucalypt Regeneration.

Two major problems in obtaining eucalypt regeneration in the Florentine Valley are the browsing of eucalypt seedlings by native game and the removal or destruction of eucalypt seeds.by insects. A third problem is that young seedlings up to one inch in height suffer considerable mortality through loss of leaves and buds, probably due to small invertebrates, including insects.

Seedlings between 2 and 24 inches tall are heavily reduced in numbers and growth rate by attacks from browsing animals. The most important species responsible for this damage are the kangaroo (<u>Protemnodon rufogrisea v. frutica Ogilby</u>, the wallaby (<u>Thylogale billardieri Desm</u>) and the brushtail possum (<u>Trichosurus vulpecula fuliginosus Ogilby</u>). The first is less important in the denser forest types. In the Florentine Valley the Ringtail possum (<u>Pseudocheirus convolutor Oken</u>), theWombat <u>(Vombatus ursinus tasmaniensis, Spen. and Ker.</u>) and the European rabbit (<u>Oryctolagus cuniculus</u>) are not (yet) important. The two most important species, namely the wallaby and the possum are widely distributed and numerous throughout the forest. They present an increasingly serious problem as their populations grow in response to the creation by logging of larger areas of suitable habitat.

Insects may prevent the large majority of sown seed from germinating. The small black ant <u>Tridomyrmex foctans</u> Clarke and the Lygalid bug <u>Dieuches notatus</u> Stal. have both been observed to remove <u>E. regnans</u> seed in Victorian forests (Ashton, 1957, Grose 1957). The presence of the latter species in large numbers and its keen seed robbing activities on recently burnt seedbed have been noted also in the Florentine. Ants also occur here.

CHAPTER II

THE PROBLEM OF OBTAINING REGENERATION

A. <u>NATURAL REGENERATION IN THE VIRGIN FOREST</u>

All virgin stands of <u>E. regnans</u> have originated from fire. The wild fires of the past have produced a combination of circumstances favourable for regeneration (Gilbert, 1959). These conditions are:

- The excessive shade is removed by destruction of the understorey.
- A favourable seedbed is prepared by the burning of slash and litter layers.
- Seedrobbing insects and the slowly breeding marsupials which browse eucalypt seedlings are destroyed on or driven out of areas so large that they could not be fully re-invaded before the regeneration of eucalypts had become established.
- The eucalypt seed survives on standing tree crowns and is shed after a fire onto a well lit, suitable seedbed free from excessive seed robbery and plant browsing.
- The combination of climate and soil fertility resulted in a suitable fire frequency on the areas which now carry eucalypt forest.

B. <u>PAST LOGGING METHODS</u>.

The great majority of Australian eucalypt forests is logged and probably regenerated under the "group selection system" (Jacobs, 1955). This system is an adaption of the original forest exploitation practice of selective logging. It works in the drier forests where the eucalypts are of all ages and advantage can be taken of the seedlings and saplings which became established before logging.

Extensive regeneration surveys in the felled *E.regnans* forests of Victoria and Tasmania have shown that adequate regeneration is not the normal result of logging for logging's sake. The small number of useless eucalypts left standing after the logging of even-aged high quality forest areas, especially when logging for pulpwood, were an inadequate source of seed. Advance growth was not present. The mostly unmerchantable understorey of wet sclerophyll and rainforest species remained standing to cast excessive shade; and outside the 20% or so of mineral soil exposed by the logging operation, the seedbed was hidden under too much slash. Regeneration was successful only where logging was so selective as to leave an adequate number of useless standing trees as seed source and provided a fire destroyed the remaining understorey and slash.

C. PRESENT LOGGING METHODS -"The Two-Stage-Logging System".

Based on observations of natural regeneration in the virgin forest and upon the researches of Cunningham (1960) and Gilbert (1958), the Tasmanian Forestry Commission and the A.N.M. Company decided in 1959 to adopt a system of logging for regeneration called "Two-Stage-Logging" and which resembles the European Uniform System.

A.N.M.'s practice of this system was introduced in 1959, and described by Frankcombe (1960). The following are its main prescriptions:

1. All merchantable understorey trees are logged
2. Abour five dominant, well spaced eucalypts per acre are marked for retention as seed trees on a demarcated coupe some 20 to 50 acres in area. (See photo. No.3)
3. The unmarked eucalypts are felled and removed.
4. The slash is burnt when the seed trees are found to carry an adequate seed crop (" Regeneration burn").
5. Browsing animals are poisoned or trapped while the seedling regeneration is vulnerable.
6. The seed trees are removed when adequate regeneration has become established.

Where the number of eucalypts in the unfelled forest is less than about 10 per acre, as is the case in most of the older forests, all the eucalypts are reserved as seed trees.

The wet sclerophyll understorey is prepared for the regeneration burn by dozing or (more cheaply) by highlead logging instead of tractor logging.

Tractor logging implies that the logs are dragged by tractor from the stump to the roadside. With highlead logging, the logs are pulled to the roadside by a long wire rope which passes over an elevated pulley at the roadside. Tractor logging causes more extensive and more thorough

Photo No. 3 : Coupe of five reserved seed trees of *E. regnans* per acre ready for regeneration burn. Former spar stand with rainforest understorey.

soil disturbance, while highlead logging causes very much more of the understorey to be pushed over.

It should be noted that the two-stage logging system became economically feasible only after the recent introduction of the one man chainsaw and the crane type mobile log loader called "Skagit".

D. PROBLEMS THAT WERE TO BE SOLVED IN TWO-STAGE-LOGGING

Part B. of this thesis deals with the problem of natural regeneration from two-stage-logging and Part C. deals with problems of artificial regeneration from sowing and planting.

Earlier workers, especially Gilbert (1958) and Cunningham (1960) had determined the following facts and requirements for successful natural regeneration:

(1) At least 10 to 30% of daylight is needed at ground level. This means that most understorey must be removed.

(2) Thick layers of slash, such as are normal after logging in E. regnans stands, constitute an almost impossible seedbed. The slash must be removed by burning or dozing.

(3) In the presence of seed robbing insects at least one to two pounds of well distributed seed are required on each acre of suitable seedbed protected from browsing. Seed is not stored in the ground for over 18 months, nor does it survive

a fire, except on standing trees. Effective seedshed from trees is limited to a distance within tree height. Trees which are left standing because they are unmerchantable are likely to be poor seeders.

(4) Browsing by native game seriously reduces survival and growth of eucalypt seedlings. The regular annual increase in logged areas gives the population of browsing anamils, which is relatively sparse in the virgin forest, a chance to increase rapidly with the extension of this suitable habitat. The relatively small, new logging coupes are then rapidly invaded by a large population.

There were a lot of additional unsolved problems in connection with the production of satisfactory regeneration from the two-stage-logging system. These problems are dealt with in Part B. of this thesis:-

Chapter III deals with methods of removing the useless understorey. The results of a tree poisoning experiment are summarized here. The Forestry Commission of Tasmania are studying alternative mechanical methods of removing the unwanted understorey.

Chapter IV goes into the normal seasonal pattern and mechanism of seedshed. This chapter shows when to expect the seedshed which is to produce

natural regeneration without the use of fire.
Chapter V is a report on investigations concerning the dispersal of seed from isolated seed trees and from the edge of an uncut forest. Both distance and direction of seed dispersal are studied.
Chapter VI deals with the effect of various types of fire upon the survival of eucalypt seed trees and their ability to produce a useful supply of seed after the regeneration burn. There is also a discussion of the ecological significance of different types of fire in the virgin forest and of differences in fire resistance due to the species, age and vigour of individual trees and due to their environment.
Chapter VII is a report on observations and experiments concerning the effect of fire on the acceleration of seedshed.
Chapter VIII gives observations and discussions on the factors which determine the quantity of seed production. The necessity for the proper selection of seed trees and the proper timing of regeneration burns in relation to annual variations in seed production is demonstrated. A method for assessing and predicting seed crops on standing trees is given. The Forestry Commission of

Tasmania are continuing this work.

Chapter IX describes the pattern of germinations, deaths and growth after regeneration burns in autumn. The Forestry Commission of Tasmania are studying the effect of logging the seed trees on the survival of the young eucalypt seedlings.

The final part of this thesis, Part D., concerns both natural and artificial regeneration. It is a study of the early plant succession on completely felled and burnt areas of forest. It gives information on how long after a burn sowing and planting are possible and on when the seed trees should be harvested.

E. PROBLEMS OF ARTIFICIAL REGENERATION.

Prior to the commencement of these studies no sizeable areas of *E. regnans* regeneration had been established by artificial means in Tasmania. However, considerable relevant knowledge had been accumulated mainly by the researches of Cunningham (1960) and Gilbert (1958) and by some sowing and planting experience with *E. regnans* in Victoria.

The sowing and planting experiments described in Part C. of this thesis were designed to answer the following main questions:

(1) Applying the findings of earlier workers, what level of success can be expected from measures of artificial regeneration on a field scale, in the Florentine Valley?

(2) How do broadcast sowing, spot sowing and planting methods compare with each other?

(3) What is the quantitative benefit of protection from browsing?

F. <u>RELATIVE ADVANTAGES OF DIFFERENT METHODS OF REGENERATION.</u>

The "best method" is the one which gives suitable results at minimum costs in the long run. Though highly desirable, detailed economic investigations into alternative methods of regeneration have not been made. Perhaps the most important and also the most difficult question is what maximum expenditure is justifiable? How does this maximum vary with the location and productivity of the site? What expenditure on any one site offers the optimum return? Consequently, what is the standard of regeneration required on any one site? The standard of "no regeneration" is probably not justified anywhere, in the long run. There must, however, be very large differences in what is the most profitable standard on a fertile accessible site close to the consumer, as against inaccessible, distant sites.

Natural regeneration is possible only where there are seed trees with seed. The understorey has to be removed and burnt in any case. The special cost of natural regeneration is, therefore, the marking, retention and separate logging of seed trees. This cost is probably less than the cost of collecting, extracting and sowing of the seed. It is certainly less than planting, at least in the short run. Natural regeneration is not so easy to obtain where the logging has to be done by high leading, because of the hampering effect of the standing seed trees. One advantage of the seed from seed trees selected for their dominance is the superior genetic quality of the seed.

Where no effective natural seed source is present or where natural regeneration has failed, artificial regeneration must be used. Sowing can only be used before the growth of weeds following the fire has become too dense (See Chapter XIII).

If sufficient seed is available at sufficient densities for easy collection, artificial sowing may be cheaper than retention of seed trees. Such seed sources are available in some areas in some years. The relative merits of spot sowing as against broadcast sowing are discussed in Chapter XI. Sowing is probably more reliable than the use of seed trees.

Planting is initially the most expensive, but also the most versatile and reliable of regeneration methods. It may be used at certain stages of the secondary succession after fire when weed competition is already too heavy for seedlings starting off from seed. Planting reduces the rotation age by one year. Planted seedlings remain vulnerable to browsing for a shorter period than sown seedlings.

On at least some *E. regnans* sites in Victoria planting of *E. regnans* is cheaper, more successful and more profitable than the usually planted *Pinus radiata* (Redmond, 1953). Because of their superior competitive ability, planted seedlings will always have at least a limited usefulness in filling up or restocking areas where seed was partly or entirely unsuccessful in establishing satisfactory regeneration.

PART B

NATURAL REGENERATION

CHAPTERS III TO IX

CHAPTER III

REMOVAL OF THE UNDERSTOREY

Enough of the understorey must be destroyed so that a safe and efficient regeneration burn can be achieved.

A. THE RAINFOREST

Nothofagus and Atherosperma are the only important tree species in the rainforests of the Florentine Valley. The treefern Dicksonia is excessively dense only in some localities, especially in gullies.

Most of the timber from these two tree species has in the past been unmerchantable due to local market conditions. Since the introduction of the semi-chemical pulping process Atherosperma has been used for newsprint pulp and its use is increasing.

Nevertheless, utilization of the rainforest species in the past and probably for a long time in the future will not be intensive enough in the Florentine Valley to prepare a coupe for burning. Some method of rainforest destruction is needed to provide enough fuel on the ground and to permit this fuel to dry out rapidly. In tropical rainforests, such as Malaya's, poisoning is the main method of removing the competition of undesirable trees.

A tree poisoning experiment was carried out to find some cheaper alternative to felling the unmerchantable trees of the rainforest. Full details of method and results are given in the Second A.N.M. Forestry Research Fellowship Report No.6 (1960). A brief summary is given here in

Table III.1.

TABLE III.1

SUMMARY OF TREE POISONING EXPERIMENT

S = Successful kill
F = Failed to kill

	Treatments of Trunk			Treatments of Crown	
	Solution in frill cut	Solution on blazes	Solution sprayed on uninjured bark	Foliage sprayed	Soaking of apex
2.4.D	Noth(F)	Noth.(F)	(Noth.(F)	Noth.(±S)	
6% (by weight)			Ath. (F)	Ath. (±S)	
solution in					
Diesoline	Dick(F)			Dick.(S)	Dick.(S)
2.4.5T	Noth(F)	Noth.(F)	Noth.(F)	Noth.(±S)	
6% (by weight)			Ath. (F)	Ath.(±S)	
solution in					
diesoline	Dick.(F)			Dick.(S)	Dick(S)
As_2O_5 30% (by weight	Noth.(S)		Noth(±S)		
			Ath.(±S)		
solution in water plus wetting agent	Dick.(s)				Dick.(s)
Diesoline only				Noth.(S)	
				Ath.(S)	
				Euc.(S)	
					Dick.(S)

Species: Eucalyptus regnans, Atherosperma, Nothofagus, Dicksonia

Additional treatments:

1. Crystals of As_2O_5 in a horizontal, continuous frill cut were moderately effective in killing Nothofagus trees.
2. Removal of a two inches deep girdle of wood from the trunk did not always kill Nothofagus nor Atherosperma within one year.
3. A three inch deep frill cut into the trunk of Dicksonia did not kill this species within two years.

Each treatment was done on each of 10 individually numbered trees, except for the eucalypts (5 each). The hormone treatments were done in November, 1958 and the arsenic treatments in February, 1959.

Only the treatments in which the foliage was sprayed and those treatments where arsenic was applied to the trunk were successful in causing most of the foliage of the treated plants to die within one year. Other treatments failed to defoliate the plants within one year. The spraying of the bark on the butt of the eucalypts was done to check whether the bark could be loosened prior to harvesting, so that debarking costs would be reduced. There was no effect. The bark on mature trees is apparently much too thick to permit entry of externally applied chemicals.

Conclusion:

It is now felt that standing rainforest trees, alive or dead, are too great a fire risk because of the sparks they disperse from their dead wood and epiphytic mosses. Consequently the arsenic-frilling method, though found successful, cannot be recommended. The method may be useful for the killing of treeferns where these are dense.

SURVIVAL OF THE TREES BEYOND THREE YEARS AFTER THE ABOVE TREATMENTS.

1. Foliar spraying with diesolene solvent with and without a heavy concentration of 2.4D or 2.4.5T killed the sprayed leaves of all species. However, most of the trees recovered except those sprayed with 2.4.5.T.

2. Girdling. The removal by axe from the butt of the tree of a continuous girdle of bark plus 1-2 inches of the outer sapwood led to the slow death of most *Nothofagus* without permanent sprouting from below the girdle. Three years after the girdling the crowns of *Atherosperma* varied from weak to vigourous, and in all cases, there were vigourous sprouts from below the girdle which presumably nourished and kept the roots alive.

3. Frilling of *Nothofagus* with the addition of 2.4.D or 2.4.5.T was as effective as mechanical girdling. However, the addition of AS_2O_5, especially when in solution, brought about much more rapid death and killed all the crowns. A

few of the roots were still alive three years after the AS_2O_5 treatment.

4. The spraying of the bark at the butt of the tree.with 2.4.D or 2.4.5.T or AS_2O_5 caused the sprayed bark of *Atherosperma* (a thin barked species) to die; but only the AS_2O_5 spraying was markedly more effective than purely mechanical girdling. The two hormone sprays had no effect on the thick bark of the eucalypts. The solution of AS_2O_5 on the butt of *Nothofagus* killed only the small individuals (9 inches diameter) which had thin bark.

5. The treatment of *blazes* with 2.4.D or 2.4.5.T had no marked effect.

6. Lateral and downward translocation of arsenic seems negligible. Arsenic was not translocated to twin stems nor to neighbouring trees, even though root fusions at least within the same individual of *Nothofagus* and *Atherosperma* are very frequent. Sprouts arose from below arsenic frills, even where the crown was killed. The leaves were killed in a few weeks, but hung on for over a year. Timber killed by arsenic was attacked by borers.

B. THE WET SCLEROPHYLL SCRUB

This type of understorey cannot reasonably be cleared by felling or poisoning because of the great number of thin stems. Cunningham (1960) suggested dozing such scrub. The A.N.M. in a small trial have found dozing rather expensive (£12 to £15 per acre in 1960) and impossible on rocky soils where much of this forest type is found; but it has been found that if highlead logging is employed rather than tractor logging, enough of the scrub is knocked over to carry an efficient fire at a reasonably safe time and that overall costs are not much higher than the normal highleading without the retention of seed trees.

The Forestry Commission of Tasmania are investigating various mechanical methods of destroying understoreys of rainforest and wet sclerophyll scrub.

CHAPTER IV

THE SEASONAL PATTERN AND THE MECHANISM OF SEEDSHED

A. Paper presented to Second F.A.O. World Eucalyptus Conference at Sao Paulo, Brazil; in August, 1961.

The Mechanism of Seedshed in *Eucalyptus regnans* F.v.M

by

K.W. Cremer.

ABSTRACT

A capsule does not release its seed until it dies and dries out. The death of the capsule is brought about by its abscission or (less frequently) by the die-back of its supporting twig. Both fire and prolonged hot, dry weather can accelerate capsule abscission. Current weather appears to be of relatively minor influence in seedshed, it merely helps to dry out already dead capsules.

The release of seed from a capsule depends on the shrinkage of the placental cushion, the widening of the loculus and the retraction of the valves into the capsule. The latter two events are made possible by the structure and extraordinary shrinkability of the ovary walls. In overmature capsules the release of seed is hindered by excessive growth of wood at the mouth of the capsule.

Seed ~~c~~annot be extracted from immature capsules because of the collapse of the non-woody receptacle and/or because of inability of the valves to dehisce.

I. INTRODUCTION

Some seed is shed at all times of the year. A distinct seasonal pattern of seedshed emerges only after what are relatively droughty summers in the E. regnans regions of Tasmania. More than half of the year's seedshed is then concentrated into February-March-April (Cremer 1961).

Fire can cause a drastic acceleration of seedshed without directly scorching or killing the capsules or their sustaining twigs. The whole of a large, mature capsule crop may thus be abscissed in two months, a process which normally would have taken two years(Cremer 1961).

The eucalypt fruit is developed from an inferior, multilocular ovary. Though strictly a false fruit, it usually is called a capsule. When mature, the capsule is woody. It opens by loculicidal valves. See figure IV.3. In the developing capsule, fertilized as well as unfertilised ovules grow in size until they fit together like a three-dimensional jigsaw puzzle, completely filling each loculus and even causing the top of the ovary to lift, so that the base of the style becomes separated from the placental column and the loculi themselves begin to dehisce along a radial line.

Though partially exposing the topmost seed particles, this dehiscence does not permit any seedshed, nor does it seem to extend after maturity unless and until the capsule begins to dry out shortly before shedding its seed.

There is a slight variation in the width of this dehiscence according to weather conditions. This is due to swelling and shrinking of the spongy, dead, outer covering on the upper ovary wall.

II. NECESSITY FOR THE DEATH AND DESICCATION OF THE CAPSULE BEFORE ITS SEED CAN BE SHED.

Dead capsules are relatively rare on living twigs or branches. Such capsules have usually shed at least part of their seed and are generally very loosely attached. Most of the capsules on a living tree stay alive till shortly before they shed their seed. A living capsule, even when its surface is old, grey and cracked, is enclosed in chlorophyllous, spongy, moist tissue. Living capsules are always closed and full of seed.

Insects are the most common predators on living capsules. They include the larva of the chalcid wasp (Grose, 1957). The injuries they cause may stimulate capsule abscission and hence seedshed. A more direct cause of seedshed are the cockatoos or parrots. Their beaks are powerful enough to crush mature capsules and extract the seed. Their effects are localized and have been noted only rarely in Victoria (Cunningham, 1960) and Tasmania.

Such causes of seedshed are relatively unimportant. The dissemination of seed from the capsule to the ground normally depends upon its release, shedding and dispersal. The release is the most critical step. It involves separation of the seed from its placenta, the opening of the capsule valves and a widening of the loculus.

Seedshed from the randomly orientated capsules is then brought about by the action of gravity and by agitation due to wind and rain. Dispersal of the seed depends upon the wind.

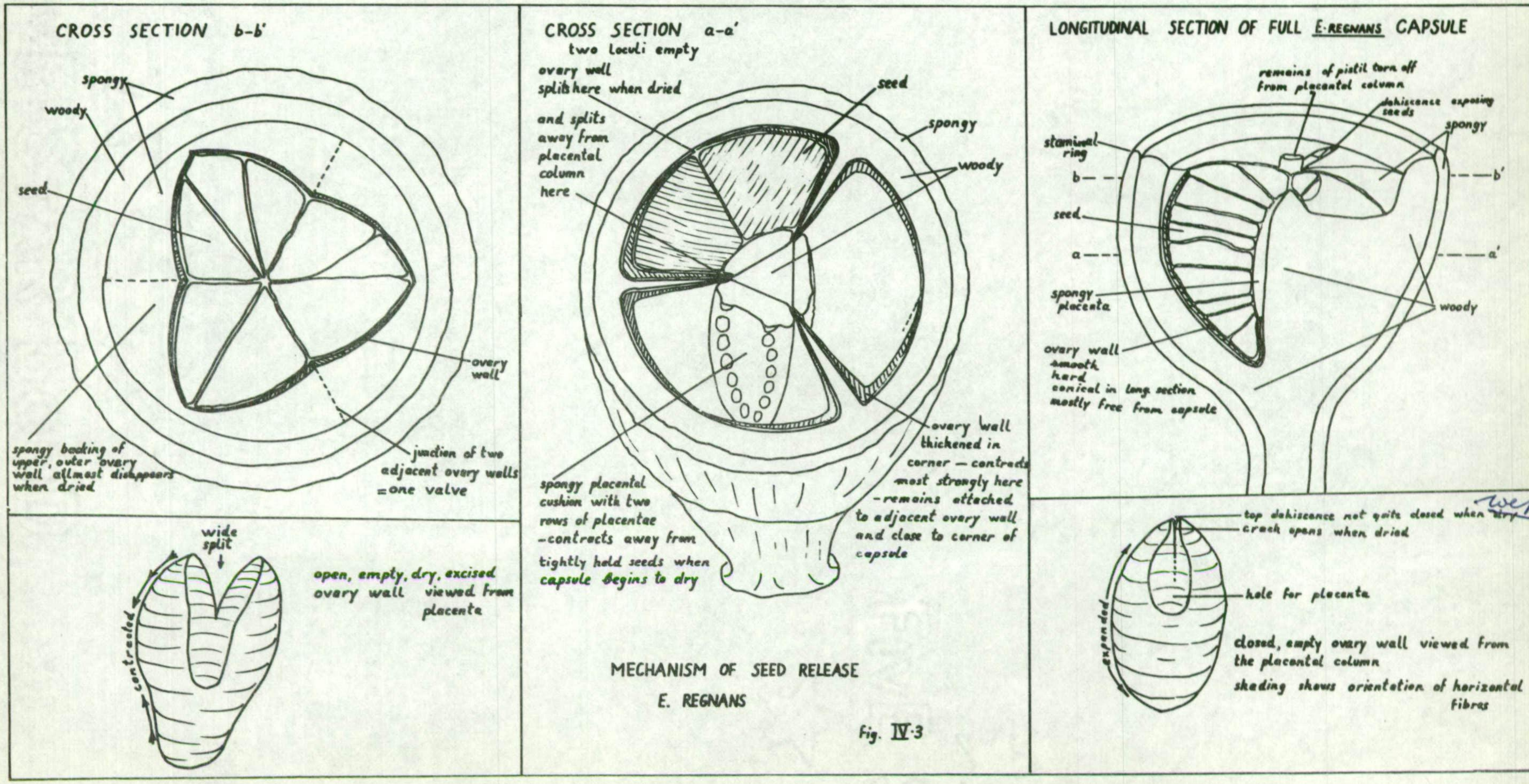
To test whether there is an active ejection mechanism, two lots of fifty freshly collected full capsules were planted upright with their pedicel in sand. Drying without agitation did not result in any seedshed.

The critical event of seed release normally occurs only as a result of capsule desiccation. A living capsule does not dry out sufficiently to release its seed.

III CAUSES FOR THE DEATH AND DESICCATION OF A CAPSULE.

A capsule does not dry out until the sapstream to it has been cut off. This is done very positively by the formation of an abscission layer, usually at the base of the capsule's pedicel. The alternative, more conspicuous, but less common mechanism is the die-back of the capsule bearing twig.

(1) <u>Abscission</u>

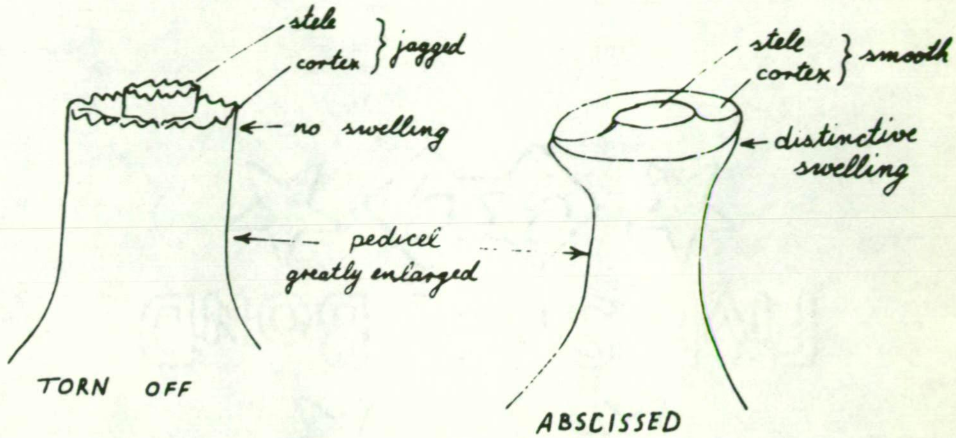


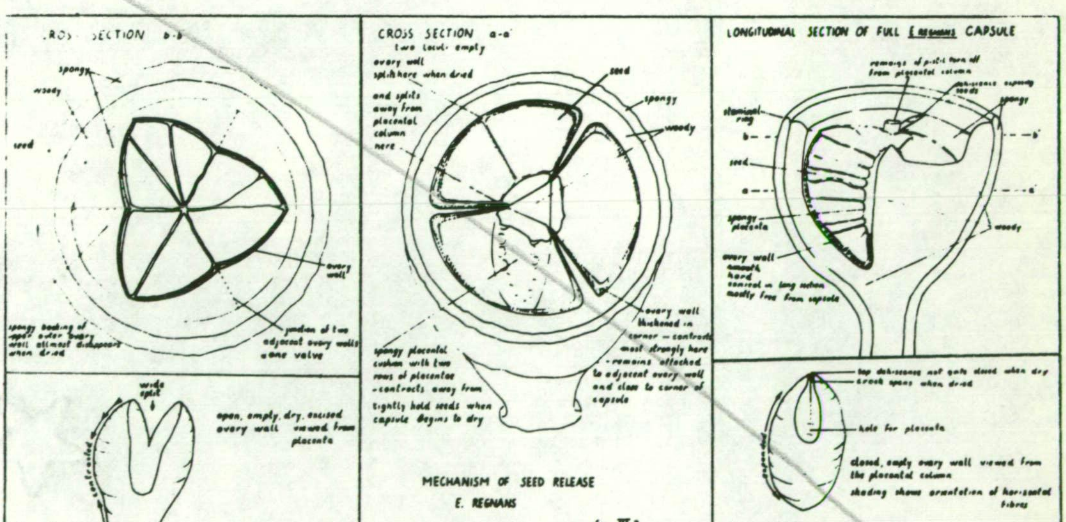
MECHANISM OF SEED RELEASE

E. REGNANS

Fig. IV·3

fig. IV 2





MECHANISM OF SEED RELEASE
E. REGNANS
fig IV 3

<u>Abscission</u> is the detachment by an active growth process of organs such as leaves, floral parts, fruits, seeds, bark and even twigs. It involves formation of a distinct separation layer, which when complete cuts off the distal organ from phloem and xylem connection. This cut of the organ's life lines will here be called <u>disjunction</u>. Disjunction involves the physical separation of living cells and the plugging up (by tyloses and secretions) of the xylem cells in a characteristic, and usually predetermined place. Unlike "abscission" the term disjunction does not imply the shedding of the organ. The shedding may be delayed indefinitely depending on the amount of xylem at the point of disjunction. Twigs, for instance, are not usually shed soon after disjunction.

The abscission layers responsible for capsule desiccation are developed at the base of the pedicel, at the base at the peduncle, or at the base of the capsule bearing twig. Disjunction at the base of the pedicel is usually the primary cause of capsule desiccation. The peduncle is usually abscissed after all its capsules have been shed. Quite often, especially with heavy seed crops, the capsule bearing twig is also abscissed, or disjointed. Sometimes twig disjunction precedes and prevents the abscission of the more distal organs (peduncle and pedicel). The twig then appears to have "died-back". Photo No.10 shows twig disjunction after injury by fire. The phloem separates at the abscission ring. The xylem remains physically continuous, but becomes plugged up. This is shown by the fact that air cannot be sucked by mouth across a dead/live boundary. Air can be sucked through all live or all dead junctions.

By examining capsules on the forest floor for the characteristic signs of abscission (see figure IV.2), it is possible to assess the relative importance of the various methods of seedshed. Such an assessment was made by inspecting all the capsules found on 30 one-square-foot plots systematically located at 50 link intervals in each of three relatively well seeding stands. Of the 378 capsules with fairly distinct pedicels 239 could be identified as having been abscissed. The majority of the remainder was either still attached to the peduncle or showed definite signs of having broken off. It appears, therefore, that over half (at least 63%, in this case) of all capsules are abscissed singly, that a small proportion is abscissed with the umbel peduncle and that a significant proportion (perhaps 30%) is shed from or with died-back twigs or branches. This type of assessment is not influenced by seasonal and annual variations in mechanism of seedshed, because the capsules on the ground represent about four years' seedshed in this forest (Cremer, 1961).

Two seed traps (each 1/4,400 acre in aperture) installed under two different groups of E. regnans trees recorded the following catch of capsules between 4.1.61 and 28.8.61: F/N caught 130 capsules, 78.5% of which appear to have been abscissed singly. The corresponding figures for F/NE were 167 capsules and 77.7%. Amongst the remaining 22% of capsules, about half were firmly attached to the umbel peduncle which itself had been abscissed from the twig.

This proportion of singly abscissed capsules is high (78%) when compared with the four-year-average (63%) and may be a consequence of the unusually dry 1960/61 summer.

(2) Die-back.

Cunningham (1960) states "The normal process of seedshed occurs after the twigs bearing the mature capsules have died back". This does not agree with the observations made by the author.

With low intensity seed crops, most umbels are located singly or in pairs on twigs with a life expectancy much beyond that of the capsules. With heavier crops a larger proportion of umbels are located in recemes or short twigs which shed their leaves and do not increase in length.

Such twigs or racemes have only a limited life span; but even in these cases capsule abscission usually precedes the die-back of the twig. Die-back tends to be basipetal in several stages, from axil to axil and eventually to its origin at the main shoot. The extent of the die-back is not random, but is controlled by the formation of distinct disjunction rings just above an axil.

IV THE PROCESS OF SEED RELEASE FROM THE CAPSULE.

In a living capsule the seeds are tightly packed, and completely fill the loculus. There is very little change in the volume of a seed when it dries out. This was determined by observing that there was no noticeable increase in volume after repeated waterings of tightly packed, originally air dry seed in a glass tube $\frac{1}{2}$ x 2 inches in size.

When a capsule begins to dry out the spongy placenta shrinks away from the tightly held seeds. This ensures that the seeds are abscissed.

If a capsule is dried (to ensure seed abscission) without disturbing the arrangement of the seeds and then moistened again the seeds cannot be shaken out after cutting off the valves. This means that three conditions are necessary for the release of seed; namely abscission of the seed, opening of the valves and widening of the loculi. The loculi must widen, even though the capsule as a whole will shrink when dried. The external woody diameter decreases by 1-2%.

In eucalypts with exsert valves the loculus can open by the folding back of these valves (e.g. E. viminalis). In these cases the valves are fairly thick due to their backing of spongy tissue which contracts strongly when dried, thus folding back the valves. In E. regnans and especially in eucalypts with more sunken valves, there is no room for the valves to fold back effectively. In the case of E. regnans the shrinkage of the small amount of spongy tissue only serves to make room for the valves to retract efficiently. In fact, the valves open up by retracting into the capsule.

In E. regnans the opening and widening of the loculus is due to the ovary wall. This ovary wall is very hard and smooth. It is attached to the receptacle only at its base. It is capable of extremely great longitudinal contraction (at least 10%) because the fibres are oriented at right angles to the longitudinal axis. The degree of contraction can be appreciated by watching a marked portion of the valves disappear into the capsule when dried.

Before the outer capsule becomes too woody, the ovary wall can be easily excised. It then opens and closes quite independently of the capsule.

In all the eucalypts examined, the ovary wall was easily distinguishable from the receptacle. It provided the main seedshed mechanism only in the sunken-valved capsules. In E. globulus there are no distinct valves. The release of the seed is entirely due to contraction of the thick spongy tissue outside the thin ovary wall. In E. viminalis the seed is released by a combination of ovary wall and spongy tissue mechanisms plus ability of the excert valves to fold outwards effectively.

As *E. regnans* capsules grow older, they become more woody. Old capsules do not release their seed as easily as young, mature capsules. This appears to be due to restriction of the aperture by wood instead of the highly contractile spongy tissue. As the capsule ages, the woody annulus inside the staminal ring grows and tends to constrict the valves.

Ashton (1957) found that seed of *E. regnans* becomes viable before the end of the year in which flowering occurs but that it cannot be extracted by drying till early in the following year. This is because the receptacle of a very young capsule is not yet woody enough to prevent the extreme shrinkage and collapse of the entire fruit. The dried and shrunken receptacle encloses the ovary very tightly. Rigidity of the receptacle must, however, be accompanied by ability of the valves to open up before seed can be shed. The opening of the valves can be prevented by an outer covering of tough, living tissue. At this stage, the dried ovary may shrink away from the woody receptacle without dehiscing. Seed release is, therefore, not prevented at this point by the collapse of the receptacle. This is confirmed by the observation that the ovaries will not open even when the receptacle is peeled off. If the peeled ovary is dried after cutting off the valves, seed release (widening of the loculus) is very effective. Seed release is also moderately effective if the valves are cut off when the ovary is not peeled. However, the ovary wall still has some tendency to shrink away from the receptacle.

In the immature capsule the loculi are covered by a tough continuous layer of green tissue outside and above the ovary walls. This layer, together with the chaff and the remainder of the style are the only parts of the capsule which die when the capsule matures. This layer then splits as a sign of the capsule's maturity.

V. CONCLUSIONS.

Nearly all capsules on living E. regnans are alive and completely full of seed. This is important knowledge for seed collection and for seed crop assessments by telescope designed to forecast the success of planned regeneration burning.

Ease of seed extraction varies with the age of the capsules. This means that the different ages should be kept and treated separately when convenient. A partial dehiscence of the valves is probably the earliest sign of the capsule's maturity, i.e. ability to release its seed after being dried out.

The type of observations outlined in this paper should help to determine the mechanisms of seed release in other eucalypt species.

Amongst the factors which influence timing of seedshed , those producing capsule or twig disjunction are of greatest importance.

B. THE SEASONAL PATTERN OF SEEDSHED

I. INTRODUCTION

This chapter deals with the pattern of seedshed undisturbed by fire. The system used to obtain natural regeneration in the Florentine Valley does, however, involve exposure of seed trees to fire. Hence the findings set out in this chapter apply only to that minor proportion of seed which is not brought down by the fire within two to three months and to those seeds which mature after the fire and do not begin shedding within one year.

II. METHOD OF STUDYING SEEDSHED -

The problem is to catch seed over a known area and interval of time in such a way that no seeds are lost between scorings due to insects, fungus or wind removal. Most experiments in the following chapters are made with twenty-one traps made with sheets of galvanized iron in the shape of a large funnel whose aperture is 1/4,400 acre in area and whose narrow end runs into a detachable bucket with a wire gauze bottom. This trap was suspended about three feet above the ground by means of driven pegs. The steep smooth funnel walls and their very high temperature in the sunshine probably discouraged insect robbers. Ants were seen inside only one trap (F/S). Dieuches was never seen inside any trap. When and where insect danger was high the legs of the traps were covered with thick mineral grease (W54 traps during the summer 58/59). This trap was designed by Gilbert (1958).

Another type of trap of similar principle was made for temporary use. A square frame, 1/4,000 acre in aperture was suspended above the ground and covered with deeply sagging detachable calico sheeting (two traps at W54).

Twelve more traps involved the use of a flat tray, 1/4,000 acre in size, with gauze bottom and 3 to 4 inches tall sides. The tray rested on four bricks each standing in an oil-filled canister to prevent access by ants. Two such traps were used at W54 and ten in the direction of of seedthrow experiments.

The traps were emptied at suitable intervals. The capsules were picked out and separately wrapped so that the seed inside them would remain distinguishable from the seed which was shed free. The trap contents were then dried, sieved and searched. Seeds were squashed to assess their soundness.

All traps remained in fixed positions except in the distance of seedthrow experiments located at W48 and at Road 11. The seed trapping data used in this chapter are based on three fixed traps called F/N, F/NE and F/S which were located near Road 11 underneath three different, selected groups of trees inside the edge of a virgin stand of 150 years old E. regnans with a rainforest understorey.

Fixed traps show up trends in seedshed more reliably than roving traps would, because they eliminate a major source of variation due to differences in seed crop densities on different trees. Fixed traps are located underneath selected trees, usually dominants and, therefore, give an overestimate of the absolute rate of seedshed on the area as a whole.

III THE PATTERN OF SEEDSHED

(1) The Fall of free Seed

Seed is "free" when it is outside the capsule on hitting the ground.

(a) The Fall of free Seed in the Florentine Valley.

The seasonal pattern of seedshed in the Florentine Valley is illustrated in figure IV.1. During 1956 and 1957 the pattern was highly irregular (Gilbert, 1958). There were often very large changes in rate of seedshed from month to month and one group of trees often increased its rate of seedshed while another group decreased its rate of seedshed and vice versa.

During 1958 to 1961 a more regular pattern emerged. In these years 48 to 72% of the annual seedshed occurred in February-March-April and seedshed in the other months of the year was fairly regular and low. There was always some seed shed at all times of the year.

(b) Comparison with other Areas

A number of seedfall studies are summarized in table IV.1. In eight out of eleven instances at least half of the annual seedshed occurred in three months. The peak months were February, March, April, sometimes shifting towards January, sometimes towards May. Peak seedshed was usually not coincident with but somewhat delayed after the hottest part of summer. In all cases some seed fell in all parts of the year.

TABLE IV.1

See Page 40

TABLE IV.1

SUMMARY OF STUDIES ON THE SEASONAL PATTERN OF SEEDSHED (FREE SEED)

Worker	Species	Year	Months of peak seed shed	% of annual fall shed in peak three months	Locality
Loneragan	E.diversicolor	56/57	Jan-Feb.	50%+	S.W.of W.A.
Grose	E.delegatensis	54/55	F.M.A.	70%	Vic.
Grose	"	55/56	F.M.A.	45%	Vic.
Cunningham	E. regnans	55/56	F.M.A.	72%	Ada Riv.Vic.
"	"	56/57	M.A.M.	72%	"
"	"	57/58	(F)M.A.	49%	"
Gilbert	"	1956	F.M.A.	38%	Florentine
"	"	1957	F.M.A.	26%	Valley
Author	"	1958	F.M.A.	48%	Tas.
"	"	1959	F.M.A.	59%	"
"	"	1960	F.M.A.	53%	"
"	"	1961	F.M.A.	72%	"

(c) Factors responsible for the Pattern of Seedshed

It is obvious that a capsule must dry out before it can shed its seed. It was shown in Part A. of this chapter that a capsule on a living tree cannot dry out until an abscission layer has cut the capsule from the sapstream of the tree. Once its sapstream is cut off, the capsule takes a relatively very short time to dry out and shed its seed, namely several days in summer, or a few weeks in winter. The main pattern of seedshed is, therefore, determined by the pattern of capsule abscission and the die-back of twigs.

Hourly variations in the drying power of the atmosphere (temperature, humidity, wind) may be directly correlated with the diurnal pattern of seed release from dead capsules. However, the main pattern of seedshed is apparently determined by conditions which precede the actual shedding of seed by days, weeks, or even months.

What are the factors which accelerate abscission and die-back? The factors must be of sufficient intensity and duration to influence the physiology of the whole tree. The physiology of fruit abscission can be very complex and is related to the senescence of the fruits and to the hormone balance in the plant. The latter can be influenced by environmental factors such as drought (Addicot and Lynch, 1955).

The patterns of seedshed acceleration after a hot summer and after certain types of fire (see Chapter VII) suggest that drought or heat may be the main factors which determine the timing of seedshed. Evidence such as that presented in table IV.1 leads Cunningham (1960) to believe that seedshed is concentrated in late summer if the summer is dry.

Figure 1V. 1:

Seasonal pattern of total ~~fr~~ free seed fall ~~m~~ measured in three fixed traps each 1/4,400 acre in aperture.

The monthly rainfall figures and certain screen temperatures recorded at the A.N.M. Depot are given for comparison. The imformation from the years 1959 to 1961 is represented in a different manner as part of figures VII. 2.

Fig. IV.1

TOTAL FREE SEED SHED/ 1/4400 ACRE / MONTH

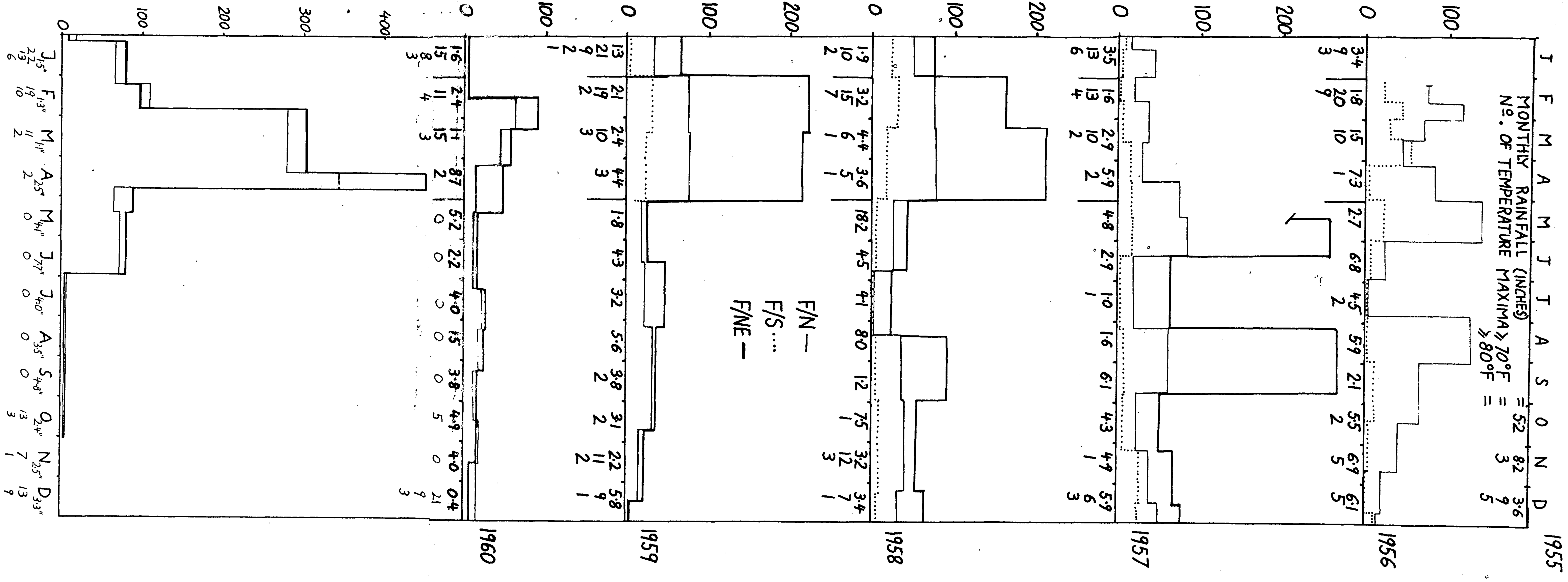


Table IV.1 and figure IV.1 show that peak seedshed is not coincident with the hottest part of summer but is slightly delayed.

Table IV.2 suggests that the degree to which seedshed is concentrated in late summer is related to high temperatures and low rainfall in the three to six preceding months. The correlation is not perfect and suggests that other factors may also be important for the timing of seedshed. The size and age of the seedcrop is one obvious probable factor. This might account for 1958 being out of step with the other five years.

Table IV.2

See Page 43.

	1957	1956	1960	1958	1959	1961
1. % of annual seedshed which fell in February to April	23%	40%	41%	49%	71%	72%
2. Rainfall: Oct.-Mar.	26"	24"	16"	24"	19"	13"
Dec.-Mar.	8"	7"	5"	9"	6"	4"
3. Potential evapotranspiration: Oct.-Mar.	17"	17"	18"	16"	18"	19"
Dec.-Mar.	9"	10"	9"	9"	10"	10"
4. Water balance (2 minus 3) Oct.-Mar.	+10"	+7"	-2"	+9"	"1"	-6"
Dec.-Mar.	- 1"	-3"	-4"	0"	-4"	-6"
5. Mean daily temperature °F Dec.-Mar.	55°	58°	58°	57°	59°	60°
6. Frequency of high temperatures (x)	62	69	88	57	94	122

Note (x) One point was given for each occasion when the maximum daily screen temperature exceeded 69°F. plus another point for temperatures above 79°F., plus another point for temperatures above 89°F. etc.

The potential evapotranspiration was calculated from the mean daily temperatures by Thornthwaite's method (1948).

(2) The Fall of Capsules

The pattern of capsule fall was much less distinct than the pattern of seedshed. The rate of capsule shedding was usually highly variable from month to month and occurred irregularly throughout the year. There was usually no correspondence with seedshed except on an annual basis. Only where seedshed reached a very high peak in February to April did the shedding of capsules reach a distinct and corresponding peak. Such was the case with trap F/N in 1959 and with both traps (F/N and F/NE) in 1961. The peak of capsule shedding came 2-4 weeks later than the peak of seedshed. In 1961, half of the annual capsule shedding occurred in two months, about March.

3. The Fall of Seed enclosed in Capsules.

Contrary to expectation during 1957 to 1960 the number of enclosed seed shed per capsule during February-March-April was not different from other times of the year. Capsules did not appear to shed their seed more completely during summer than during winter.

(a) The Proportion of Seed which fell in Capsules

Some workers have estimated the percent of seed that is shed out of the capsule by using the ratio of free to enclosed seed caught in fixed traps. When - as was usually the case - the trap is fixed underneath a selected tree this direct method is likely to yield an underestimate of the free seed because the wind tends to disperse the free seed further from the tree than the much heavier capsules. If the number of ovules per capsule is reasonably constant and known, it is much more reliable to express the number of enclosed seeds shed per capsule as a percentage of the original number of seeds contained in the capsule before shedding.

Table IV.2 sets out the results of counting all the seeds from completely extracted, originally unopened capsules.

TABLE IV.2

SEED COUNTS FROM COMPLETELY EXTRACTED GREEN CAPSULES OF *E. REGNANS*

Tree No.	1	2	3	4	5	6	Total
No. of full capsules	40	44	50	80	20	10	244
No.of seeds (chaff & sound)	1130	1397	1582	2523	595	261	7488
No.of seeds/full capsule	28.3	31.7	31.7	31.6	29.7	26.1	30.7

These counts were done on crops of various intensities of 1958 and 1959 flowering from various localities. They show that capsule lots of at least twenty average close to 30.7 seeds per capsule. Ten individual capsules from tree No.6 proved to contain between 24 and 32 seeds each, 1 to 6 of which were sound. (Note that one lot of 10 *E. obliqua* capsules contained 40.7 seeds per capsule.)

Table IV.3 shows that, provided at least 100 capsules are used in the estimate, the proportion of enclosed seed is fairly constant from tree to tree, and averages about 15%.

The variation from year to year was a little greater.

These figures are a little below the estimate of 23 to 25% obtained by Cunningham who used the direct method with roving traps underneath E. regnans in Victoria. They disagree with the figures obtained by the direct method on the above fixed traps. F/N, F/NE and F/S would have 16%, 39% and 56% respectively instead of 12%, 16% and 17%. This is due to the tendency of capsules to fall closer to the parent tree than free seed would. Grose (1961) found that E. delegatensis sheds nearly half of its seed enclosed in capsules.

In one small trial to test the efficiency of one artificial method of seed extraction from collected capsules of E. regnans it was found that only 74% of all the seed had been extracted. Nature's efficienry of 85% compares well with this.

TABLE IV.3

Average number of seeds (chaff and sound) found inside the capsules caught under five different groups of trees in five different years. The figures inside brackets show the number of capsules actually caught. The data for 1956 and 1957 are after Gilbert (1958).

Trap No.	Year of Catch						$\bar{x}$ % enclosed
	1956	1957	1958	1959	1960	Total	
F/N	(6) 4.3	(49) 2.6	(14) 3.6	(22) 3.6	(35) 5.7	3.7	12%
F/NE	-	(158) 4.3	(145) 6.0	(82) 2.7	(43) 7.1	4.8	16%
F/S	(12) 9.6	(11) 11.6	(31) 11.9	(169) 3.1	-	5.1	17%
W54(1)	-	-	-	(73) 3.9	-	3.9	13%
W54(2)	-	-	-	(38) 6.5	-	6.5	21%
Total	7.8	4.1	6.8	3.6	6.4	4.73	15.4%
$\bar{x}$ % enclsd.	25%	13%	22%	12%	21%	15.4%	

Note: x. In these columns the number of seed inside the caught capsules is expressed as a percentage of 30.7, i.e. the total number of seeds which would normally be contained in a full capsule.

(b) The Proportion of Sound Seed.

Table IV.4 sets out the proportion of sound seed caught in the fixed traps at Road 11 during the 20 months following February, 1959.

TABLE IV.4

THE PROPORTION OF SOUND SEED CAUGHT IN FIXED TRAPS

Trap	Free Seed	In Capsules	(T) Average
F/N	57/540 = 10.5%	22/198 = 11.1%	10.7%
F/NE	113/971 = 11.6%	43/571 = 7.5%	10.1%
F/S	9/61 = 14.7%	6/59 = 10.2%	12.5%
(T)Average	11.4%	8.6%	10.4%

The two Road 7A traps underneath trees with a very heavy 1959 capsule crop recorded about 20% of sound seed. If the average capsule contains 30.7 seeds then the Road 11 trees (F/N, F/NE, F/S) must have carried 3.2 sound seeds per capsule and the Road 7A trees 6.1 sound seeds per capsule.

Cunningham (1960) found that the "1954" capsules averaged 1.6 sound seeds each and the "1956" capsules 3.1. Adhton (1951) showed that Eucalypt pollination is done by insects and perhaps birds. Pryor (1957) showed that pollination conditions can make a large difference to the number of ovules fertilized. However, Eldridge (1961) was not successful in increasing the number of viable seeds per capsule by placing beehives near the flowering trees. His bees were laden with Eucalypt pollen. E. regnans flowers during a period of uncertain weather in Tasmania (March - May). It is, therefore, not surprising if the proportion of sound seed varies greatly from tree to tree and from season to season.

10% of sound seed seems to be an average figure.

In E. regnans and E. delegatensis the ovules of the placental end away from the stigma are successfully fertilized more often than those nearest the valves. The topmost ovules are probably never fertile. This is illustrated by Table IV.5.

TABLE IV.5

POSITION OF FERTILE SEED IN THE LOCULUS

		Proportion of cases with fertile seed:		
		Topmost	Middle	Lowermost
E.delegatensis		0/11	8/11	11/11
E.regnans Tree No.	1	0/14	12/14	7/14
(from different	2	0/15	12/15	7/15
localities)	3	0/10	7/10	6/10
	4	0/11	9/11	3/11
Total E.regnans		0/50	40/50	23/50

The location of the fertile seed away from the valves and larger size of the fertile seeds would lead one to expect that fertile seeds are less readily extracted or shed than the chaff. This was indeed the case with the one test of artificially extracted seed. The final fraction of the seed which was extracted by more intensive drying and shaking contained a higher proportion of fertile seeds than the first fraction. Table IV.4 suggests that the reverse was the case with naturally shed seed. Out of 499 individually scored capsules 59% were empty or contained only one seed. This means that most capsules shed their seed readily and completely. The great majority of loculi were either completely full or completely empty. Amongst the unopened capsules an unusually large proportion contained only chaff. Many such capsules appear to be underdeveloped. Apparently, the fertilized ovule(s) which initiated the development of the capsule became aborted thus preventing the capsule from becoming fully mature.

(c) <u>The Fate of Seed enclosed in Capsules</u>.

Needham (1960) believes that enclosed seed of <u>E. delegatensis</u> will remain viable on the forest floor for many years and will give rise to regeneration when the canopy is opened up. Grose (1961) has evidence that most seeds of <u>E. delegatensis</u> in capsules on the forest floor are eaten by insects or become non-viable within two years. The subject in relation to <u>E. regnans</u>

is being studied by the Tasmanian Forestry Commission.

A glass tube about 5 c.c. in volume was filled with _E. regnans_ seed and watered repeatedly. The stoppered tube permitted fungal growth but no germination at room temperature in two months. Then the seed was spread out in a petri dish and began to germinate promptly. This suggests that germination conditions in a tightly packed, closed capsule are likely to be unfavourable. Freshly shed capsules close up before they become moist enough to permit germination. It is likely that the seed is germinated or killed by fungus before the woody capsule is rotten enough to permit the emergence of the seedling. No germination appeared from 35 full capsules kept moist at about 60°F. for six months. The author has noticed only one seedling emerge from a capsule on the forest floor amongst what must have been thousands of capsules seen. It seems, therefore, that enclosed seed might possibly serve as ground stored seed, but that it is of little significance in normal regeneration.

Normally only gravity or agitation can free a seed from a capsule and then only from a dry capsule. _Dieuches_ bugs have been seen to dislodge seeds from open capsules. Presumably, they remove or destroy most of the viable seeds they find. The minority of capsules are shed on twigs

The singly shed capsule, though preferring to lie on its side or on its valves because of its shape, is unlikely to shed its enclosed seed. It dries out infrequently and is not usually agitated. If one third of the 15% of seed which is shed enclosed in capsules manages to escape its capsule, only about 10% of the whole seed crop remains permanently enclosed. This means that the fate of enclosed seed is of minor importance in normal regeneration.

IV CONCLUSIONS.

Some seed is shed at all times of the year. It appears that a distinct seasonal patterm of seedshed emerges only after what are relatively hot and dry summers in the Florentine Valley. More than half of the year's seedshed is then concentrated into February-March-April.

The fall of capsules is more irregular and shows little correspondence to free seedshed. The proportion of the total seed crop which falls enclosed in capsules is similar at all times of the year and amounts to about 15%.

The proportion of sound seed to chaff varies considerably from year to year and from place to place. Usually about 10% of all seeds are sound. E. regnans capsules average 30.7 seeds each, 1.6 to 6.2 of which are sound.

CHAPTER V

DIRECTION AND DISTANCE OF SEEDTHROW

A. DIRECTION OF SEED THROW

I. WIND DATA

The nearest systematic wind records were made by the Commonwealth Meteorological Bureau at Fitzgerald in the Tyenna Valley which is rather narrow and runs NE to SW (see fig.I.D). The relative wind frequencies at 9 a.m. are

N	NE	E	SE	S	SW	W	NW	Calm
0	15	0	5	0	39	1	39	1 %

80% of all winds came from the western half of the compass. No winds blew oblique to the direction of the valley, presumably because of the channelling effect. Hence the majority of winds above the valley probably came from WNW.

The N-S orientation of the Florentine Valley would tend to channel these winds into a more northerly direction. This influence is probably not strong in the main part of the valley which is 3 to 4 miles wide.

The wind channelling effects of forest edges and valleys is likely to be complex and variable from place to place. It should be useful to remember nevertheless that the strongest and most numerous winds are westerlies.

II SEED TRAPPING EXPERIMENT

Two isolated open-grown, tall (200 ft.) E. regnans trees separated from each other and from the nearest other

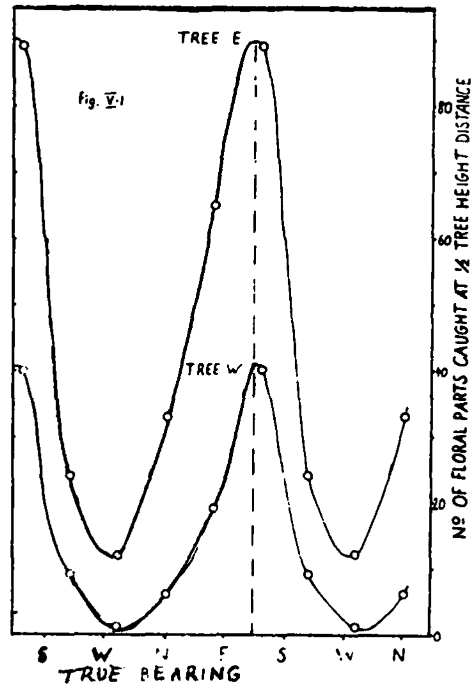


Figure V. 1 : Relative rates of dissemination at half tree height distance in various directions. Each point represents the total of various eucalypt floral parts caught during 16 months in a trap 1/4,000 acre in aperture.

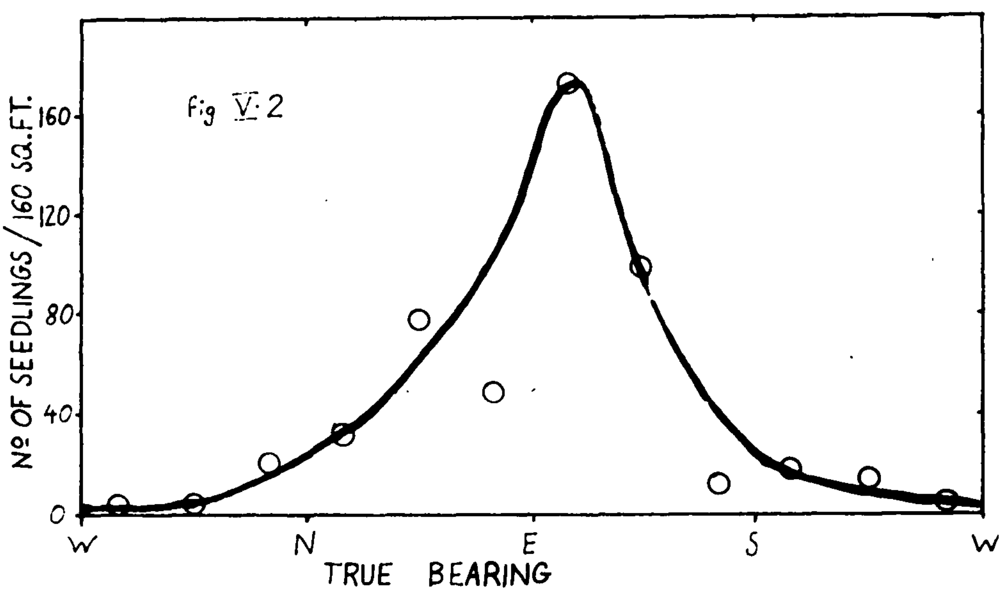


Figure V. 2 : Relative numbers of seedlings at different bearings counted at two fifth tree height distance from an isolated *E. regnans*.

eucalypts by 20 chains and located in the flat middle part of the Florentine Valley were selected to study the direction of maximum seedshed in the different seasons of the year. Five seed traps were arranged in a circle about each tree. The traps were oriented at bearings 0°, 72°, 144°, 216° and 288° placed halfway between the tree base and the point where the angle of elevation to the top of the crown was 45°. This gave a spacing at an effective distance equal to half tree height, thus overcoming minor topographic variations.

Previous inspection of the tree crowns with field glasses confirmed the presence of a moderate capsule crop. It was not realized that the apparently harmless bracken fire in March 1958 would have brought down nearly all the seed before the experiment started in December, 1958 (see also Chapter VII). There was no good new seedcrop before the termination of the experiment in April, 1960. The total of 15 free seeds caught in the ten traps during sixteen months was insufficient to realize the full aim of the experiment; but taking into account all eucalypt floral parts (capsules, free seed, opercula, flowers, flower buds, umbel peduncles) sufficient particles were caught to give an indication of the direction of maximum dispersal.

The results are presented in Fig. V.1. The two trees produced remarkably similar patterns. The peak dispersal to SE agrees well with expectations from the wind data. Minimum dispersal was in almost the opposite direction and only one seventh as high. The pattern was similar in summer and in winter.

There were 15 free seeds, 30 capsules, 50 opercula, 67 flowers, 105 single flower buds or umbels and 26 peduncles. Most of these items, because of their greater mass/surface ratio, are not as easily wind blown as free seed. It may, therefore, be expected that the ratio of peak to trough is even greater for seed alone, than for all these items combined especially at greater distances from the seed tree. Figure V.1 is, therefore, a conservative representation of relative rates of seedshed in the various directions at half tree height distance.

III SEEDLING COUNTS.

To confirm I and II above, a count of established seedlings was made on the circumference of a circle 60 ft. in radius around an isolated 150 ft. high E. regnans standing on reasonably uniform and level ground. Seedlings were counted on four feet wide strips along 30 ø arcs at known bearings to the three. The number of observed seedlings per 160 square feet of available seed bed (logs were discounted) are plotted for each arc against its true bearing in figure V.2.

The results from this experiment are in agreement with the predictions from I and II. Peak dispersal was

was to ESE and many times higher in this direction at 2/5 tree height than in the opposite direction.

B. <u>DISTANCE OF SEEDTHROW</u>

I. INTRODUCTION.

Wind is probably the only significant agent of seed dispersal for eucalypts. Distance of dissemination, therefore, depends on seed flight properties, height of seed release and on wind speeds. <u>E. regnans</u> seed is fairly small (1 mm diameter, 1 million seeds per pound) but wingless. Its terminal velocity is, therefore, fast at 11 to 13 ft. per second (Gilbert 1958, Gross, 1957). Consequently the great majority of all seeds land within tree height. Douglas fir seed has a terminal velocity of 3-5 ft. per second and may be abundant at seven times tree height distance (Isaak, 1943). Because terminal velocity is reached in the relatively short space of 15 to 20 ft., the distance of seed dispersal is almost proportional to the height of tall trees. Hence results obtained from trees of different heights may be compared by expressing the distance of dissemination as multiples of tree height or in angles of elevation to the tree crown. The average wind speed affecting the seed between crown and ground level depends on the exposure of the tree as well as on climate and topography.

Two patterns of dispersal are of interest here; namely dispersal from a forest edge and dispersal from isolated, reserved seed trees. The former indicates the proportion of a coupe which may regenerate from the uncut forest edges and the latter helps with information on the spacing of reserved seed trees on the coupe.

The following points from the work of Caborn (1957) on the effect of shelterbelts are important to our problems of seed dispersal:

1. A shelter belt (or a forest edge) reduces wind speeds on its leeward side for a distance of over ten times tree height.

2. A moderately penetrable shelter belt (sparse forest with low undergrowth) may reduce wind speeds for a greater distance from its edge and with less turbulence than an impenetrable shelter but an impenetrable shelterbelt (dense forest with tall understorey) will be much more effective in reducing windspeeds within a distance of 1 to 2 times tree height.

3. Measured at 5 ft. above bare ground the wind speed within twice the tree height of a moderately penetrable shelterbelt is about 15 to 30% of the free wind.

4. Winds which do not blow across the shelterbelt at right angles tend to be channelled along the shelterbelt.

II EXPERIMENTAL METHODS

Quantity and distance of seedshed from a given forest edge varies with different points along this edge and with time. For this reason, a technique similar to that used by Wilm (1946) in making micro-climatic studies was adopted at Road 11 and W48. Samples of seedshed were taken in time and two-dimensional space by traps moved at 2 to 10 weekly intervals to new random positions within a row of three square strata running at right angles from the forest edge. Each stratum was sampled by two traps. Three fixed traps (F/N, F/NE and F/S) were installed inside the adjacent forest at Road 11 and scored at the same intervals as the roving traps so that the ratio of actual to mean monthly seedshed under the canopy could be used to convert monthly seedshed in the open to mean monthly seedshed.

At Road 11, the forest was dense (20 eucalypts/acre) 150 years old, 250 ft. high and with a 100 ft. high rain-forest understorey. The strata were 250 x 250 ft. each. They ran at $146^{\circ 1}$ true bearing from the forest edge.

At W48, the forest was 250 ft. high and very much more open. The eucalypts were older and sparser (perhaps 10 per acre) and had a wet sclerophyll understorey only 20 ft. high. The three strata here were 125 x 125 ft. and ran at 110° from the forest edge.

Both these experiments were laid out and operated till early 1958 by Gilbert, the previous A.N.M. Research Fellow.

To test dispersal with minimum wind restriction, i.e. with reserved isolated seed trees, a third experiment

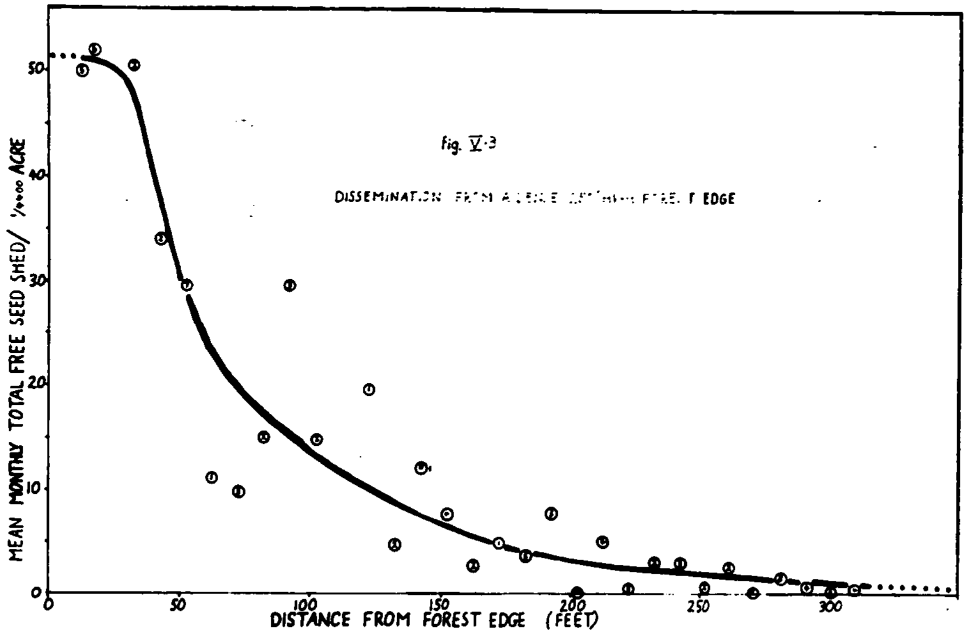


Figure V. 3 : Free chaff plus sound seeds caught at various distances to the S.E. (146°) from the forest edge. – Mean monthly rate – . Multiply by 0.053 to get pounds/acre per year. The figures inside the circles indicate the number of trap periods each 2–10 weeks long which contributed to the average value at this distance. Dense forest, 250 feet high.

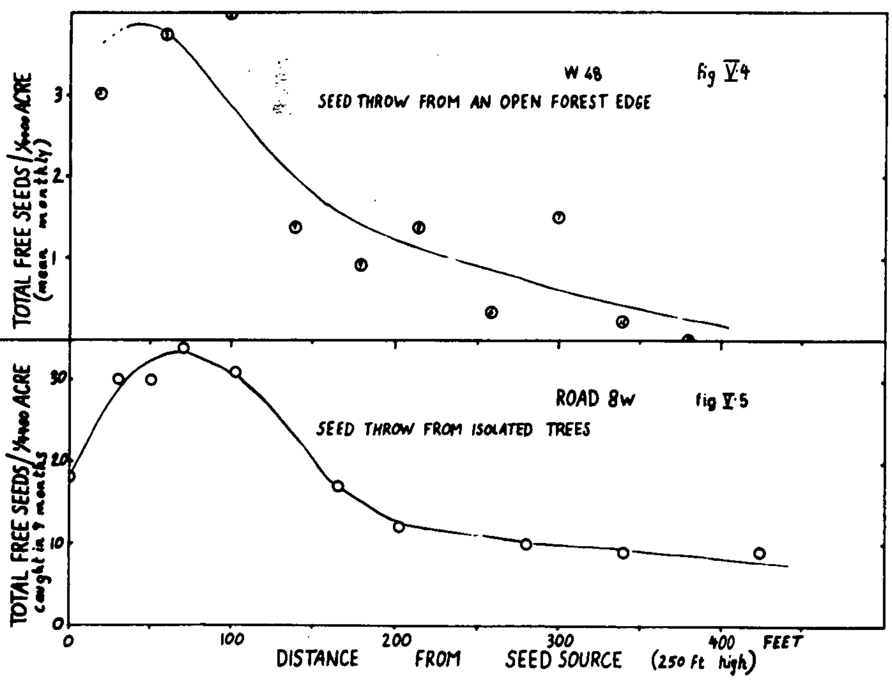


Figure V. 4 : Mean monthly rate of total free seed shed recorded at various distances to the S.E. (110°) from the edge of an open 230 feet high forest. The figures inside the circles indicate the number of trap periods each 4 to 10 weeks long which contributed to the average value at this distance.

Figure V. 5 : Total free seed shed at various distances to the east from an isolated tree. Results from 10 fixed traps operated for 9 months.

was carried out at Road 8W. In this case, most of the seed came from one tree and some from another shorter one 1 chain behind it. Seedshed was sampled by a row of ten fixed traps running at 90° from the tree to a distance of 350 ft.

III <u>DISPERSAL FROM THE EDGE OF A DENSE FOREST-ROAD 11.</u>

The results of $2\frac{1}{4}$ years seed trapping are presented in figure V.3 and in table V.1 and in Appendix I. The data permit the following conclusions:

Especially over the first 200 ft., seedshed was very variable. The rate of seedshed dropped off very rapidly over the first 100 ft., levelled out over the next 100 ft., and then decreased only very slowly. Dissemination of seed from the edge of a dense forest is very poor.

Catches between 1 and 3 times tree height were very low and sporadic, but did not decrease much with distance. This may be a reflection of increasing wind speeds away from the forest shelter. A 15 m.p.h. wind should carry a sound seed to twice tree height distance, which is 500 ft. in the case of 250 ft. high trees.

Chaff is a little smaller and lighter than sound seed, and may, therefore, be expected to fly further. The percentage of chaff caught in this experiment did not show any marked increase with distance:

	Seed Catch	
	Total free seed	% of chaff
under canopy	2,400	89.6%
255 to 500 ft.	100	91%
505 to 750 ft.	47	83%

Mapping of particularly good and poor catches did not reveal any marked variation with distance along the seeding edge.

Capsules drop very fast. A 15 m.p.h. wind would carry them to a distance equal to less than tree height, namely 200 ft. 45 capsules were caught within t~~h~~ree height but only 3 capsules beyond tree height. Occasionally, capsules attached to leafy twigs torn off in a storm may serve to spread the species over extra long distances.

Only 5.3% of the free seedshed to the SE was carried beyond tree height. Hence the average wind speeds affecting the flight of the seed in this direction exceeded 7 m.p.h. only on 5.3% of all occasions. Observations at Fitzgerald estimated the frequency of winds above 7 m.p.h. in any direction at over 60%. Even if the Bureau observer was inclined to overestimate wind speeds, the comparison of 5.3% and 60% is still good evidence that the dense forest edge greatly slowed down the wind over several chains.

TABLE V.1

MEAN MONTHLY RATE OF TOTAL FREE SEEDSHED PER TRAP OF 1/4,400 ACRE SIZE (ROAD 11)

Ft. distance of seed trap from forest edge:	310' to 350'	355' - 395'	400 - 440	445 - 485	490 - 530	535 - 575	580 - 620	625 - 685	690 - 750
No. of trapping samples (periods):	8	18	3	12	10	7	9	15	13
No. of seed shed 1/4,400 acre/month	1.7	2.8	0	.15	.10	.10	.07	.46	.90

Note that seedshed beyond 500 ft. may have been increased by trees other than those studied.

IV DISPERSAL OF SEED FROM THE EDGE OF AN OPEN FOREST (W48)

The results of $1\frac{3}{4}$ years seed trapping at W48 are plotted in figure V.3, and recorded in Appendix II.

The overall rate of seedshed here was perhaps only one tenth as high as at Road 11. The small seed catch makes conclusions less reliable.

At least over the first 100 ft., the rate of decrease in seedshed per acre with increasing distance from the forest edge was much lower than at Road 11.

17% (34 out of 200) of all seeds shed to the S.E. within $1\frac{1}{2}$ tree heights fell beyond tree height. This suggests that the frequency of above 7 m.p.h. winds between tree crown and ground level was about three times as high (viz. 17%) as at Road 11.

It may be concluded that dispersal of seed from the edge of an open forest is more efficient than dispersal from the edge of a dense forest.

V. DISPERSAL FROM ISOLATED SEED TREES: ROAD 8W

The aim of this experiment was to compare the efficiency of dissemination from a forest edge with that from isolated seed trees without understorey. The number of germinations in May, 1960 at 300 ft. from the nearest seed tree on this area burnt in February, 1960 indicated unusually effective seed throw. The installation of the traps three months after the trees were killed by fire missed the shedding of most of the heavy 1959 seed crop that had been on the trees. Enough seeds were caught to confirm the impression of especially efficient seed throw.

The results of the catches are summarized in Table V.2 and figure V.5.

TABLE V.2

FREE SEEDS (CHAFF + SOUND) CAUGHT AT ROAD 8 AT VARIOUS DISTANCES AT 90° FROM AN ISOLATED SEED TREE

Actual distance of trap (1/4400 acre) from 200 ft. tree on uneven terrain (ft.)	0	30	48	65	100	150	200	250	300	350
Angle of elevation from trap to top of crown:	-	-	-	-	67°	56°	48°	42°	36°	31°
Equivalent distance from 250 ft. tree on level terrain (ft.):	0	30	50	70	105	165	205	280	340	426
Total No. of free seed caught from										
23.5.60 to 8.8.60	3	3	3x	5	13z	3	2	5	1	0
22.8.60 to 15.10.60	7	6	6	3	1	2	3	0	2	1
16.10.60 to 17. 2.61	8	21	20	26	17	12	7	5	6	8
Total	18	30	30	34	31	17	12	10	9	9

x underestimate because trap not installed until 7.7.60.

z high figure might be accounted for by seed shed from four capsules caught in this trap.

Unlike the pattern of Road 11, the seed here was spread more evenly and more widely. This tendency had already been apparent at W48, and seems to be even more pronounced here with maximum exposure of the seed source.

The seed dispersed beyond tree height distance was in the order of 40%. This means that frequency of above 7 m.p.h. winds underneath this seed tree approached that observed at Fitzgerald in the open.

The above evidence is supported by several cases where plentiful natural regeneration has been observed by the author at a distance equal to more than tree height from the nearest seed tree on exposed areas.

It is concluded that dispersal of seed from isolated, exposed seed trees is much more efficient than dispersal from forest edges. This would be expected from a knowledge of wind behaviour. Forest edges not only slow down the winds which blow across them but also tend to channel oblique winds so that they are parallel with the forest edge.

Comparison of the Above Results with Seedshed Studies made by other Workers.

The rate of seedshed at various distances is expressed as a percentage of the rate of seedshed beneath the tree.

	At ½ tree ht.	At tree ht.	At 1½ Tree ht.
Cunningham (1960)	15%	3%	Less than 1%
Road 11	17%	7%	" " ½%
W48	63%	18%	2½%
Drangsholt (1956)	60%	20%	½%
Road 8	65%	40%	15%

Both Cunningham and Drangsholt had studied isolated trees. However, Cunningham's figures do not agree with the Road 8 pattern and Drangsholt's figures agree with the W48 pattern only. The differences in these findings are probably due mostly to differences in the prevailing wind speeds and due to differences in the exposure of the seed source to wind. This emphasises the importance of exposure of the seed trees both in relation to other trees and to topography. At the same time and for the same reason, it is emphasized that efficiency of seed dispersal is likely to be very variable.

VI. CONCLUSIONS : THE EFFECTIVE AREA OF SEED DISTRIBUTION

The forester is concerned with effective distance of seed throw, i.e. the distance from the seed source where quantities of seed are sufficient for adequate regeneration. This distance cannot be stated precisely for all cases because of the large number of variables which determine it. For one region these variables include the height of the seed source and its exposure to winds as discussed above; the amount of seed available for dissemination; the number of seedlings required; the receptivity of the bed and the degree of seed robbery and seedling survival.

Seedshed from Standing Forest at the Edges of a completely Felled Area.

Vigure V.3 shows the relationship between distance of seedshed from a dense forest edge and the rate of seedshed per acre in the direction of optimum dispersal. It may be calculated from this figure that dispersal of seed was adequate only to a distance equal to half tree height, assuming that only 600 established seedlings per acre were required and that the seedbed was so good that one percent of all viable seeds which were shed on it during 20 months produced established seedlings. It must also be remembered that this particular forest shed 2.3 lb. of seed/acre/year and was, therefore, a relatively good seed producer.

In actual fact, there is no adequate regeneration near the edge of this forest at all, because the slash was not furnt and the seedbed was, therefore, unfavourable.

To obtain satisfactory regeneration under favourable circumstances on the whole of a coupe by relying on the seed from the edges of uncut forest, it would be necessary to restrict the width of coupes to 2 or 3 chains. This would make logging uneconomic. It is, therefore, necessary to make use of seed trees within the coupe.

The same conclusion was reached by Cunningham (1960) for E. regnans forest with a low understorey in Victoria.

Seedshed from Isolated Seed Trees.

If a seed tree carries abundant seed it may satisfactorily restock more than one acre of ground. Dissemination, especially to the SE is quite efficient. However, only exceptionally good seed trees carry the 2 - 3 lb. of seed necessary to sow one acre. Usually, most selected seed trees carry little or no seed. Quantity of seed production is, therefore, more critical than quality of seed distribution. It is more important to select seed trees for productivity than for spacing, provided no single acre is left entirely without a seed tree.

Dissemination from exposed seed trees is probably good enough to restock an area with only one well spaced fruitful seed tree per acre. How many additional trees are needed depends on seed productivity. This is discussed in Chapter VIII.

CHAPTER VI

THE EFFECT OF FIRE ON EUCALYPTS RESERVED FOR SEEDING

THE EFFECT OF FIRE ON EUCALYPTS RESERVED FOR SEEDING.

by

K.W. Cremer

Summary

This paper discusses the effects of fire on the ability of especially reserved trees of *Eucalyptus regnans*, *E. obliqua*, and *E. delegatensis* (syn. *gigantea*) to produce a useful supply of seed for the regeneration of logged forest areas with a dense understorey of rainforest or wet sclerophyll scrub.

Observations are given on the fire resistance of the different eucalypts at different ages and in different environments. There is a discussion of the ecological consequences of various combinations of fire resistance with various types of fire.

The surface soils in the moist cool forests of Tasmania usually accumulate a large amount of raw humus. At the butts of mature eucalypts the humus forms a mound of amorphous, combustible material which is at least several inches deep and commonly reaches several feet in depth. The humus can burn only after an unusually dry summer. A fire which consumes the humus will kill or severely injure all local tree species

almost irrespective of bark thickness. The death of the tree is due to the killing of the cambium where the humus was burnt in contact with the bark.

On the other hand, a fire which consumes only the surface fuels and leaves the humus intact will be much less injurious, especially to the trees with the thicker bark. Even a complete scorching of the crown is rarely lethal without the girdling of the trunk.

Fire may accelerate the abscission of twigs, leaves, capsules, and immature floral parts. The abscission of capsules is accompanied by accelerated seed shed. Immature floral parts do, however, often survive in good numbers provided the twig subtending them survives.

Twigs may be killed either as a result of the girdling of the tree or else by being directly scorched by the radiant heat. The leaves and floral parts on killed twigs must die, but are not abscissed. Seedshed occurs as soon as the capsules dry out. The seeds inside the capsules on the tree often survive in good numbers.

Because of these findings and because burnt seed beds become relatively unreceptive to eucalypt seed after one to two years due to excessive weed growth, it is unwise to rely on regeneration from any seed crop which is <u>not</u> mature at the time of the fire.

I INTRODUCTION

E. regnans grows in the wet, cool climates of Tasmania and south-eastern Victoria on soils of medium to high fertility and is invariably associated with a dense understorey of either temperate rainforest or wet sclerophyll scrub (see photos No. 1 and 2). Gilbert (1959) has pointed out that these conditions do not favour continuous regeneration and that the majority of the stands consist of trees of the one age. He has assembled evidence to show that these stands of trees of the one age arise from regeneration following destruction of the previous forest by uncontrolled fires. These fires produce conditions favourable for regeneration. Seed is available in quantity and falls on a good freshly burnt seedbed. The fire also kills the understorey which would otherwise shade the ground too much for the survival and growth of seedling Eucalypts.

In the Florentine Valley in Central Tasmania where the following studies have been made, there are extensive stands of eucalypts with dense understorey. The methods used here to obtain satisfactory regeneration after the logging of eucalypts, attempt to imitate the conditions of natural regeneration after wild fire. Frankcombe (1961) has described these methods.

Photo No. 4 : Butt of *E. regnans* showing remainder of large humus mound accumulated under rainforest conditions. Humus fire has exposed several major roots some of which are adventitious.

Photo No. 5 : "Gum veining". Butt of *E. regnans* eight months after a humus fire killed the lowermost cambium. Axe cut in centre shows dead portion underneath newly laid-on wood. This dead portion will become a gum vein if the tree survives.

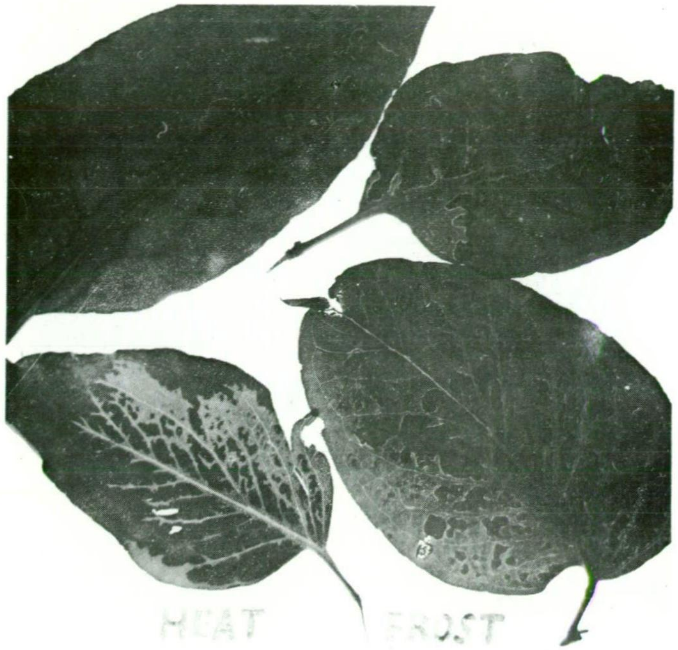


Photo No. 6 : Comparing slight frost damage with slight heat damage. Note that areas between major veins die first. *E. regnans.*

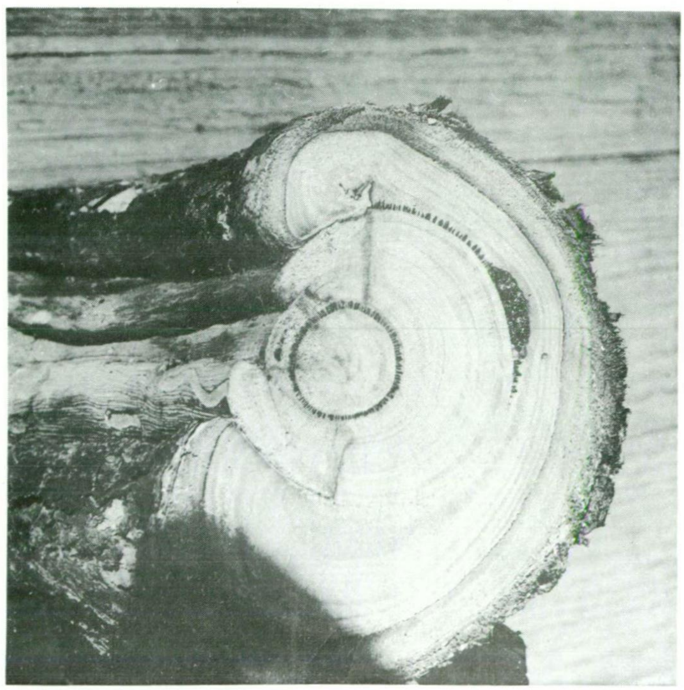


Photo No. 7 : Branch of *E. obliqua.* Side facing ground was twice killed by radiation from fire. Latest fire is damage associated with gum vein and gum pocket.

Photo No. 8 : Recovery of *E. obliqua* from complete crown scorch - two years after fire. Note that all leaf bearing twigs were killed. The new leaf bearing twigs arise from larger, more fire resistant branches.

Photo No. 9 : Recovery of *E. regnans* from complete crown scorch - two years after fire.

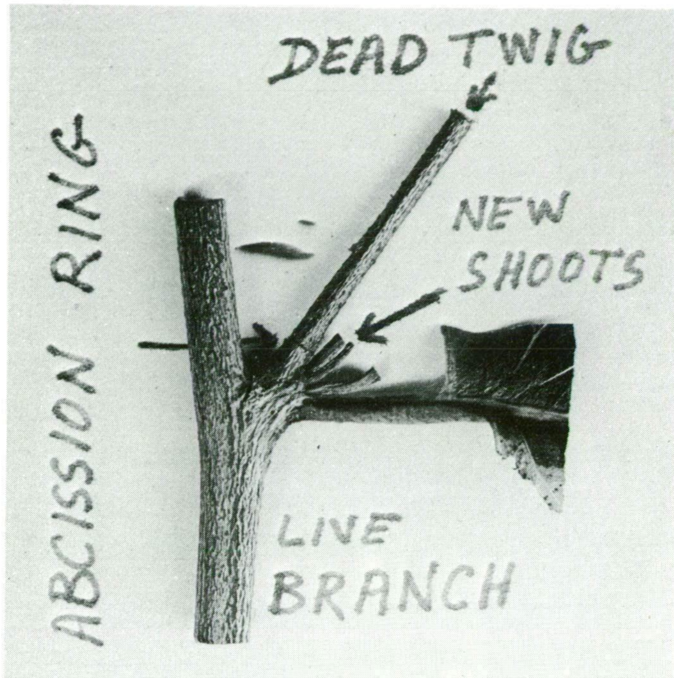


Photo No. 10 : Showing distinct abscission ring at base of fire killed twig

Before logging operations begin about 5 dominant trees on each acre are marked for retention as trees to supply seed. The remainder of the useful trees are felled and their logs are removed. All useless trees and shrubs are then felled or flattened. The resulting very large quantities of readily dried out fuel are burnt by a controlled fire when the weather conditions are suitable. Essentially the fire is used as a means of removing large quantities of woody material and for preparing a suitable seedbed. The youhg eucalypt seedlings are browsed by native possums and wallabies. To reduce this damage the local population of game is decimated by trapping and/or poisoning. The trees which have been left to provide seed are removed after several years if they are usable.

This system of regeneration and its consequent problems have been investigated by Cremer (1960) and (1961). It has been found that seed on the ground is destroyed by fire, the only seed surviving being that carried by the standing seed trees. The effect of the fire on the seed trees is therefore of prime importance. It is also shown that in the Florentine Valley a dense seral layer of herbs, mostly mosses, forms within 2 years of the fire. This herb layer greatly reduces the chances of successful regeneration from seed. Thus if the ability of the trees to produce a reasonable crop of seed in the first two years is impared by the fire, a very poor stocking is likely even if the trees consequently bear heavy crops.

II TYPES OF FIRE WHICH OCCUR IN REGENERATION BURNING

The type of fire obtained in any one instance depends on the fuel, the weather, and the topography. The fuel conditions are defined by the presence and abundance of the different classes of fuel, their moisture content, and their arrangement. The two main classes of fuel which may be burnt in regeneration fires are the surface fuel, and the subsurface fuel.

Preparation for a regeneration burn involves the felling or flattening of the dense understorey by chain saw, axe, bulldozer, and by the dragging of logs. The flattened understorey, plus the crowns of the felled eucalypts, provides very large quantities of surface fuels which can dry out rapidly and are close to the ground. The nature and arrangement of these fuels, and the absence of a standing, live canopy are the main features which distinguish a regeneration burn from a wild fire in the virgin forest.

The second class of fuel is the subsurface fuel or raw humus.

Hoover and Lunt (1952) define the humus or H layer of the soil as "a layer consisting of well decomposed organic matter unrecognizable as to origin". According to their system of classification the humus type on the dolerite soils of the Florentine Valley would be called a "thick duff mull", and the humus type on the soils derived from limestone (Ashton, 1956) would be called a "thick mor". The mor type of humus layer does not merge with the mineral soil horizon below it; there is an abrupt boundary. The important point in this context is that the undisturbed forest in the moist, cool climate of the Florentine Valley accumulates a considerable depth of amorphous combustible material on the forest floor, and that this combustible matter forms especially deep mounds of peaty material in close contact with the butts of the eucalypts. These mounds may be only a few inches deep under a canopy of wet sclerophyll scrub, but are commonly several feet deep under a rainforest canopy.

The average depth of humus found under these rainforests appear to be similar to that found under some hardwood forests in North eastern U.S.A. (Hart, 1961; Sartz et al 1950) namely 2 - 3 inches. Some softwood forests in Alaska accumulate a much greater depth of humus, namely an average of 4"- 6" ~~miles~~, and sometimes over 12 inches (Lutz 1960).

Burning in spring is considered dangerous because there is a chance that the fire may survive inside a stump or in the humus for weeks and might break out at a time when the fire hazard is high. For this reason most regeneration burning is done during February and March. Unless otherwise stated all observations recorded below are based on fires which occurred in February and March.

Davis (1959) distinguishes between three types of forest fire in northern America, and adds that in actual fire situations these three kinds of fire may occur simultaneously and in all combinations. He distinguishes between surface fire, crown fire, and ground fire. These terms agree with those used below except that a ground fire is here called a humus fire, for the sake of clarity.

(1) SURFACE FIRES

In the absence of humus or when the humus is not dry enough to burn, the fire is restricted to consuming only the fuels on or close above the surface of the ground. Such a fire is called a surface fire. Because the litter and logging slash dry out much more rapidly than the humus, it is possible to have hot surface fires which leave the humus almost untouched.

A crown fire consumes the taller, standing vegetation, and may be regarded as a special type of surface fire. Crown fires do not occur in regeneration burning because not enough crowns are left standing.

(2) SUBSURFACE OR HUMUS FIRES

Any fire which consumes a "considerable" amount of humus is here called a humus fire. The fire is a pure humus fire if little or no surface fuel is burnt in addition to the humus.

A humus fire can be quite independent of surface fuel. The humus may burn at the same time as the surface fuels, or it may burn several days or years after the surface fire. If the regeneration burn, ie. the first fire, has been a humus fire, the burnt area is sometimes left quite devoid of humus. Usually, however, enough humus is left for at least one more fire.

This means that the regeneration burn is usually a poor insurance against subsequent burns, and that a regenerating area must be carefully protected from the possibility of subsequent humus fires. A humus fire will spread only very slowly unless it is fanned by fairly strong winds. Once the humus is dry it takes more than one inch of rain to make it safe against fire. These two features help to make a spreading humus fire very difficult to control.

Because of their great distructiveness both in cut over and in virgin forest, uncontrolled humus fires should be avoided with especial care. It is therefore important that the inflammability of the humus is known at all times during a dry summer. The usual fire danger rating systems which involve measurement of the variation in moisture content of a small, exposed piece of wood are <u>not</u> suitable for assessing the hazard of humus fires, because the moisture content of humus is not related to that of exposed, small sized surface fuels. One way to obtain a realistic humus fire danger rating is to measure the moisture content of the humus in situ under various degrees of exposure. The measurement could be done, as for soils, by periodically recording the electrical resistance of buried blocks of Plaster of Paris.

Frequency of Humus Fires

The humus underneath the canopy of undisturbed rainforest only very rarely becomes dry enough to burn, perhaps only once or twice in each century. Even on completely felled sites the humus cannot burn until after a relatively dry summer. The humus never burns in spring.

The weather records and inspection of burnt forest areas suggest that in the twelve years from 1950 to 1961 the opportunity to burn much humus in the Florentine Valley arose only three times, namely in 1950, in 1960, and in 1961. The recently introduced practice of completely felling the understorey after an area is logged will probably increase the frequency of humus fires because ~~the humus fires because~~ the humus is given a better chance to dry out.

Humus fires must be relatively infrequent, otherwise there would not be so much humus. Further evidence for the infrequency of humus fires comes from the fact that the destructive nature of humus fires in the forest had not been recognized in Tasmania.

(3) COMPARISON OF THE EFFECTS OF SURFACE VERSUS HUMUS FIRE.

(a) <u>Effects on the Soil</u>

The layer of humus which is left intact by a surface fire is useful in cushioning the impact of rain, in impeding surface run off, in favouring infiltration, and in storing of water (Hart, 1961).

If, on the otherhand, the humus is removed by a humus fire the surface of the soil is often characterized by a layer of dust or loose, hard-baked mineral soil crumbs. This loose layer is subject to much frost lifting in winter and to rapid desiccation in summer. The dust or loose crumbs probably represent the mineral content of a mull type of humus.

In a few spots the loose layer is so deep that a human foot can sink in as much as six inches deep.

Where the fire has been particularly hot, eg. around stumps and under logs, and where the soil had been compacted by tree roots or tractors, the soil surface exhibits a layer of reddish, hard, brick-like crumbs.

These different effects of fire on the soil strongly influence the recolonizing vegetation.

(b) Effects on the Trees

The most striking difference between the effects of a surface fire and those of a humus fire is that the former is relatively harmless to the trunks with resistant bark while the latter is invariably most injurious, and commonly kills the whole tree. The great destructiveness of a humus fire is probably due to prolonged heating at high temperatures in close contact with the bark.

The lethal temperature of most plant tissues is about 50°C. All fires are much hotter than this, namely between 200 and 1000°C. Organic matter may glow at 200°C. The temperature of flames from wood is about 950°C, (Davis 1959). Hatch (1960) found that the temperature in the centre of a burning heap of slash may remain at 700-850° for one to two hours. The author noted that a fire which burnt only humus plus some herbs was able to melt aluminium tags, ie. reached at least 660°C. A humus fire may be a little cooler than a hot surface fire.

It is obvious from the above that any fire will produce temperatures much above those necessary to kill plant tissues instantaneously. The important point in this context is whether the cambium is heated to a lethal temperature. This depends on the insulation afforded by the bark and on the degree and duration of the heating.

Surface fires are usually of relatively short duration. They affect the tree mostly by radiation because relatively little of the surface fuel is in direct contact with the bark. For this reason the destructiveness of surface fires is often limited to the unprotected organs such as leaves, and twigs, and thin bark.

A humus fire, on the other hand, lasts very much longer. A humus mound often smoulders for days. Humus fire does not produce radiant heat of high intensity and therefore kills mostly by contact. The bark of the trees is heated by conduction from the glowing humus in immediate contact. All the dead bark and some of the live bark may be burnt away. Many trees of both E. regnans and E. obliqua were seen with only about ¼ inch thick bark where the humus was burnt away. None of the types of bark found on the local tree species is effective in protecting the cambium from damage by a hot humus fire.

It is possible that the destructiveness of humus fire can vary with the actual moisture content of the humus.

Jacobs (1955) has pointed out that a portion of the butt of a tree may be killed by the long-continued fire that results from the flue action which develops between the tree and any log resting against its base. A burning humus mound produces a similarly long-continued fire and is all the more devastating because it completely encircles the tree.

The destructiveness of humus fire is fully realized in Northern America (Lutz, 1960).

The following three local case histories illustrate the great contrasts which can be found between surface and humus fire.

(c) Case Histories.

Case No. 1

The rainforest understorey of coupe W54 was completely felled in the summer of 58/59. The western half of this coupe was burnt by a pure surface fire in February 1959. This fire scorched 15% of the eucalypts' crown volume and killed one suppressed individual out of the 64 eucalypts under observation. The eucalypts were *E. regnans* and *E. gigantea* 150 and 250 years old.

In February 1960 the same area was burnt again, this time by a pure humus fire. Most trees, irrespective of species were killed. The few that did survive subsist on as little as 1/20 of their former live butt circumference.

In February 1960 also the eastern half of W54 was burnt. This area still carried all its surface fuel from the complete felling of the understorey. The surface fire was followed by a humus fire after a few days. The result was as devastating as after a pure humus fire.

Case No. 2

Coupe P19 wasa150 years old stand of *E. regnans* with a 26 years old wet sclerophyll understorey and several inches deep humus at the butt of the eucalypts. Part of P19 was burnt by a pure surface fire in spring (October) 1959. All the eucalypts survived this fire.

The rest of P19 was burnt in autumn (March) 1960. This fire burnt the surface fuel as well as the humus and killed nearly all the eucalypts.

Case No. 3

In January 1959 a wild, uncontrolled fire burnt a large area which carried *E. obliqua* with a wet sclerophyll understorey but without humus. Though all its foliage was killed the recovery of *E. obliqua* was excellent - nearly one hundred percent (See photo No. 8).

In March 1960 a stand of mature (250 years old) *E. obliqua* opposite Road 8W was almost completely killed by a regeneration burn. In this case the fuel was a felled understorey of rainforest plus a large quantity of humus. The humus burnt!

III THE EFFECT OF FIRE ON ROOTS AND BUTT

(1) NUTRITIONAL EFFECTS

The burning of large quantities of organic fuel suddenly releases an abundance or perhaps even a super-abundance of plant nutrients. A humus fire may in addition profoundly influence the microbial life and physical properties of the soil. Nothing is known about the effect of these phenomena on the growth of the surviving eucalypts.

(2) DESTRUCTION OF ROOTS.

The humus layer of the soil is invariably matted together by a dense maze of rootlets. There are reasons to believe that some of these rootlets belong to the eucalypts. It is therefore expected that a humus fire can destroy a large proportion of the eucalypts' feeding rootlets. A surface fire would probably be relatively harmless to the rootlets.

Lutz (1960) reports that a humus fire in the boreal forests of Alaska may consume living roots as large as 8 to 9 inches in diameter. In the Florentine Valley it is usual for large, exposed roots to be killed by humus fire but in all cases where a large root was consumed it was evident that the root was dead and dry before the fire.

3. INJURY TO THE BUTT OF THE TREE

If the butt is killed, the stem and crown must die, and unless the roots can sucker from below soil level, the roots must die also. Because they are generally insulated by mineral soil, the roots are rarely all killed directly by any fire. Eucalypts usually recover remarkably well from complete defoliation by fire. The crowns of very tall trees are not exposed to extremely intense and prolonged heating. The butt is therefore usually the weak link which determines the resistance of a tree against fire.

(a) Resistance against Injury by Humus Fire

If a layer of humus at least several inches deep is burnt in close contact with the bark of a tree the cambium underneath the burnt bark is likely to be killed irrespective of bark thickness and tree species. If the killed cambium completely girdles the trunk, the tree will usually die. Big trees with irregular butts commonly survive a humus fire because of the survival of a small strip of cambium in a crevice sheltered from good contact with the fire.

The amount of damage done to a tree by a humus fire is to some extent influenced by the rooting and suckering habits of the tree species.

Eucalypts in rainforest tend to have relatively shallow roots. They may have germinated on top of a humus layer and therefore have formed the beginnings of their major roots above the safe mineral soil. In any case, diameter growth of the roots would tend to raise their upper surface above the mineral soil. This is especially so with the buttress roots typical of old eucalypts in rainforest, because such roots concentrate most of their growth _above_ the pith. In addition, both _E. regnans_ and _E. obliqua_ commonly form adventitious roots from the portion of the butt covered by the humus mound (see photo No. 4)

These rooting habits increase the amount of damage which a humus fire can do to each tree, but at the same time they increase the chance that some portion of the butt will survive. On balance, these habits appear to be of little significance to the survival of the tree.

Ability to sucker from the underground roots appears to be the only reliable method of surviving a severe humus fire. This ability is present in young _E. obliqua_, because of its lignotuber, and in _Olearia argophylla_, _Nothofagus cunninghami_, and _Atherosperma moschata_. Only about five percent of the individuals of these species do recover by suckering. The recovery is sometimes and perhaps always only temporary.

In summary, no local tree species can efficiently resist or survive a severe humus fire. Difference in fire resistance between individuals and between species becomes important only where the fires are less severe (Davis 1959).

This means that the type of fuel associated with a tree is just as important to its fire resistance as its own protective mechanisms. The type and quantity of fuel which accumulates about a tree depends to some extent on the tree itself and depends very largely on the environment. For instance, E. obliqua grown in the environment of temperate rainforest which favours the accumulation of much humus, is very fire sensitive. Nevertheless, E. obliqua has the reputation of being extremely resistant against fires. This reputation is based on E. obliqua in its more usual habitat which is free of humus.

The corollary of these observations is that a naturally resistant species such as E. obliqua can be kept resistant in a potentially dangerous environment such as a rainforest site by using repeated fires to prevent the accumulation of humus or other dangerous fuels.

(b) Resistance against Injury by Surface fires

Surface fires are usually much less destructive than humus fire, but do vary very widely in their severity. They are relatively common throughout the eucalypt forests of Australia, and most eucalypts are remarkably resistant to them. The following observations describe the mechanisms of resistance against fire exhibited by the local eucalypt species and relate how the efficiency of the resistance varies with species, age, and vigour. Because of the moist temperate climate all the local eucalypts are likely to have dense undergrowths, and therefore severe fires.

The bark on the butt is the most important factor which determines the fire resistance of a tree. For the purpose of the following descriptions the terminology of Chattaway (1953) is used here. The bark includes all tissues outside the wood. The dead outer region of the bark is called rhytidome, and the live inner region is called phloem. The phloem is bounded and protected by the phelloderm which is a relatively thin layer and originates from the phellogen. Where the rhytidome does not persist the phelloderm is the outermost layer and gives the bark its smooth appearance.

Jacobs (1955) states that fire resistance in smooth barked eucalypts " is probably related to bark thickness and the rapidity with which new periderms can be formed in the live bark tissues if the outer protective layers are destroyed by heat".

It seems that eucalypt barks may be fire resistant for one or both of two reasons. Firstly, damage to live tissues may be avoided by a layer of persistent rhytidome which serves as insulator. The degree of this type of fire resistance depends largely on the thickness of the rhytidome and its inflammability. The protection is best if the insulator is thick and does not burn away. (eg. E. obliqua)

The second method of fire resistance is ability to recover from the killing of live tissue. Two conditions are necessary for this, namely a thick phloem, and the ability to form a protective periderm very rapidly between the injured and healthy portions of the phloem. Eg. E. Maculata

(Jacobs 1955). The live outer phloem is, of course, a highly non-inflammable insulator for the inner phloem.

The relative fire resistance of different eucalypt species depends on how efficient these mechanisms are in each species and how early in the tree's life they start becoming effective.

The following observations describe how the thickness of persistent rhytidome, and ability to form new periderms may vary within and between the local eucalypt species.

E. regnans

E. regnans develops rough bark (persistent rhytidome) relatively late in life - and then only on the lower portion of the trunk. The smooth bark, even on large trunks, is less than half an inch thick, and is usually between $\frac{1}{8}$ and $\frac{3}{8}$ of an inch thick. Consequently the smooth bark is very fire sensitive, and the fire resistance of E. regnans depends almost entirely on the thickness of the persistent rhytidome.

In its first 20 to 30 years E. regnans is injured or killed by most of the fires which are hormal in its environment. Thereafter, the rough bark achieves a more protective thickness and height, and by the age of 100 years E. regnans can tolerate everything but crown fires and humus fires. On mature trees the rhytidome is usually over half an inch thick, and sometimes as much as $1\frac{1}{2}$ inches or more.

Chattaway (1953) observed that formation of mature, rough bark on the butt of E. regnans appears to depend on the size rather than age.of the tree. Similarly the resistance against fire depends on size rather than age.

E. regnans

For instance, a fire of just the right severity was able to kill the suppressed trees and spare the dominants in a 26 years old stand of *E. regnans*. Such thinnings by the selective killing of suppressed trees might also occur at later ages (see photo. No.2).

The smooth bark of *E. regnans* does have some hope of surviving the killing of the phelloderm, or outermost, protective layer. If the inner part of the phloem is not directly killed it may form a new phelloderm to control its water losses. The bark outside the new phelloderm is abscissed and can be lifted or peeled off within a few weeks of the fire. The thickness of the abscissed layer of bark varies with the intensity of the fire.

E. obliqua

By contrast with *E. regnans*, the closely related *E. obliqua* is very much more resistant against surface fires, because it forms thick, rough bark early in its life (20 years). The mature bark develops on all the stem and major limbs.

E. Viminalis

Like that of *E. obliqua*, the natural range of *E. viminalis* is a very wide one. It occurs on the fringe of rainforest, where it can be killed by humus fire; but usually it grows on sites free of deep humus and has a reputation for great fire resistance.

E. viminalis has practically no persistent rhytidome but has a thick phloem which reacts like that of *E. maculata*.

The thickness of the bark layer which is abscissed in response to fire injury depends on the severity of the fire. For instance, one individual which was exposed to fire on one side of the trunk, abscissed a sheet of bark which was half an inch thick nearest the fire and tapered away to zero twelve feet up the tree on the exposed side. The other side of the trunk did not absciss any bark.

The undisturbed phloem on the butt of E. viminalis is usually not much more than one inch thick and - judging by the annual rings - represents many years of growth. This means that the fire resistance of E. viminalis is decreased for several years after each fire. In one area where E. viminalis was subjected to two hot fires in two years, each fire removed half an inch of bark with the result that some trees were left with patches of exposed wood and other patches of very thin phloem. These trees are now extremely fire sensitive.

The corollary of these observations is that E. viminalis is very resistant to occasional fires but quite sensitive if the fires are frequent and severe. Fire can, therefore, eliminate E. viminalis from areas which are frequantly burnt and possess an undergrowth which recovers rapidly after each fire to provide enough fuel for severe fires - e.g. areas of dense bracken.

(c) Patterns of Injury caused by Fire

The lightest form of damage consists of the charring or burning of the outer portion of the rhytidome. This is apparently harmless except where the bark is scarred, e.g. by insect damage. More intense or prolonged heat may kill part of the phloem. This does not appear to be very harmful either. Still more intense or prolonged heating may kill <u>all</u> the phloem including the cambium. In this case the injury is permanent. The undiscoloured sapwood continues to function apparently normally for several months but cannot survive indefinitely without phloem. The next degree in fire injury is the killing of part or all of the sapwood. Killed, i.e. discoloured, sapwood may function for several months. Complete discolouration of the sapwood can cause the crown to wilt in a few days. The rarest and most severe damage occurs when live tissue is actually charred or burnt away. In extreme cases the bark as well as the sapwood may burn away. Any one tree usually exhibits several of these degrees of damage after a humus fire.

The death of the cambium can be recognized by a discolouration distinct from desiccation almost immediately after the fire by chopping the barkaway. After a year or so the bark starts to splitt off spontaneously. Within a few weeks of the fire the sapwood underneath the killed cambium becomes heavily infested by the <u>Ambrosia Beetle (Platypus omnivorus Lea)</u>. The fine white dust at the entrance of the flight hole in the burnt-black bark is most conspicuous. It is expected that this beetle which is confined to unseasoned timber, attacks fire killed trees more heavily than felled trees, because the standing trees take longer to dry out.

The lower limit of cambium which is killed by humus fire is one to two inches below soil level. The upper limit of killed cambium is usually also quite distinct but does not seem to be predictable in its location from any external evidence. It may be a long way above the contact with fire. Very commonly the extent of the fire-aged dead wood surface is greater than the extent of killed phloem. This means that new wood is laid on over the "fire-killed" wood surface. This boundary often, but not always, becomes a gum vein. By far the greatest extent of such "gum veins" is vertically above the area of direct fire injury. Gum veins are located in the new wood; and in the true gum vein, the old and the new wood are connected by ribs (see photo No.7). The spaces between the ribs are filled with gum. Such gum veins can only be developed by a living cambium. In other cases the cambium at the time of the fire seems to have died. In this event new wood is laid on over the old wood surface without any physical radial connection and at least sometimes without any gum. The new wood must come from a cambium regenerated from the phloem . (see photo. No.5)

Jackson (pers. comm.) suggests that the extensive killing or injury of the wood surface above the point of direct injury by fire could be due to the take-up and transfer of heat by the sapstream as it moves past the area which is being heated directly by the fire.

This description of the patterns of fire damage is oversimplified and very superficial. A closer study should reveal much more information, not only on the effects of fire, but also on the physiology of trees in general.

IV-THE EFFECTS OF FIRE ON CROWN AND FOLIAGE

Fire can kill the foliage of a tree either by causing the leaves to wilt by cutting off the sapstream, or else by direct heating of the foliage, i.e. by scorching.

1. Wilting

Wilting is caused by the girdling of the tree at the butt. Wilting foliage turns pale green at first and after a few weeks becomes grey to grey brown in colour.

The behaviour of the crown depends primarily on the least damaged portion of the butt's circumference. In the following discussion the injury referred to affects the whole of the butt at or above the intensity mentioned.

Killing of the phloem and the cambium without discolouration of the sapwood is not immediately fatal to the crown. Many, perhaps all, trees thus affected seem to continue functioning normally at least until after the winter. The crowns may even sprout new shoots. During winter the water demanded by living crowns is very low. A trunk full of water felled in late autumn will keep the branches attached to it green all winter, while unattached branches wither within two or three weeks. Many trees which were girdled by fire suddenly wither in spring (September) when the transpiration rate increases due to the warmer weather.

Eventual death of all these trees is inevitable due to starvation of the roots.

If part or all of the sapwood is killed (discoloured) the crown may wither within a few days of the fire, usually within a few months. Most such trees wilt in 2 to 4 weeks if the weather remains hot.

In suppressed trees both the bark and the sapwood are relatively thin. It is expected that the sapwood of such trees is more easily killed completely and that the crowns will wither faster than those of dominants.

According to the usually accepted theory, the function of xylem in the ascent of sap is only passive. The vessels in the xylem may not be the only route for the transport of sap, but they do probably transport the greatest volume of sap when the transpiration rate is high (Scholander 1958). So long as the vessels remain air tight the main sap stream need not be interrupted. The prolonged air tightness of the vessels is, however, assured only by the live cells in the xylem which in _Eucalyptus_ is not necessarily paratracheal. (Chattaway, 1953). Deep penetration of heat would kill the protoplasm. This may explain the more rapid wilting of the crown when the whole of the sapwood on the butt is discoloured due to scorching by fire.

Neither discoloured nor undiscoloured sapwood underneath the bark killed by fire will become blocked up like heartwood. Air can easily be sucked by mouth through a piece of killed or living sapwood, but not through a piece of heartwood.

The water columns in the vessels of killed or living sapwood continue to remain under tension. This is evident from the hiss of air sucked into freshly cut sapwood and by the rapid disappearance of saliva applied to the freshly cut surface. Ink, when applied to the freshly cut surface, will rapidly ascend and descend through the vessels. It may rise several feet in two minutes.

The hiss in the undiscoloured sapwood of a girdled tree continues for a long time after the fire. It may continue for over eight months and may even be present for a short time after the crown has wilted. The hiss may disappear a few months earlier if the sapwood has been discoloured (killed). There is no hiss in trees - felled, or standing - where crowns have been dead for a year or longer.

2. Scorching.

In Eucalypts scorched foliage is diagnosed by a characteristic reddish brown colour. This colour is quite distinct from that of wilted foliage from the second day after the fire until several months later, when all dead leaves have gradually assumed a grey brown shade.

Drying conditions in the tree crown due to hot air convection must be quite severe. Winds caused by the updraught from the fire are obviously strong. However, neither hot air nor smoke is as evidently related to the scorching of the crown as radiant heat is. Normally the lower part of the crown is more severely scorched. On steep slopes the side of the crown nearest the slope is worst affected. Lower crowns, protect the crowns above them by direct screening. Tissue poisoning by smoke, or desiccation by hot air seems therefore much less important than the protein denaturation due to high temperature from radiant heat. The patterns of incipient leaf ~~left~~ damage by frost and fire are remarkably similar (see photo. No.6).

The amount of scorching suffered by a crown depends on whether it has been exposed to radiant heat of sufficient intensity and duration. This, in turn, depends on the height of the crown or the height of the fire and on the rate and amount of energy released. The latter is determined by the amount, condition and disposition of the available fuel and by the weather. A large amount of heat released slowly at a long distance from the crown would not scorch the foliage.

Three degrees of scorching are recognised here:- firstly, the scorching of leaves only, secondly, the scorching of twigs plus leaves, and thirdly, the scorching of branches plus twigs plus leaves.

(a) The Scorching of Leaves

Some or all leaves and twigs may be partially or entirely killed by the radiation from a surface fire. When a leaf is excessively scorched while its sustaining twig remains alive, the leaf is usually abscissed and drops off quickly. Abscission is a growth act employed by the living plant. A separation layer is formed at the base of the leaf petiole cutting off nutrient and water supply. Saplings do not seem to absciss scorched leaves as readily as trees. Scorching of leaves is the lightest form of direct injury to the crown and becomes almost invisible in one or two months unless the forest floor is inspected for leaves with the typical scorch pattern, or some live twigs are noted for their unusual lack of leaves. A few partly scorched leaves hang on indefinitely. Entirely dead leaves attached to live twigs are seen only very rarely.

(b) The Scorching of Twigs.

More intense heat may kill the twigs as well as the leaves. A dead twig cannot absciss its leaves. Such leaves are torn off eventually by rot and wind. The younger leaves with the weaker petioles break off first. The rate of leaf shed depends on exposure to winds. Exposed tall crowns may be almost bare after half a year, while sheltered crowns are well covered.

The death of a moribund twig is finalized by the formation of an abscission layer at its base (see photo. No.10). This causes the killed twig to die back to the axil of a living leaf or to its origin at a larger, live branch. The bark is separated in a neat abscission ring. The xylem remains physically intact but its vessels are plugged up. This is confirmed by the observation that air cannot be sucked by mouth through a dead/live junction in a twig, whereas air can be sucked through any continuously alive or continuously dead portion of a twig.

The author has looked at both E. regnans and E. delegatensis but has seen no evidence that these species can shed woody twigs by abscission. Some other species do absciss woody twigs and even branches up to one inch in diameter, e.g. Prunus (Eames and MacDaniels, 1947), Atherosperma moschata (Cremer 1960 c) and Populus. The abscissed branches are shed neatly in a ball-and-socket fashion.

(c) The Scorching of Branches and Major Limbs

Still more intense heat can kill larger branchlets entirely and can also kill the lower side of more or less horizontal branches of any size (see photos.7,8,9). Abscission rings on such large organs are not so distinctly visible as in the case of small twigs.

Abscission of scorched leaves and the die-back of twigs may occur in different portions of the same crown. The acceleration of leaf abscission due to fire is additional to the normal peak of leaf shed in late summer. Leaf abscission without the killing of twigs is unlikely to denude a crown. Defoliation due to scorched twigs, on the other hand, can remove any fraction or all of the foliage of a tree.

Given the tall seed trees and the very large quantities of fuel on coupes prepared for regeneration burning in the Florentine Valley, the amount of scorching suffered by the crowns of the Eucalypt seed trees depends largely on the moisture content of the fuel, i.e. the interval between the felling and the burning of the understorey. On freshly felled (1-4 months) coupes less than 20% of the total crown volume of the seed trees may be scorched, while delayed burns (6-18 months) may scorch nearly all the crowns. Only the leaves and small twigs may be dry enough to burn if the felling is only a few weeks old. The result can be a clean but very inaccessible forest floor.

(d) Recovery from complete Defoliation by Scorch

Though usually conspicuous for the vigour of their recovery, Eucalypts *can* be killed by defoliation.

One experiment reported by Cremer (1960 b) showed that a single complete defoliation of 4 to 18" tall *E. regnans* seedlings in Tasmania was lethal in most cases if the defoliation occurred between February and June but was almost harmless between July and January. Campbell (1960) reports that adult ash type Eucalypts may be killed by repeated defoliation by phasmids.

Death following defoliation is probably due to starvation. Hartigan (1961) reports that *E. saligna* trees which have died following a long period of psyllid attack contain no sapwood starch. On the other hand, normal trees of *E. saligna* and *Angophara castata* show a regular and very marked seasonal trend in sapwood starch levels, with peaks around September and troughs around February-March. The peak level of starch content was 2 to 3 times as high as the trough level. *Angophara castata* stored two to three times as much starch as *E. saligna*.

Any plant which relies on its leaves for carbohydrate nourishment must starve to death if it is completely defoliated when its food reserves are insufficient to regenerate adequate new foliage. Additional food reserves are needed if a dormant season intervenes between the date of defoliation and the time of new leaf growth. The seasonal variation in mortality following defoliation reported by Cremer (1960 b) can be explained in terms of starvation and seasonal variation in food reserves such as that demonstrated by Hartigan (1961).

The above findings lead one to expect that the vigour of recovery or the mortality from complete defoliation by fire depends largely on the level of food reserves, which, in turn, varies greatly with seasons, with species and probably with the vigour of individuals. Defoliation by fire at spring time is probably followed by more vigo~~u~~rous recovery than defoliation by fire in autumn. Suppressed individuals are probably killed more easily than dominant individuals. Species with lignotubers store perhaps more food reserves than species without lignotubers.

The author has not had the opportunity to test all these hypotheses.

Dozens of E. regnans have been observed to recover from complete defoliation by a fire in January, 1959 (see photo No.9). It is not known, however, what proportion failed to recover in spite of sound trunks. The combination of complete defoliation by fire plus sound trunks is much more frequent in E. obliqua. Amongst hundreds of E. obliqua crowns which were completely scorched in January, 1959, less than 1% could be said to have failed to recover in spite of a sound trunk (see photo. No.8). Only two E. obliqua with sound trunks but with their crowns completely scorched by a fire in March, 1960 were kept under observation. Both died after sprouting a few very weak shoots.

Given a sound trunk, the recovery of the crown of E. regnans appears nevertheless weaker than that of E. obliqua. E. regnans just does not seem to be able to sprout so readily. While E. obliqua can sprout profusely from butt to crown tip, the sprouts of E. regnans tend to be confined to the thinnest live branches. E. regnans is at a disadvantage for having only very thin and vulnerable bark even on its biggest limbs. This means that the side of the limb facing the source of heat radiation - i.e. the lower side - is frequently killed. Presumably this would reduce the vigour of the crown. E. obliqua, on the other hand, usually has its limbs well protected by thick rhytidome down to a branch diameter of two or three inches (see photo. No.7). Due to an abundance of well protected proventitious buds (Jacobs, 1955) most, perhaps all Eucalypt species do not lack buds to sprout from. It seems most likely that the more vigo~~u~~rous recovery of E. obliqua is related to the fact that E. obliqua stores more food reserves in its sapwood than the non-lignotuberous E. regnans (R. K. Bamber and F. R. Humphries, 1961 pers. comm.).

V. THE EFFECTS OF FIRE ON IMMATURE FLORAL PARTS

1. Floral parts on girdled Trees and on Scorched Twigs

All floral stages from primordia to mature full capsules are alive and located on live twigs. They die when the twig dies. Persistent brown foliage indicates dead twigs and, therefore, dead persistent floral parts. Killing of the twigs or girdling of the tree must, therefore, kill all floral parts. If the girdling causes the crown to wilt before the following December no immature floral parts of E. regnans will produce any seed. Seedshed follows as soon as the mature capsules dry out.

It is expected that a fire which is hot enough to kill large branches may also kill the seed in the suspended capsules. Abundant germinations have, however, been seen under completely scorched crowns on some occasions. On another occasion, there has been a striking scarcity of seedlings under a completely scorched E. obliqua stand which had carried at least a moderate crop of mature capsules at the time of the fire. This point needs further investigation.

Because floral primordia take~~s~~ three years to develop into mature capsules (Gilbert, 1958), an E. regnans crown which was completely scorched cannot produce any seed within four years of the fire. At this time the seedbed is not receptive any more. It is, therefore, concluded that only the seed mature at the time of the burn can significantly contribute towards regeneration if the seed trees are girdled or their crowns completely scorched.

2. Floral Parts on Twigs which remain alive

(a) Capsules

Abscission of capsules is a normal prerequisite for seedshed from E. regnans (Cremer, 1961 a). Fire can accelerate the abscission of capsules. The acceleration is sometimes so drastic that two years' normal seedshed is contracted into two months. Fire does not always cause all mature capsules to shed their seed within two to four months (Cremer 1961 b).

(b) Old Flower Buds

The floral primordia appear about March. They unfold their umbels of flower buds in the following November to February. The flower buds each shed their operculum and burst into bloom 15 to 16 months later (March to June). The capsules are mature by the following February, three years after the initiation of the primordia (Gilbert, 1958). This means that two generations of flower buds are present at the time of the February-March fires. The older generation is about to flower.

Table VI.1 shows that some flowering can take place after a fire. In the 1959 fire (surface fire only) the development of old buds does not appear to have been affected adversely at all. There was a similar number of potential capsules on trees which were exposed to the 1960 fire (surface plus humus fire) but apparently none of these buds survived, though the crowns remained green all the winter.

TABLE VI.1

Effect of Fire on Buds about to Flower

Figures show totals of floral parts caught in 2 or 4 fixed traps, each 1/4,400 acre in size. Half of the traps were installed under trees suffering less than 20% crown scorch. The other traps were under unburnt trees.

	Burnt	Not Burnt
	(at W54)	(At W54 & Rd 11)
trapping period~~s~~: 11.2.59-15.12.59	(4 traps)	(4 traps)
time of fire : 23.2.59		
opercula	367	2,997
aborted flowers	289	1,762
aborted flower buds	197	559
% of buds which developed into capsules(1)	14%	10%
trapping period: 7.8.59-7.7.60	(2 traps)	(2 traps)
time of fire: 18.2.60		
opercula	37	574
aborted flowers	48	352
aborted flower buds	581	1,104
% of buds which developed into capsules(1)	nil	13%

(1) This is estimated by $\frac{\text{opercula} - \text{aborted flowers}}{\text{opercula} + \text{aborted flower buds}} \times 100$

$$\text{e.g.} = \frac{367 - 289}{367 + 197} \times 100 \quad = 14\%$$

To check the findings obtained by the trapping of floral parts, a small experiment was carried out using a blow torch to heat one of a pair of branches selected from each of nine short E. regnans trees. The twigs which survived the heating shed 83% of their crop of potential capsules (626) between February and August, 1960. At the same time, the unheated control twigs shed only 40% of their potential capsule crop (455).

Inspection of felled trees has shown numerous instances of plentiful, healthily maturing capsules which had developed from flowerings that occurred one to three months after a fire.

These three lines of evidence show that, if the twigs survive, a fire is not necessarily disastrous to buds which are about to flower. They show that the flowering may be quite satisfactory in many cases and very poor in some other cases.

(c) Young Flower Buds

Gilbert's finding (1958) that February-March is the peak mortality period of young flower buds has been confirmed in both 1959 and 1960. Any effect of fire would be superimposed on this pattern. The traps which yielded the results shown in Table VI.1 gave some indication about the effect of fire on the survival of young buds.

The detailed results are presented in Appendix III, but are not analyzed here. The ratio of the number of buds which fell after the fire to the number of buds which fell before the fire varied between 2.3 and 6.0 in the controls, while under the burnt trees the ratio varied between 5.3 and 198.3. In the latter case 10 buds fell in the 65 days before the fire and 1,983 buds fell in the 139 days after the fire. In this case (humus plus surface fire) the fire must have seriously reduced bud survival. In another case (ratio 5.3) the fire (surface fire only) seems to have had no marked effect on the survival of the young buds.

Numerous instances have been seen where normal young buds were present in large numbers several months after a fire which had scorched the leaves on the same twigs on which the buds were surviving. Young buds have been seen to survive on trees which had abscissed almost every one of their many young capsules.

The blow torch experiment supports the finding that fire is not necessarily fatal to the whole of a young flower bud crop.

It is concluded that, if the twigs are not killed, the survival and development of young flower buds is in many (perhaps most) cases not very adversely affected by fire. In some cases, all or nearly all, young flower buds are aborted and abscissed.

(d) Floral Primordia

At least part of the primordia crop is not yet or not any more present as such at the time of burning in February/March. Healthy, abundant primordia have been seen on partially scorched crowns. They were present even in the axils of the very leaves which had been abscissed apparently because of scorch. However, the instances seen may all have developed after the fire. It is expected that very young primordia actually exposed to a fire are at least as vulnerable as leaves.

VI ECOLOGICAL : EFFECTS OF WILD FIRE ON THE VIRGIN FOREST

It was recognized that even-aged stands of Eucalypts with a rainforest understorey owe their existence to a wild fire which must have killed all or nearly all of the parent stand. It was thought that E. regnans almost never survived any fire (Gilbert, 1959).

It was not realized how a fire could kill a whole mature Eucalypt stand, especially one that concists of the usually fire resistant E. obliqua or E. delegatensis. Nor was it realised that extensive stands of the fire sensitive E. regnans could survive some types of wild fire, and that this was an apparent paradox.

1. Eucalypt Stands with an Understorey of Rainforest (see Photo. No.1)

In the Florentine Valley, the important Eucalypt species which occur over rainforest are E. regnans, E. delegatensis and E. obliqua. Each of these species typically occurs in ~~a~~ pure, even-aged stands with a rainforest understorey of the same age as the Eucalypts. The main rainforest species are Nothofagus cunninghami and Atherosperma moschata. These stands were initiated by fire (Gilbert, 1959).

The absolute quantity of humus in this type of forest varies widely even between similar looking stands of the same age. However, all stands examined had large quantities of humus at least around the butt of the Eucalypts. Only a severe humus fire can explain the even-aged nature of the normally fire resistant E. obliqua and E. delegatensis.

Undisturbed rainforest burns only very rarely. The following descriptions of fire in rainforest are, therefore, speculative and based only on observations of fire under partially disturbed canopy and on the fringe of the rainforest.

There might be three main types of fire in the undisturbed rainforest:

(a) Firstly, the fire may be restricted to the litter and perhaps the top of the humus layer. Such a fire kills the rainforest species but may allow the Eucalypts to survive with severe scarring. The Eucalypts would then acquire an understorey of wet sclerophyll scrub.

It might be possible that several fires within a few decades of each other can gradually remove all the humus but leave most of the Eucalypts alive. This would result in a Eucalypt forest with a wet sclerophyll understorey without humus.

(b) Secondly, the fire may consume most or all of the humus. This would probably kill all trees and initiate a stand of Eucalypt regrowth with wet sclerophyll scrub of the same age as the Eucalypts. It is thought that this type of fire is responsible for the origin of many Eucalypt stands in the Florentine Valley.

(c) Thirdly, there is a type of crown fire which may be concurrent with and aid the spread of the above two types of fire. The rainforest canopy itself is probably never thoroughly burnt because of the lack of lower storeys. Mount (pers. comm.) has, however, pointed out that the rotten trees and very abundant bryophytic epiphytes in old, decadent rainforest can become highly inflammable and serve as the propagators of spot fires. The tinder-dry mosses, liverworts and lichens are easily ignited by sparks and become floating embers as they drop off the trees. This type of "epiphytic fire" may be essential for the fast spread of fires in rainforest.

2. Eucalypt Stands with an Understorey of Wet Sclerophyll Scrub. (See Photo. No.2.)

Gilbert (1959) described the wet sclerophyll scrub in the central Florentine Valley as an early stage in the succession from a disturbance by fire towards the climatic climax of temperate rain-forest. He did not fully discuss the significance of mature *E.regnans* stands with a much younger understorey of wet sclerophyll scrub.

Extensive stands in the northern Florentine Valley, and most mature stands of *E. regnans* in Victoria (Cunningham, 1960) are of even age (100 to 300 years old) and have an understorey of much younger age, (20 to 30 years old). The Eucalypts owe their existence to one fire but must have survived the second fire which gave rise to their understorey of wet sclerophyll scrub. Ring counts show that the scrub, too, is essentially even-aged.

The scrub forms a very dense and usually relatively low canopy. Its main species in the Florentine Valley are *Pomaderris apetala*, *Acacia dealbata* and *Olearia argophylla*. In some stands, *Phebalium squameum* and *Zieria arborescens* are predominant.

Three main types of fire may occur in the wet sclerophyll scrub:-

(a) Firstly, the fire may be confined to the surface litter. This type of fuel is usually quite abundant here, especially if the Eucalypt overstorey is dense. Several instances of such fire have been observed. The fire killed the understorey but not the Eucalypts. These stands are now developing a new and younger understorey of wet sclerophyll scrub.

(b) A more vigorous fire may burn the canopy of the scrub as well as the litter. One such instance was observed in a 150 year old E. regnans forest with a 15 to 20 ft. high understorey of Pomaderris. The E. regnans was killed because it was girdled by the fire, not at ground level, but at the level of the understorey crown fire where the E. regnans bark was very thin and highly sensitive to heat. This stand is now becoming Eucalypt regrowth with scrub of the same age as the Eucalypts.

This sort of fire probably accounts for many of the E. Regnans stands in Tasmania and Victoria.

(c) Finally, it is possible to have a humus fire under the wet sclerophyll scrub. It might be possible to burn the humus plus the litter layer without burning the scrub canopy, especially when the scrub is tall.

Most stands of E. regnans with a wet sclerophyll understorey which were examined had at least some combustible humus on the floor. In some stands the humus mound around the Eucalypts approached one foot in depth. The Eucalypts in most of the stands showed more or less severe fire scars at ground level, but almost none higher up on the trunk. These scars date back to the fire which gave rise to the scrub understorey. This pattern of scarring on E. regnans of this age could have been due only to a humus fire without a scrub crown fire. If the understorey killed by that fire was wet sclerophyll scrub, then the humus probably was burnt without the scrub canopy - otherwise the Eucalypts probably would have been killed, or scarred high up on their trunks.

One 150 year old stand of E. regnans showed very severe fire scars but had practically no humus on its floor when a wild fire burnt through its litter layer in 1959. This litter fire caused practically no injury to the Eucalypts but the scrub was killed. The scarring which was as old as the scrub must have been caused by a humus fire about 1934. The presence of rainforest in otherwise similar adjacent stands suggests that the 1934 fire burnt the humus under a sparse rainforest canopy and originated both the wet sclerophyll scrub and the scars on the Eucalypts.

VII CONCLUSIONS AND DISCUSSION

It is necessary to use fire for the regeneration of Eucalypts in the moist, cool forests of Tasmania. Humus fires must be expected. The regeneration burn usually leaves enough humus for a second fire. A second fire should be avoided even if the seed trees survive the first fire, not only because it kills the already established regeneration, but also because it is quite likely to be followed by little or no seedshed if the interval between the fires is less than at least five years.

If the regeneration fire burns a lot of humus, it is likely to kill the seed trees, irrespective of species. The killing of seed trees can be avoided by burning in spring. A fire which burns a dense felled understorey, when it is very dry, is likely to scorch most of the foliage on the seed trees. The scorching of the crowns of the seed trees can be very much reduced by keeping the interval between the felling and the burning of the understorey to less than six months. However, the advantage of keeping the seed trees and their crowns alive is probably outweighed by the advantage of having a chance to obtain a hot fire in late summer, which produces a clean and easily accessible seedbed.

Fire is likely to accelerate the shedding of mature seed and it is unwise to rely on seed not mature at the time of the fire. The regeneration burn should, therefore, be timed to coincide with the presence of an adequate mature seed crop on the trees.

The natural fire resistance of a stand may, in certain circumstances, be maintained only if repeated burning prevents the accumulation of dangerous fuels.

In the experiment referred to earlier (Cremer 1960 b) the height growth of E. regnans seedlings during the first year after complete defoliation was very much less if defoliation occurred in autumn than if it occurred in spring. If the same thing applies to other plants, this means that controlled burns aimed at reducing fuel quantities (dead and living fuel) should be carried out in autumn, while burns designed to produce vigourous growth for grazing should be done in spring. Catchment areas should then never be burnt in autumn. Careful measurements are required to confirm this suggestion and show which species recover at what rates after fire at different times of the year. Superficial observations are likely to be misleading or exaggerated because autumn fires are followed by a dormant season while spring fires are not.

Fire is a most important ecological factor and silvicultural tool in wet Eucalypt forests. It is, therefore, necessary to know what a fire does to the forest before one can reasonably decide when to control a forest fire and before one can determine when and how to use fire in planned forest management. The information on the effects of fire presented in this paper is only a small fraction of what needs to be known.

Most Eucalypt forests in Australia have experienced relatively frequent fires in the past and appear to be well adapted to survive them. Now that man is gaining better control over fires, it is becoming increasingly important to know more precisely what are the effects of fire on the ecology and timber production of the forest. Similarly, it is becoming more important to know how fire affects the value of certain types of vegetation for grazing or watershed management.

Much more information is needed before fire can be controlled and used intelligently, with less destructiveness and greater usefulness.

References

Ashton, D.H. (1956) - Studies on the autecology of *Eucalyptus regnans* Ph. D. thesis, Botany Dept., University of Melbourne.

Campbell, K.G. (1960) - Paper on phasmids. Proc. Linn. Soc. N.S.W. 81, 1 : 121-141.

Chattaway, M.M. (1953) - The Anatomy of Bark I The genus *Eucalyptus*. Aust. Journ. Bot. 1, 2:402-433.

Cremer, K.W. (1960a) - Eucalypts in Rain Forest. Australian Forestry, 25, 2 : 120-126.

(1960b) - Problems of Eucalypt Regeneration in the Florentine Valley. A.P.P.I.T.A. 14, 2:71-78.

(1960c) Amazing growth habits of *Atherosperma moschata*. Newsletter, Institute of Foresters of Australia 2, 6: 24-25.

(1961a) The Mechanism of Seedshed in *Eucalyptus regnans*. F.v.M. Paper presented at the Second F.A.O. World Eucalyptus Conference in Sao Paulo, Brazil, August 1961.

(1961B) - Final Report: Second Australian Newsprint Mills Forestry Research Fellowship.

Davis, K.P. (1959) - Forest fire: Control and Use. McGraw-Hill Book Co. New York (584 pages).

Frankcombe, D.W. (1961) - Logging for Regrowth. A.P.P.I.T.A. 14, 5:179-184.

Gilbert, J.M. (1958) - Eucalypt-rainforest relationships and the regeneration of the eucalypts. Ph. D. thesis, Uni. Tas.

(1959) - Forest Succession in the Florentine Valley, Tasmania. Pap. Proc. Roy. Soc. Tas. 93: 129-151.

Hart, G. (1960) - Humus depths under cut and uncut Northern Hardwood Forests. U.S.D.A; N.E. For. Expt. Stn.: For. Res. Note No. 113.

Hoover, M.D. and Lunt, H.A. (1952) - A key for the classification of forest humus types. Am. Soil Science Soc. Broc. 16: 368 - 370.

Jacobs, M.R. (1955) - Growth Habits of the Eucalypts. F. and T.B., Dept. of the Interior, Canberra (262 pages).

Lutz, H.J. (1960) - Fire as an ecological factor in the Boreal Forest of Alaska, Am. Journal For. 58,6: 454-460.

Sartz, S.R. and Huttinger, W.D. (1950) - Some factors affecting humus development in the Northeast. Am. Journal. For. 48, 5:341-344.

Scholander, F. (1958) - The rise of sap in Lianas. Physiology of Forest Trees. Ronald Press Co., New York. pp 6-17.

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Nomenclature of Plants

The authorities and common names of the plant species mentioned in the text may be found in Curtis, W.M. (1956) "The Student's Flora of Tasmania" and in Blakely, W.F. (1955) "A Key to the Eucalypts".

CHAPTER VII

THE PATTERN OF SEEDSHED AFTER A FIRE

A. INTRODUCTION

It can be assumed that only the seed on top of standing trees can survive a hot and uniform fire on the ground (Powles, 1940).

Knowledge of when the trees shed their seed after preparation of the seed bed by fire is of interest for several reasons. It will help to answer such questions as when to remove merchantable seed trees; when to expect peak seedshed; when to expect germinations; when to assess whether natural regeneration will be adequate or not and when to take supplementary action with artificial regeneration measures, should this prove necessary.

The mechanism of seedshed has been described in Chapter IV. It was stated that normal seedshed occurs only when the capsule dries out either after the formation of an abscission layer at the base of its pedicel or after the capsule-bearing twig has died back. Fire can accelerate seedshed by both of these mechanisms. There is no evidence that fire can delay seedshed.

Acceleration of seedshed after a fire is due to one or more of the following causes:

1. Death of the tree due to the girdling of the trunk at its base.
2. Die-back of twigs or branches due to direct scorching by radiated heat.
3. Abscission of capsules.

In this way 2 - 3 years normal seedshed may be contracted into 2 - 3 months.

B. SEEDSHED FROM TREES GIRDLED BY FIRE

If the fire kills only the bark and cambium at the butt, the tree does not usually die before spring or sometimes even later. In the meantime, the crown seems to keep growing normally. Survival of even a small fraction of the cambium at the butt may permit the crown to continue indefinitely without obvious harm. Seedshed will then be accelerated as under C. and D. below or by the eventual death of the completely girdled tree.

Grose (1957) reports that the removal of a girdle of bark in early December, 1955 did not affect the rate of seedshed from E. delegatensis trees until one year later, when seedshed suddenly accelerated and was completed by mid-January, 1957. On the other hand, the trees whose sapwood had been cut by deep girdling, cast most of their seed in one to two months.

If death after fire is due to deep girdling, wilting usually becomes evident within 2 - 4 weeks of hot weather. The crown wilts, becoming grey green, in a manner similar to felled trees.

Deep girdling inevitably accelerates seedshed because it is soon followed by the death of the crown. Seedshed may be further accelerated by the die-back of twigs. Abscission of capsules appears to be rare under these circumstances because of lack of time before wilting stops this life process. Formation of abscission layers may be a response to water stress but apparently cannot continue once wilting has begun. Most capsules on deeply girdled trees stay aloft indefinitely until torn off by rot and weather.

Standing, deeply girdled trees with crowns not scorched were common in 1960 and 1961. There was, nevertheless, no opportunity to examine such a crown on the ground until 8 months after the fire. At this time, the capsules of E. obliqua retained only 3% of their original seed contents. It is reasonable to expect rapid seedshed soon after the crown has begun to wilt.

C. SEEDSHED FROM CROWNS WHICH ARE DIRECTLY SCORCHED BY RADIATION

Capsules on heat killed twigs cannot be abscissed and remain aloft until torn off eventually by rot and weather. Nevertheless, seedshed acceleration is prompt and complete.

Cunningham (1960) reports that a stand of E.obliqua/ E.radiata whose crowns were completely browned by fire had shed 350,000 sound seeds per acre in two days.

Inspection of trees at Road 8 immediately after felling in July, 1960 showed that four months after the fire, capsules on scorched twigs of both E. regnans and E. obliqua had shed over 95% of their seed, irrespective of whether the tree was girdled or not and irrespective of the presence

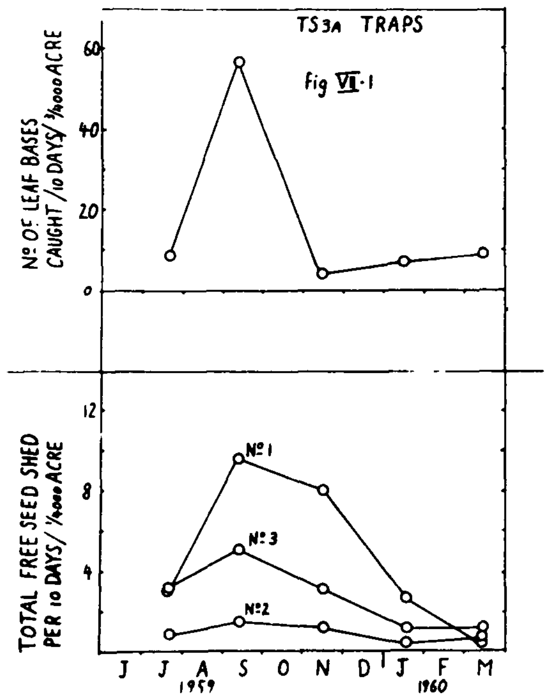


Figure VII. 1 : Number of leaf bases and total free seeds caught underneath *E. regnans* crowns with at least 80% crown scorch from a fire in March 1959. Plotted midway between collection dates.

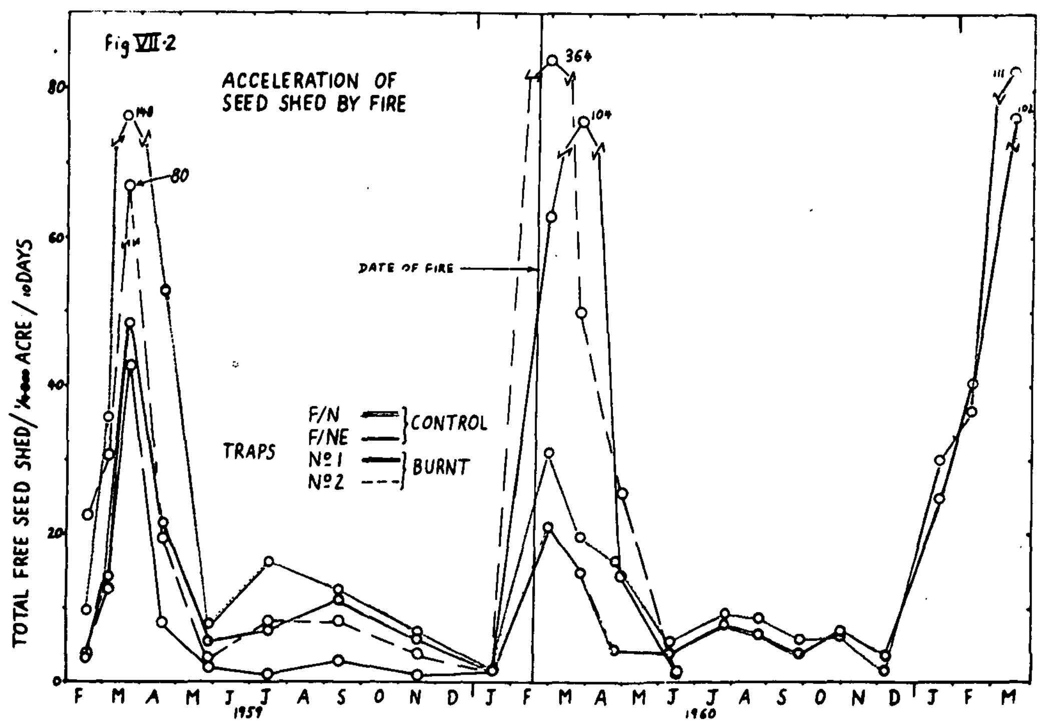


Figure VII. 2 : Rate of free seed shed (sound plus chaff) from four different groups of trees; plotted on dates midway between scorings. Fixed traps.

of a proportion of green crown. 30 to 150 capsules which were collected from each of five trees contained only 0.3 to 1.2 seeds (sound and chaff) per capsule.

Judging from the appearance of often prolific germinations, a large number of seeds may survive the complete scorching of a eucalypt crown. This does not mean that significant quantities of seed can survive all intensities of scorching short of actual crown fires. Evidence for seed dormancy or death caused by fire is discussed in Chapter IX.

To determine the pattern of seedshed from scorched crowns after the autumn peak of seedshed, five different groups of trees with over 80% crown scorch were tested by seed trapping. It was felt that any capsules which do not dry out and shed their seed in autumn probably do so with the coming of spring or summer.

Three traps were installed on 26/6/59 under three different groups of trees at TS3A which had been burnt in March, 1959. The main contributing trees carried moderately heavy crops of capsules at that time and over 80% of their foliage was scorched. The results of the trapping are graphed in Figure VII.1. They show that a second peak of seedshed did indeed occur in springtime around September/October. After November, seedshed was at a very low rate, probably indicating that its source was practically exhausted. It is notable that leafshed also showed a very marked peak in

September while leafshed from green crowns was at its lowest around this time. This may be a reflection of the first time that petioles became dry after being weakened by rot during winter. A dry petiole is much more brittle than a moist one.

The rate of seedshed during September to November was in the order of 0.25 lb. per acre. This is a significant amount, but may indeed represent only 5 to 10% of the original seed crop. The regeneration around the seed traps could have come from two to four pounds of seed per acre,

A further set of two traps was set up on the 7/7/1960, one at Road 7A (No.8D) and one at Road 8W (No.9D). These traps had caught 0.3 lb. and 0.4 lb. of seed per acre respectively by 16/11/60. Both trees tested had crop intensities similar to traps No.8L and No.15 which caught 50 to 60 lbs. of seed per acre between 4/3/60 and 7/7/60. See appendix III. The peak of seedshed in spring was not observed with these two traps. However, the main conclusion reached from the TS3 traps were confirmed: namely, significant seedshed continued for at least 9 months after the fire, but the seed shed after 4 to 5 months was only a small proportion of the total.

D. SEEDSHED DUE TO ABSCISSION OF CAPSULES.

The term "disjunction" is synonymous with abscission, but does not imply the shedding of the organ. Disjunction is a distinct growth response and can, therefore, take place only in living tissue. Fire may cause all or nearly all of a heavy capsule crop to become disjointed without having any other obvious effects on the crown. This cases a drastic acceleration of seedshed. Often the acceleration is not so drastic but still very significant.

I. DRASTIC ACCELERATION OF SEEDSHED.

Acceleration of seedshed is here called "drastic" if all or nearly all the capsules in all portions of a green crown are cut off by an abscission layer within a few weeks after a fire. This type of acceleration of seedshed from E. regnans has never been observed in the absence of fire. Drastic acceleration of seedshed may be recognized by the following features:-

1. Inspection of the green crown felled a few weeks after the fire shows that nearly all capsules are drying out and are very loosely attached. There may be very many empty umbel peduncles.

2. Inspection of the freshly burnt ground underneath the green eucalypt crown may show the presence of very large numbers (100 to 1,000 per square yard) of freshly abscissed, unburnt, single capsules plus some abscissed umbels of capsules. The absence of this feature is by itself no proof that drastic acceleration of seedshed did not take place, firstly because most crowns do not usually carry enough capsules for such spectacular effects and secondly, because the more woody capsules such as old E. regnans capsules and any

E. obliqua capsules may be dry but still attached to the tree.

3. An unusually heavy rate of seedshed may also be reflected by the appearance (between March and October after the fire) of an unusually large number of eucalypt seedlings.

By inspection of felled trees, by counting of capsules and germinations on the ground and by viewing of standing trees through a telescope, the occurrence of drastic acceleration of seedshed has been recognised over large areas and under a wide variety of circumstances:

Tree species :	*E. regnans* and *E. obliqua*
Date of fire :	October, January, February, March, 1959 and 1960.
Type of fire :	*Pteridium* fire; litter fire in wet schlerophyll scrub; slash fire; humus fire.
Locality :	At Misery, Florentine Valley, Junee, Fitzgerald
Age of trees :	30 to 250 years old

However, it is certain that an *E. regnans* tree which survives a fire does not always respond by drastic acceleration of seedshed. Failure to respond is not easy to confirm and no systematic observations on this point were possible.

The pattern of drastic acceleration of seedshed was measured by trapping the seed. Two traps, each 1/4400 acre in size and separated from each other by 3 chains, were installed underneath a group of mature E. regnans at Road 7A. The E. regnans had flowered heavily in the previous year. It had survived and suffered less than 10% of crown scorch from what was mainly a humus fire on 4/3/60.

The results are given in table VII and the following points should be noted:-

1. The two traps caught 56 to 62 lb. of free seed per acre in the first 10 weeks. This extraordinary rate and amount of seedshed commenced within 3 days of the fire and was almost completed within five weeks. After 10 weeks the rate of seedshed was very slow. Nearly all the seed present at the time of the fire appears to have been shed by mid-winter.

2. Capsule shedding was also enormously accelerated but did lag a little behind free seedshed. The great majority of capsules were abscissed singly. After about 20 weeks some capsules came down still attached to died-back twigs.

3. Compared with the normal figure of 4.7, the number of enclosed seeds shed per capsule was unusually high during the first two weeks but was well below normal during the later weeks.

4. Leaf abscission showed a similar pattern to capsule abscission but was not nearly so drastic. No tree was obviously denuded within 10 weeks, though several

TABLE VII.1

SEED CATCHES UNDER TREES WHICH SUFFERED DRASTIC CAPSULE DISJUNCTION FROM A FIRE ON 4/3/60 AT ROAD 7A
(Traps No.8L and No.15)

Period of catch From - to	No. of weeks after fire	No. of particles caught per 10 days per trap (1/4000 acre) Leaves		Capsules		Enclosed seeds per capsule		Free seeds	
		8L	15	8L	15	8L	15	8L	15
4.3.60 - 18.3.60	0-2	74	68	503	349	9.5	7.9	8,800[x]	6,300[x]
18.3.60 - 25.3.60	3	50	79	25	18	3.9	0.9	2,200	4,000
25.3.60 - 7.4.60	4-5	23	53	38	140	0.8	0.7	600	1,600
7.4.60 - 11.5.60	6.10	9	17	25	69	1.3	1.4	20	36
11.5.60 - 7.7.60	11-18	3	6	3	8	0.8	0.7	6	4
7.7.60 - 8.8.60	19-23	-	1	-	5	-	1.1	-	6
8.8.60 - 9.9.60	24-27	-	1	-	2	-	1.2	-	2
9.9.60 - 15.10.60	28-32	-	-	-	5	-	1.0	-	6
15.10.60- 5.9.61	33-90	-	-	-	0.25	-	0.0	-	0.00

xNote - The traps were not installed until 18.3.60. Very numerous abscissed capsules were observed beneath these trees on 7/3/60. The capsules underneath the seed traps were counted on 18/3/60. The free seedshed which had occurred during the first two weeks after the fire was estimated from the difference between the enclosed seeds and the expected total number of seeds per capsule. These figures for free seedshed are, therefore, underestimates because free seed fall precedes capsule fall.

were bare later on, probably due to the delayed effects of damage to the butt.

5. There was an unusually high proportion (about 20%) of sound seed.

The above evidence shows that fire may greatly accelerate seedshed from green crowns. In addition, it is important to know what proportion of the seedcrop mature at the time of the fire will be retained on the surviving tree until a new seedcrop matures. This is important in case a second fire follows the first one within one to three years.

Table VII.1 gives some information on this question. Further evidence was obtained firstly by comparing regeneration obtained after a first fire with that obtained after a second fire; and secondly, by inspecting freshly felled crowns which had shed large quantities of seed. The felled crowns were inspected to see how much seed was still retained by the crowns.

The area around roads 7A and 8W was burnt in March, 1960 and again, accidentally, in March, 1961. Many eucalypts survived the first fire and responded by drastic acceleration of seedshed. Three lots of 10 half-milacre quadrats were permanently established under three different groups of eucalypts which had survived the first fire. The identical plots were scored in late September after each of the two fires, with the following results:-

Number of eucalypt seedlings present per acre:

After the first fire	:	91,500
After the second fire	:	430

Ten living mature eucalypts which had shed very large quantities of seed following the fire in March, 1960, were felled in July, 1960 and the capsules on their crowns were sampled to determine their seed content. It was found that the "1959" capsules of both E. regnans and E. obliqua always averaged less than two seeds (sound plus chaff) per capsule. In fact, the 554 capsules which were collected, contained only 1.3 seeds per capsule. This represents less than 5% of the total original full content of the collected capsules. Seeing that most capsules had been shed before the felling of the trees, the conclusion is that nearly all seed had been shed within four months of the fire. This agrees with the seed trapping and with the seedling counts reported above.

One tree carried both "1958" and "1959" capsules. Both crops were dry but most of the "1958" crop was, apparently, still on the tree. The "1958" capsules still contained 6.4 seeds each while the "1959" capsules held only 1.8 seeds each. This confirms that old capsules do not shed their seed as readily as young capsules (see Chapter IV) and it indicates that acceleration of seedshed is likely to be less marked with old capsules.

It is concluded that seedshed from crowns which survive a first fire can be almost complete within half a year and that a second fire after one year may be followed by little or no seedshed.

II LIMITED ACCELERATION OF SEEDSHED.

Because seedcrops on E. regnans in the Florentine

Valley are not usually as prolific as those which gave rise to the spectacular effects of drastic seedshed acceleration described above, the acceleration of seedshed from green crowns is usually not very obvious. Apart from this, a number of trees felled a few months after fire in several areas have been observed to carry significant quantities of living capsules which must have survived the fire and had failed to become disjointed.

Figure VII.2 shows a pattern of seedshed which might be the result of every capsule on the green crown becoming disjointed. However, the results were not spectacular because the seedcrop was only small. The peak of seedshed occurred very soon after the fire and at the same time as the normal peak of seedshed from unburnt trees. During the 47 days after the fire the two burnt trees shed 73% and 81% of their annual seedshed compared with 24% and 25% from the unburnt trees.

Figure VII.3 shows a pattern of seedshed which was apparently influenced by fire but definitely not to the extent that nearly all mature seed was shed within 2 to 4 months after the fire. The response to burning was not apparent for 17 days after the fire, and once again, the peak of seedshed from burnt and unburnt trees occurred at the same date. During the 17 days of peak seedshed the burnt trees shed 57% of all the seeds which were shed during the 10 months after the fire. The comparable figure

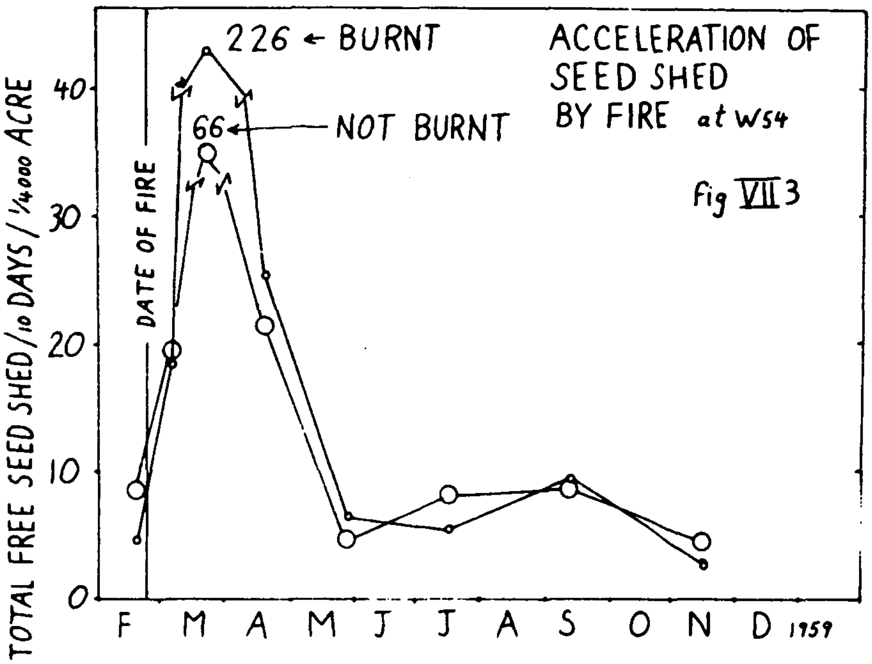


Figure VII. 3 : Average rate of total free seed shed from burnt as compared with unburnt trees at W54, plotted halfway between scoring dates. Each point is the average result from four fixed traps.

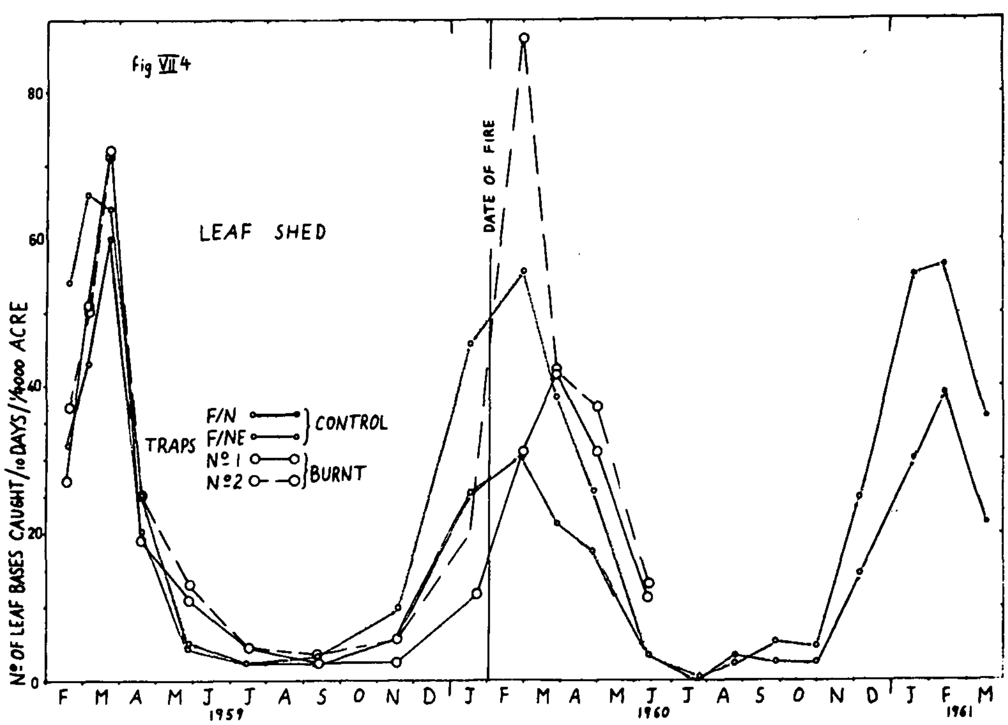


Figure VII. 4 : Effect of season and fire on the rate of leaf shed as measured by fixed traps underneath four different groups of trees. Plotted midway between scoring dates.

for unburnt trees was 34%.

Evidence that the 1959 fire at W.54 (figure VII.3) did not bring down nearly all mature seed comes from three sources.

Firstly, figure VII.3 shows that significant seed-shed continued for at least 9 months after the fire.

Secondly, trees felled in July, 1959 at W.54 showed that a considerable proportion of capsules survived the fire and were still alive.

Thirdly, assessment of regeneration on 23.9.59, after the first fire in February, 1959, showed 259 seedlings to be present on 50 half-milacre plots. The same plots carried 100 seedlings at the same date in the following year after second fire had burnt the original plots again in February, 1960.

This means that the 1959 fire did not entirely deplete the then mature seed crop and/or that some new seed developed from the flowering which took place soon after the fire.

A small amount of flowering did take place in 1959. Traps No.1 and 2 (figure VII.4) caught an average 41 operculae and 32 aborted 1959 flowers each.

Experimental Background for Figures VII.2 and VII.3.

Coupe W.54 was the first area treated under the new two-stage logging system. It was used for studies of seed-shed described in this section and for a study of the course of germination and deaths of natural seedlings following a regeneration burn (see Chapter IX). The coupe is some 50 acres in area, is located at 1,450 ft. elevation on level ground at the bottom of the middle Florentine Valley, and carried a fairly dense 100 years old rainforest understorey on dolerite soil. The Eucalypts were mostly E. regnans but included some E. delegatensis and even a few E. viminalis. The Eucalypts were of three ages viz, 100 years old, few suppressed; 150 years old, 180 ft. tall, predominating; about 300 years old, veterans, 180 ft. tall. An unusually large number of trees (about 10 per acre) were retained as seed trees. The understorey was completely felled in late 1958. The western half of W.54 was burnt on 23rd February, 1959. The north-eastern half was burnt on 18th February, 1960. This second fire developed into a humus fire which then ran over most of W.54 West once again, thus destroying the developing regeneration there.

Traps were removed just before the fires and re-installed within one day, after the fire.

The actual figures for seedshed are given in Appendix III.

III. WHAT CAUSES THE CAPSULES TO BE ABSCISSED?

In Chapter IV evidence was presented suggesting that heat or drought during summer accelerates the disjunction of capsules and consequently the rate of seedshed. That evidence, plus some observations relating to how fire may cause capsule disjunction are discussed here. Perhaps it is most logical to look for a single factor which causes all disjunction and to relate the various different causes to this single factor. As a general rule, abscission of a plant organ is stimulated by the senescence ~~of~~ or injury to the organ (Addicott and Lynch, 1955).

Fire produces ashes, smoke and direct injury by heating or combustion of plant tissue.

Combustion of fuel releases nutrients as well as possibly injurious substances. It is known that a great imbalance of Nitrogen-carbohydrate may accelerate abscission. Ashes are unlikely to account for most of the greatly accelerated capsule abscission because at least in the case of Road 7.A there was no rain to wash the nutrients to the roots until long after most abscission had occurred.

The carbon dioxide in smoke could influence abscission. Literature on the effect of high carbon dioxide concentrations is contradictory. The particles of smoke are unlikely to cause injury by fouling of stomata after exposure for only a few hours or days.

Excessive heat may cause the production of an abscission accelerant, or the destruction of an abscission retardant. Heating of capsule bearing branches with a blow torch without killing them did not accelerate capsule abscission except in the few instances where an individual capsule was injured without killing the peduncle.

Five minutes heating with a 2,000 watt radiator at 2 feet from cut off branches standing in plain water and in a solution of wood ash also failed to cause rapid capsule abscission.

Auxin is considered to be the basic regulator of abscission. In some cases it accelerates, in others it retards abscission, depending on the circumstances. Accelerated capsule abscission in eucalypts is accompanied by much loss of leaves and therefore, probably by a drop of auxin production.

This is sometimes but not invariably confirmed by the appearance of numerous epicormics.

Two attempts to accelerate capsule abscission by defoliation failed. In one case a small tree was entirely defoliated on 5.8.60. Both ringbarked and un-ringbarked branches on this tree produced only very weak shoots by 7.2.61. There was no accelerated capsule abscission by this date and many capsules were alive on living twigs. On another tree, two branches were 70% and another two branches were 100% defoliated on 22.9.60. All branches were ringbarked (i.e. girdled to the cambium). No branch died and no accelerated abscission of capsules occurred within five months. Defoliation alone is, therefore, not the cause of accelerated capsule abscission.

Injury to the individual capsules by insect damage or radiant heat can stimulate abscission. (Blow torch experiment). Fire often causes the wholesale abscission of capsules all over a crown even when most of the crown shows no scorch damage at all. This rules out the possibility of direct scorch injury to individual capsules as a major cause of abscission.

THE EFFECT OF DROUGHT

None of the above effects peculiar to fire have received much support from observations, experiments or literature reports. On the other hand, the evidence presented below in favour of drought, though not conclusive, is quite considerable.

Drought is a well known cause in stimulating abscission. (Addicott and Lynch, 1955). Drought explains why the crown is affected as a whole. It can account for both peak seedshed after summer and after fire. Drought can explain the relationship of leafshed and seedshed patterns. It can explain die-back of twigs. There are several reasons why fire can cause drought stress in trees.

A fire which accelerates capsule abscission often, but not always, consumes a lot of humus. The majority of feeder roots of trees occur within three inches of the soil surface, particularly in wet climates (Jacobs, 1955). Moist forest litter and the humus layers are intensively explored by rootlets. It must be expected that even a surface fire can consume or kill a large proportion of the fine roots. A humus fire would be all the more devastating. Loss of so many fine roots during the driest part of the year may well cause drought stress in trees.

In fire sensitive trees, or in any trees suffering humus fires, a proportion of the sapwood may be killed. This would also cause a decrease in the supply of water to the crown.

Fires tend to occur when soil moisture supply is at a minimum. In any case heated air from a fire lasting several hours or days is sure to impose at least a temporary drought stress on the trees. This itself may be enough to start an irreversible chain of events leading to abscission.

Acceleration of seed shed was immediate and drastic after the humus fires in 1960 (Table VII.1 and Figure VII.2). Acceleration was much less pronounced and delayed by over two weeks after the surface fire in 1959 (Figure VII.3). The fact that the humus did not burn in 1959 indicates that it was moist. This moisture plus the preservation of the rootlets in the humus would cause the trees much less drought stress than was the case in 1960. This supports the theory that drought accelerates seedshed.

Table VII.1 gives one instance where the shedding of capsules and leaves followed a similar pattern after a fire.

Figure VII.4 shows that leaf shed follows a very marked seasonal pattern. Comparison of Figures VII.2 and VII.3 which are both based on the same four fixed traps, demonstrates a remarkable coincidence of peaks in leafshed and peaks in seedshed. In 1959, the peaks of seedshed in all of the four instances were co-incident with each other and with the peaks of leaf shed, namely in March. In 1960, these traps recorded co-incident peaks of leaf shed and seed-shed at the end of February, while one trap (a burnt one) recorded both its peaks in late March. It is notable that leafshed began to rise steeply about a month ahead of seedshed, while the latter was still at its lowest.

The periodic weight of E. regnans leaf litter fall recorded by Ashton (1957) during 1950 to 1954 in Victoria was very similar to the pattern shown in Figure VII.4. All peaks occurred about January-February.

Wallace and Hatch (1952) recorded the weight of leaf litter from E. marginata in Western Australia at different seasons of the year 1951. Their pattern was even more marked than that in Figure VII.3 but their peak was in Jan-Feb-March, i.e. about a month earlier.

Jacobs (1955) suggests that peak leaf shed is immediately preceded by a "bürst of growth". The above three examples observed during seven different years in widely separated localities contradict Jacobs' view and suggest that the peak of leaf shed in these evergreens is related to drought. Shedding of the senescent leaves at the driest time of the year would be useful in reducing the water needs of the tree.

In the exceptionally dry summer of 1961 some deciduous hardwoods in Maydena (Salix, Robinia, Betula) shed a considerable proportion of their leaves prematurely, apparently as a response to drought.

Fire can accelerate the shedding of leaves. Fire may injure many leaves without killing the twigs, thus causing the abscission of the injured leaves. Figure VII.2 gives some support to this observation. The difference in response to burning versus controls cannot be increased much more because there would not be very many more leaves left over.

If drought is likely to accelerate the abscission of leaves, it might also similarly affect the capsules.

The capsules of moderate to heavy crops are mostly located on twigs of finite growth. These twigs loose their leaves and eventually die back to the next major branch unit. Die-back is always preceded by leafshed. Peak leafshed may, therefore, be related to acceleration in the die-back of twigs. Die-back of twigs is preceded or closely followed by seedshed.

E. SUMMARY AND CONCLUSIONS.

A fire which burns a lot of humus is likely to girdle the seed trees. If the girdling kills the sapwood, the crown wilts within weeks or even days. Most of the seed is probably shed within two to four months of wilting.

Where heat radiation is intense enough, part or all of the crown is scorched. The leaves turn red brown within 2 or 3 days. Rapid seedshed begins within a day after the fire. Most of the seed from scorched crowns is shed within four months. The remainder of the seed is shed immediately after winter.

Seedshed can be accelerated even when the crown remains alive. This is due to acceleration in the rate of capsule disjunction or abscission. Such acceleration often is so drastic that a normal two-years seedshed from a heavy, young crop is contracted into two months. When the seedcrop is sparse, theresults of seedshed acceleration cannot be so spectacular. Acceleration can, nevertheless, be distinct though seedshed is not necessarily completed within 2-4 months.

The cause of the acceleration of seedshed from live crowns is not known. The evidence is in favour of drought. A fire, especially a humus fire, may greatly increase the moisture stress of trees at the driest time of the year by destroying the tree's feeder roots.

In general, following the regeneration burns in late summer, most or nearly all of the then mature seed is shed in autumn. If the crowns are killed, relatively little additional seedshed can be expected after the end of autumn. If the crowns remain alive and the seed crop is sparse it is advisable to retain the seed trees till the second winter.

The seed retained on living or dead seed trees is likely to be insufficient for another crop of regeneration if a second fire destroys the first crop of regeneration before new seed has developed.

CHAPTER VIII

QUANTITY OF SEEDSHED AND TIMING OF THE REGENERATION BURN.

A. FACTORS WHICH AFFECT SEED PRODUCTION -

This subject is vital to efficient forest management both now and in ~~turue~~ future. Little is known about it; almost nothing is known about why one stand can be so different from another stand in seed productivity.

Seed production depends on the initiation of floral primordia and their successful development through buds, through flowering and fertilization to mature seed three years later. An abundant seedcrop is mostly dependent on abundant initiation of primordia.

Primordia losses are few except where an infestation of leaf eating insects occurs (Gilbert 1958). About 11% of flower buds, 14 to 30% of flowers and about 30% of the immature fruits develop into mature capsules. Survival from a large crop may be better than from a poor crop. Losses are due to insec~~tions~~ts, fungi, frost and competition (Ashton, 1957, Cunningham 1960).

I. SEED PRODUCTION WITHIN A TREE AND BETWEEN DIFFERENT TREES.

Ashton (1957) found that primordia production is heaviest on warmer aspects, on vigorous dominant branches on the sunny side of dominant or isolated trees. In a forest he considers seed production to be directly related to vigour. This is contrary to the idea (Mount, pers. comm.) that seeding is so exhausting that it reduces the chance of successful competition in a dense stand. Flowering begins at age 6 to 8 years, sparsely and irregularly at first, but becoming heavier per tree and per stand and more reliably uniform with age even into overmaturity if the crown remains vigorous. Good site quality is supposed to favour much heavier seed crops. Other things being equal, seed productivity is largely dependent on heredity (Ashton, 1957).

Flowering intensity per tree is extremely variable. Teller (1957) found that dominants of E. regnans were very much better than codominants and that suppressed trees were by far the poorest seeders.

Cunningham (1960) found that isolated trees grown in the open are even better seeders than the dominants in a forest but he could not demonstrate an improvement of seed production within seven years of thinning a stand.

Inspection of felled and standing trees by the author using a telescope confirmed the above findings for the Florentine Valley. Capsules are densest on the dominant branches of dominant crowns. Some extremely leafy, large crowns were an exception to this rule. Variation in seed productivity in any one year from crown to crown was extreme even amongst dominants. Large, vigorous, fairly sparsely foliaged crowns often carry much heavier crops than smaller crowns, especially small crowns with much die-back. Die-back is a conspicuous and very widespread feature in the Florentine Valley. It occurs with any density of eucalypts per acre and is as yet unexplained.

II. SEED PRODUCTION BETWEEN DIFFERENT STANDS.

Site quality, climate, aspect, vigour, density and age all affect seed production.

In 1960, much more seed was present on equivalent trees at Moogara than at Maydena 20 miles away.

Hall (1960) presents some inconclusive evidence that seed production per acre by some eucalypt species drops off as stand density in terms of basal area increases beyond a certain point. Counting of capsules on the forest floor under stands of different densities in the Florentine Valley failed to confirm Hall's finding. Some other factor over-rides the influence of density here. The only and obvious correlation was with the relative vigour of the dominant crowns. At similar densities some stands produce much better dominant crowns than others. It is expected that thinning would eventually improve the vigour of the crowns and consequently, the seed production of the stand.

The mature stands which carry few eucalypts per acre appear to be better and more reliable seeders than dense and younger stands.

Grose (1961) reports that stands on sunny aspects may produce almost twice as much seed as other stands of E. delegatensis.

III. SEED PRODUCTION BETWEEN DIFFERENT YEARS.

Ashton (1957) and Gilbert (1958) have demonstrated a two or four year rhythm of good seed years in E. regnans. In any case, a very good year is likely to be preceded and followed by a very poor year. A good year is many times better than a poor year. Generally, most trees in a stand and most stands in a region are synchronized.

Ashton (1957) estimated that a certain 220 years old stand of E. regnans produced 20,000 flowers per acre in 1953 and 400,000 in 1954.

TABLE VIII.1

Number of opercula (one operculum is shed from each flower) caught in various traps (each 1/4400 acre in size) in different years - Florentine Valley.

Trap No. / Year	F/N	F/NE	F/S	No.1	2	3	4	5	6
1959	1611	506	293	61	23	24	269	52	61
1960	170	410	-	-	-	-	-	-	-
1961	163	192	-	-	-	-	-	-	-

Table VIII.1 gives some idea of the variability of flowering intensity from year to year and from tree to tree, all dominants.

Cunningham (1960) found that at the Ada River, the 1954 capsules contained 1.6 fertilized seeds while the 1956 capsules contained 3.1. The difference might be ascribed to pollinating conditions for insects and birds at the time of flowering.

Eldridge (1961) was unable to demonstrate any increase in the number of fertilized ovules per capsule in E. regnans if bee hives were placed near the flowering trees.

However, Pryor (1957) found that pollination by hand improved the amount of seed set.

Periodicity in primordia production plus variation in hazards to floral development combine to produce great variations in the amounts of seed that mature in different years.

Gilbert (1958) and Cunningham (1960) found that the seed from any one crop is shed about equally during the second and third years after flowering. This means that normal seedshed is not so variable from year to year as flowering intensity. This point is confirmed by table VIII.2 and its comparison with Table VIII.1.

TABLE VIII.2

Total number of free seeds caught in fixed traps each 1/4,400 acre in size.

Year -	1956	1957	1958	1959	1960	1961
Trap - F/N	789	495	534	454	278	948
Trap - FNE	-	1357	1130	1017	390	1058
Trap - F/S	191	135	151	97	-	-

This does not mean that a regeneration burn in one year is likely to bring down as much seed as a burn in another year on the same area. A good flowering produces at least ten times as much seed as a poor flowering. Good flowering does not occur regularly every two years. Between 1953 and 1961 in the Florentine Valley only 1954 and, possibly, 1959 produced very widespread excellent flowering. Assume a stand produces 100,000 capsules from the 1954 flowering and 10,000 capsules per acre from the 1955 and 1953 flowerings. A fire in autumn 1955 could bring down 105,000 capsules while a fire in 1956 could bring down only 60,000 capsules. In a series of moderate years the difference would not be so great as this. Around years of very heavy flowering the difference is likely to be even greater. At Roads 7 and 8W, for instance, the 1959 flowering was very good while years before and after 1959 were very poor. The regeneration burn in 1960 was, therefore, many times better than it would have been in 1959.

B. AMOUNTS OF SEED PRODUCED -

TABLE VIII.3

Amounts of Seedshed (data from Cunningham) (1960)

Worker	Species	Locality	Age of Trees	Stand stems/ acre	1000's of viable free seeds/acre/ year
Cunningham	*E.Regnans*	Vic.	165	20-30	41
"	"	"	"	"	121
"	"	"	"	"	94
"	"	"	65	88	64
"	"	N.E.Tas.	35		41
Mann	"	Vic.	35		10
Ashton	"	Vic.	220		140
Grose	*E.delegatensis*	Vic.	105		503-1,535
"	"	"	"		353-803
Cunningham	*E.obliqua*	N.E.Tas.	35		190
Mann	"	Vic.	35		6

Table VIII.3 gives some idea of the magnitude of seedshed from *E. regnans*. It suggests that the older stands produce more seed. It shows up considerable variability between stands. It suggests that E. regnans is a poorer seeder than E. delegatensis.

Cunningham (1960) showed that failure of regeneration in Victoria may often be due to inadequate seedshed from the few (3 to 5 per acre) trees which are left standing because they are unmerchantable. Three 165 year old dominants which he sampled carried between 6,000 and 16,000 viable seeds each. Some open grown trees carried 30,000 to 90,000 seeds.

Several trees at Moogara in Tasmania yielded about 15 lb. of seed each (1,500,000 viable seeds) and some as much as 30 lbs. Such trees are rare in the Florentine Valley. Indications are that seed production in Tasmania is usually similar to that in Victoria.

Capsule counts to estimate seed productivity of stands.

The studies reported above were all done with seed traps or by collection of the seed from the felled crowns. This is very laborious and therefore cannot be used on a larger scale.

The fall of capsules must in the long run be closely related to seed production. Over several years, the number of viable seeds per capsule (2-3) is probably fairly constant. The total number of seeds per capsule (30.7) and the proportion that is shed free (85%) are probably also reasonably constant. (Chapter IV).

The number of capsules found on the forest floor of various stands is then a good indication of their relative seed productivity. If the rate at which capsules rot is known, these relative rates can even be expressed in absolute figures.

Within the Florentine Valley, under stands of E. regnans with a rainforest understorey the rate of rot is probably uniform. Trap F/NE in such a stand caught 19.5 capsules per square foot per year during 2.1 years. Four quadrats each one square foot in area laid out systematically around the edge of this trap were found to carry an average of 73.8 capsules. This very limited evidence suggests that the capsules on the ground represent about 73.8/19.5 = 4 years' seedshed. Judging from general observations that is a reasonable figure. This means that 100,000 capsules/acre on the forest floor represent an average annual free seedshed of 3/4 pounds per acre.

In February, 1960 a number of stands, all about 150 years old, and with a rainforest understorey were sampled by counting all recognizable capsules on one square foot quadrats spaced at half chain intervals along each of two four-chain long lines laid out by compass on predetermined bearings. The stocking of eucalypts was determined by counting the number of stems within one chain on either side of the laid out line of quadrats. Table VIII.4 sets out the results.

TABLE VIII.4

Comparison of seed productivity of different E. regnans stands by counting capsules on the forest floor.

Stand No.	Line No.	Euc's. per acre	1,000 cap's per acre	lbs. annual free seedshed	
				PER ACRE	PER TREE
1 Road 11	a b	19 21	285) 256)	1.8	0.088
2 Road 11	a b	6 15	63) 140)	0.66	0.063
3 N. of L1	a b	29 38	29) 0)	0.09	0.004
4 N of L8	a b	40 42	572) 601)	3.8	0.093
5 Road 11	a	20	543)	3.5	0.17

The following points should be noted from Table VIII.4.

There was no correlation between seed production and stand density in this type of forest.

Seed productivity even when averaged over several years can be very different between stands within one mile of each other. All Road 11 stands are on level limestone soils. The two L. stands are separated by a mile in distance and 500 ft. in altitude. Over the past four years, the higher L. stand produced fourty-two times more seed than the lower stand.

It is concluded that some stands are likely to produce insufficient seed for natural regeneration over periods of many years. This point should be confirmed and criteria for the recognition of chronically poor-seeding stands should be determined. Such stands are not worth treating for natural regeneration.

Gilbert (pers. comm.) inspected the felled heads in 55 stands on Lords, Westfield and Jubilee blocks to determine flowering periodicity. His data suggest that five of these stands had little or no flowering in the years of 1952 to 1956 while the other stands flowered abundantly at least once in these years.

The stands which are chronically poor seeders may, therefore, be as frequent as 10%. All poor stands occurred in the Lords' block.

The best stands in Table VIII.4 compare well with the best of Table VIII.3 but are still inferior to the *E. delegatensis* quoted.

If 1,000 established seedlings are wanted per acre and a tree % of .5 is assumed then 200,000 viable seeds (or 2 lb.) are required per acre. This means that natural supply of seed for natural regeneration is often likely to be limiting. It is essential, therefore, to time the regeneration burn so that optimum use may be made of the best potential seedcrop available on a given set of seed trees within several years. Proper timing of the burn is essential because the seed trees may be killed or their crowns severely scorched after the burn and because, in any case, the seed bed deteriorates very rapidly after one year. Only the seed mature at the time of the fire can be relied on.

C. <u>SELECTION OF SEED TREES</u> -

Cunningham (1960) successfully tried out a "shelter wood system" where the whole of a relatively dense stand of eucalypts was retained as seed trees after preparation of the seedbed. Removal of so many trees is most destructive to regeneration. Since in fairly dense stands nearly all the seed is confined to the dominants it is advisable to remove the non-seeders before regeneration starts.

Which and how many individuals from a dense stand are worth retaining as seed trees? Most dense stands can ill afford the loss of a large proportion of their potential seed trees. There must be a point, however, where an increase in the amount of seed due to increased numbers of seed trees is more than nullified by the additional destruction caused by the removal of the extra seed trees.

It seems that denser stands concentrate most of their seed on a smaller proportion of their trees than open stands. Open stands may not only produce more seed per acre but also more seed producing trees per acre. In the dense stands only the dominants are likely to be good seeders. Some dense stands have very poorly idfferentiated dominaants. The presence of a dense understorey further increases the difficulty of recognizing the dominants. From a detailed inspection of the felled trees and standing seed trees on five coupes it was estimated that only about 60% of the stand's potential seed crop was retained on the reserved seed trees (Table VIII.5). Since the seed trees represented only one quarter of the original stand, this selection is much better than random. However, less than half of the trees selected did actually carry worthwhile quantities of seed. This means that in most cases nearly all of the seed of a dense stand could be reserved by retaining five seed trees per acre if selection were perfect. There is at the moment no practicable method for a more certain selection of potential seeders.

Because selection of the seed trees precedes understorey removal, detailed inspection of the crowns by telescope is not easy at this stage. Hence seed trees are not likely to be selected with the use of a telescope.

Considerable improvement in the selection of effective seed trees should result if the conclusion of Chapter V. is observed. It is <u>not</u> necessary to have five seed trees on each acre. A minimum of one would suffice. Selection for seed productivity is more essential than even distribution of seed trees. This permits the retention of clumps of excellent trees and removal of nearby poor trees.

It is difficult to decide on the optimum number of seed trees without a previous assessment of the seed crop. The data in Table VIII.5 suggest that in dense stands

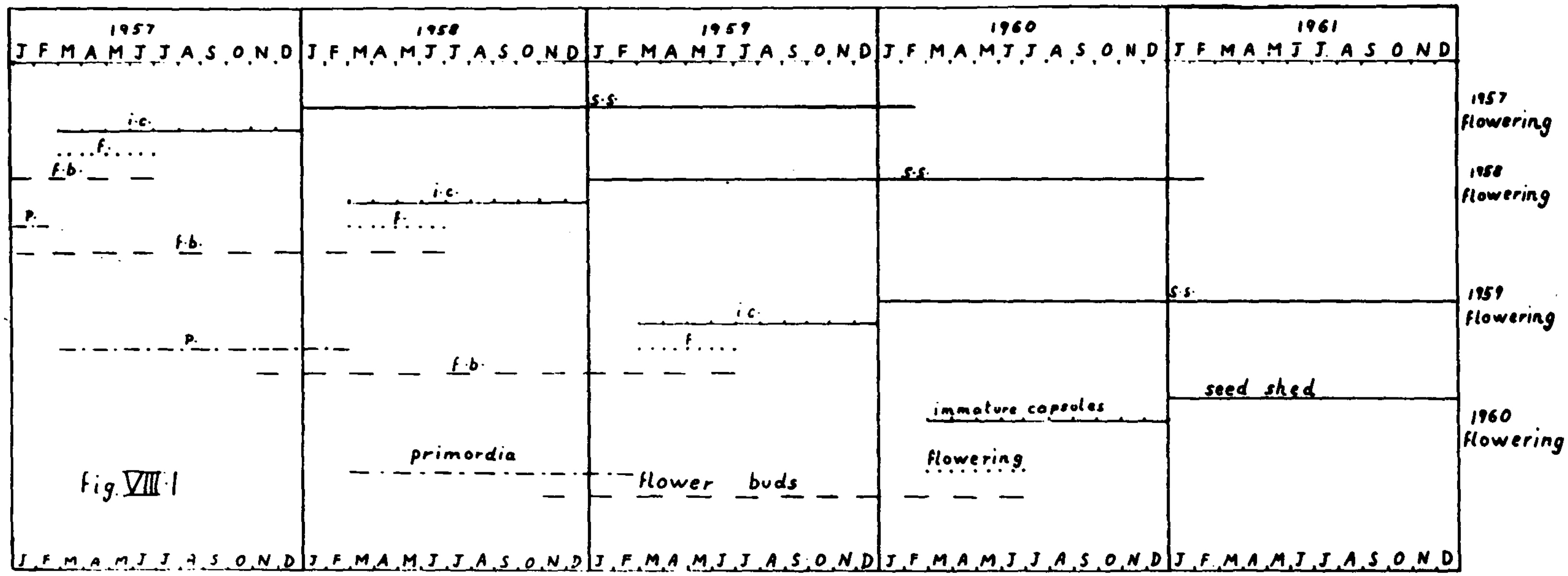


Figure VIII . 1 : The pattern of development from floral primordia to seed shed. eg. in March 1959 there is seed shed from the 1957 and 1958 flowering crops; there are immature capsules, flowers and flower buds from the 1959 flowering crop; there are flower buds and perhaps still some primordia of the 1960 crop.

with poor seed crops, less than 10% of all trees carry a worthwhile crop. This would mean that only 2 or 3 trees per acre are worth retaining from a dense stand if selection were perfect. Five trees is probably a reasonable number for practical purposes. In an open stand and/or where the seed crop is ample, retention of more seed trees may retain more seed. But in these cases extra seed supply is prdably not critical.

D. <u>ASSESSMENT AND FORECASTING OF SEEDCROPS FOR THE TIMING OR REGENERATION BURNS</u>.

Forecasting of a seed crop is based on the pattern of floral development shown in figure VIII.1 which is based on the findings of Ashton (1957), Cunningham (1960) and Gilbert (1958). These workers tried out forecasting of seed crops by the trapping of floral parts. This techhique is of rather limited value and much too laborious for practical purposes.

The author has found that a prismatic spotting scope with a thirtyfold magnification, mounted on a tripod, can be used successfully and rapidly to assess present seed crops and to forecast those maturing one and two years hence. His findings have been confirmed and successfully applied by the Tasmanian Forestry Commission who now use a telescope of similar design.

Buds, flowers and different stages of capsules can be distinguished. At five trees per acre about twenty trees can be inspected at each set-up. Where the seedcrops are very poor or very good, one set-up per 20 acres is probably enough.

In marginal cases more set-ups are needed. Where it is important, it is usually clear which of the coming two burning seasons would be more suitable. Whether the better seed crop is adequate is much harder to decide. Quantitative assessments must depend on subjective judgments. Different observers agree readily on good and very poor quantities, but vary in their estimation of the more frequent intermediate crop densities. The Tasmanian Forestry Commission is attempting to classify seed crops quantitatively.

Because quantitative assessment is so difficult it should be restricted to its most important task, namely deciding whether burning in any of the coming three autumns has a reasonable chance of success. If the present capsule crop and the immediate future crop are entirely without promise, the felled proportion of trees (if any) may be inspected for primordia. If these too are rare, it may be best to remove the seed trees before burning, preferably as part of the first stage of logging. If a large proportion of the understorey is still standing as may be the case with rainforest, slash felling and burning may be delayed for more than three years. This may involve an indefinite and uncertain delay. The stand may be a chronically poor seeder and may take over six years to respond to thinning. Slash older than four years is difficult or impossible to burn under safe conditions and the ferns may have become dense by then.

If an adequate mature seedcrop is available, the regeneration burn should occur in the next autumn. If a future flowering promises to be much heavier than the present capsule crop then the fire should occur in the autumn after that flowering.

Burning in spring is much less likely to kill the seed trees but involves a much greater fire hazard and may result in poorer regeneration because the seed fall will fail to be accelerated or will occur in the hottest and driest part of the year.

There is some evidence that regeneration burning in spring is less successful in producing regeneration than burning in the autumn.

The earliest and best time for an assessment of the seed crop is after the non-seed trees have been felled but before the removal of logs is completed. At this time the crowns of the seed trees are readily visible and a decision about their retention can be made before the logging machinery has been moved away.

A good time of the year to do the assessment is about December, January. At this time the two generations of flower buds can be distinguished and all crops that are going to be mature for the next autumn burn are present as readily visible capsules. At other times of the year, the flower buds have either not yet emerged or cannot clearly be assigned to the present or future flowering year.

Where a proportion of the eucalypts are felled in the first stage of logging, the crowns on the ground may be inspected for floral parts. While these subdominant and suppressed crowns give little indication of the abundance of the crop on the seed trees, they will indicate which is the best year to burn. This method is not quite so satisfactory as an assessment of seedtrees by telescope and is more laborious because about 100 felled crowns may have to be inspected and access is usually difficult. (See Table VIII.5).

An annual flowering survey may be useful. The flowers are most conspicuous from above the crowns and can be seen and mapped _when plentiful_ from helicopters or mountain tops (Mount, pers. comm.). Because each tree blooms for only three to 8 weeks and because flowering is spread over four months, several survey trips are needed annually for each area.

A comparison of the telescopic and the felled crown inspection methods has been made by inspection of five coupes by each of the two methods. The results are summarised in Table VIII.5.

TABLE VIII.5

Comparison of seedcrop assessment by telescope (Jan. 1960) as against inspection of felled trees (July, 1959).

Coupe	Crowns inspected	No.	% of trees with some or many floral parts for each year of flowering 1957+58	1959	1960	1961	Burn recommended for
TL 1	Felled trees	168	2	1	0	-	1960
	Standing trees	18	11	6	0	11	1960
P19	felled	64	0	0	0	-	?
	Standing	21	24	19	19	81	1960 or '62
L37	felled	187	0	5	1	-	1960
	Standing	20	0	20	0	5	1960
W91	felled	108	0	26	24	-	1961
	Standing	15	13	40	40	27	1961
W42	felled	158	1	5	5	-	1960
	Standing	28	7	54	11	61	1960
W89	felled	197	0	57	0	-	1960
E.deleg.	Standing	0	-	-	-	-	

Note 1. All figures except those for W89 refer to *E.regnans.*

2. The assessment of felled crowns was done in July 1959 by R. L. Newman.

3. W91 carried about 15 stems/acre; the other *E.regnans* coupes carried between 20 and 30 stems/acre. All stands had 3 - 5 seed trees/acre. P.19 though dense had excellent dominants. TL1 and L37 had generally poor dominants with much die-back. W91 and W89 had good crowns on most trees.

Conclusions from Table VIII.5

1. Between 1957 and 1961 the best flowering occurred in 1959 and 1961 on the coupes inspected. Neither year was uniformly excellent.

2. Inspection of 15 E. viminalis (not shown in the table) and 201 E. gigantea crowns showed that these two species flowered much more profusely than, but synchronously with E. regnans.

3. The two methods agreed in dating the burns at the same times.

4. The quantitative relationship between the results obtained by the two methods of assessment was very irregular. In dense stands with well defined dominants quantitative assessment by telescope appears to be much more reliable, than assessment of the felled trees.

5. L37 carried a poor seed crop. The coupe was burnt in March 1960 and an assessment of the regeneration showed that some additional artificial sowing had to be done.

E. SUMMARY AND CONCLUSIONS.

Seed crops are very variable from year to year, from stand to stand and from tree to tree. In some instances, the whole stand is likely to carry insufficient seed at a given time to produce satisfactory regeneration.

At least in dense stands, nearly all the seed is concentrated on a small number of individuals, namely the dominants. Only dominants should be selected for retention as seed trees even at the expense of uneven distribution of seed trees, provided at least one remains on each acre. Where extra seed supply may be critical, i.e. in dense stands, effective seed supply is not likely to be increased by retaining more than five seed trees per acre.

Fire is needed to prepare the seed bed. All seed except that on standing trees is killed by a thorough fire. A burnt seedbed deteriorates very rapidly after one year. Successful regeneration depends, therefore, upon the quantity of seed shed by the seed trees within one year of the regeneration burn. For these reasons and because flowering intensities vary greatly from year to year, the timing of the regeneration burn should be based on a previous assessment of the seed crop.

Such assessments can be carried out by inspecting the 150 to 250 ft. high standing seed trees through a telescope for the different floral parts, none of which exceed half an inch in size. Where a proportion of the eucalypts is felled during the first stage of logging, inspection of the felled crowns on the ground offers an alternative or complementary method of assessing the seed crop for timing the burn.

CHAPTER IX

DEVELOPMENT OF REGENERATION AND REMOVAL OF SEED TREES.

A. INTRODUCTION

The earlier chapters have described how and when the seed from reserved seed trees arrives on the prepared seedbed. They have pointed out what measures are necessary to give natural regeneration following the two-stage logging system an optimum chance of success. It now remains to be seen whether the natural regeneration obtained in any one instance is in fact satisfactory and to plan the removal of the seed trees after their function is performed. For both these purposes, it is necessary to know when the seedlings appear and how they develop.

B. EXPERIMENTAL METHODS

The aim was to determine the course of germinations after the regeneration burn, to obtain some picture of the pattern of mortality underneath seed trees and to follow the growth of the regeneration. Three series of plots were laid out.

Series I and II were established in 1959 at W54. Coupe W54 and its history has been described in Chapter VI.

Series I: 50 plots, each half a milacre (1/2000 acre) in size were laid out immediately after the burn in February, 1959. The plots were spaced at intervals of 30 to 60 feet and located subjectively to fall in suitable numbers on each of four previously defined seedbed types: viz. 17 plots on burnt seed bed where the humus and some litter were unburnt (BL); 15 plots on burnt seed bed where the humus was unconsumed but the litter was burnt away (BnL); 7 plots on the unburnt, puddled soil (n B,P) of tractor tracks and 11 plots on unburnt, not puddled but lightly disturbed, soils free of slash (n B n P). Logs and debris were avoided in all cases. Each plot was identified by a central numbered peg. The boundary of each plot was the circle described by a forked stick pivoted on the central peg. Scoring was at monthly intervals. The position of seedlings was marked by coloured nails or wire pegs. In this way, new germinations and deaths could be identified.

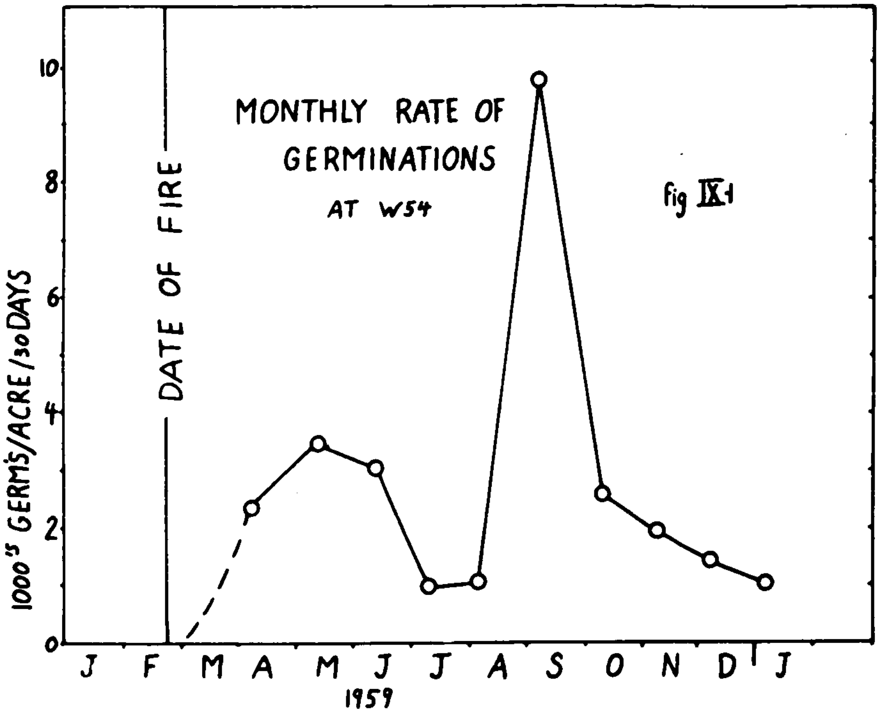


Figure IX. 1 : Monthly rate of germination recorded underneath live seed trees burnt in 23. 2. 59 at W54. Each point is based on 50 plots of 1/2000 acre. Plotted midway between scoring dates.

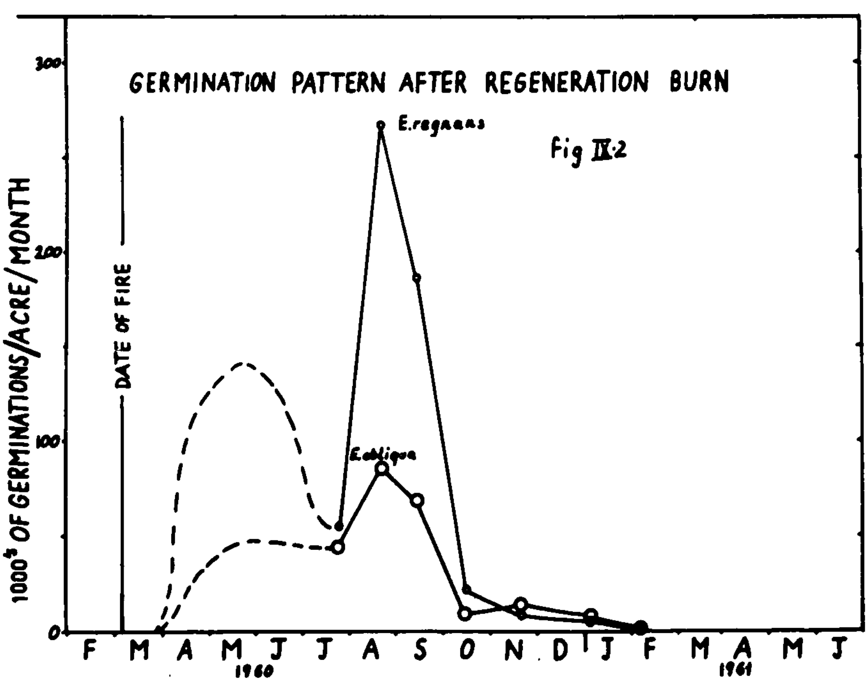


Figure IX. 2 : Monthly rate of germination recorded under live seed trees burnt on 4. 3. 60 at Roads 7A and 8W. *E. regnans* is based on 2 x 5 permanent permanent quarter-milacre plots; *E. obliqua* is based on 5 plots

Series II: This series was established at Road 7A and at Road 8W after the regeneration burns of early March, 1960. The aim here was to confirm for E. regnans and to extend to E. obliqua the results obtained in the previous year at W54. The only seedbed tested was B n L; in some cases the burning had removed nearly all the humus as well as the litter. The seed trees were all mature and carried a heavy, young seed crop, most of which was shed during March, 1960. Their crowns suffered less than 10% of scorch from the fire. The understorey had been rainforest. Plots were located and identified as in Series I and II but were only $\frac{1}{4}$ milacre in size. Germinations were scored by removing the seedlings from the plots at monthly intervals. Stocking trends were scored by counting the total number of seedlings on a paired adjacent plot. Seedlings were not pegged; mortality was not scored for. Three lots of five pairs of plots were located underneath three groups of seed trees; Lot 1 at Road 7A underneath E. regnans; Lot 2 at Road 8W underneath E. regnans; Lot 3 at Road 8 West underneath E.obliqua.

C. THE COURSE OF GERMINATIONS

I. THE PATTERN OF GERMINATION

The results from the experimental plots are summarized in Figures IX.1 and IX.2 and in appendices No.IV and V. The patterns were similar on all three series of plots.

Germinations began to appear 2-4 weeks after the seedbed became fairly continuously moist. There was a peak of germinations in autumn (May), a trough in midwinter (July) and very strong burst in early spring (late August, early September). Germinations during the two dry summers were relatively insignificant. There might be more germinations if the summer is cool and moist (see Chapter xI) after burning. From a knowledge of the pattern of seedshed and the rate of deterioration of the seedbed it can be expected that germinations during the first year after the fire are usually much more important in terms of numbers of seedlings which became established than germinations during the second and later years after the fire. The relative numbers of germinations in the first two years depends on the survival of the seed trees, the degree of seedshed acceleration by the fire and on the development of a new crop of seed. Germinations during the second year after the fire will be important, or even pre-eminent only if the seed trees survive and flower heavily after the burn, which is an unlikely event if the regeneration burn is properly timed according to the optimum seed crop position.

Judging from experience with artificial sowing (Chapter XI), the most striking feature of the pattern of germination following a regeneration burn with seed trees is the great burst in the rate of germination in early spring.

II. HOW IMPORTANT AND WIDESPREAD IS THE BURST OF GERMINATIONS IN SPRING?

During and just after the spring flush of germinations two generations of seedlings can be clearly distinguished as "new " (small, light green cotyledons) and "old" (larger, dark green cotyledons). The ratio of new to old seedlings was determined on 23.9.1960 by counting seedlings on randomly located quadrats in widely scattered areas of the 1960 burn. On the experimental plots of Series I, II and III referred to above the ratio of new to old seedlings was about 2. Eight widely scattered areas with seed trees and all burnt in March, 1960 were inspected and it was found in six cases that the ratio of new to old seedlings was between 2 and 5. In

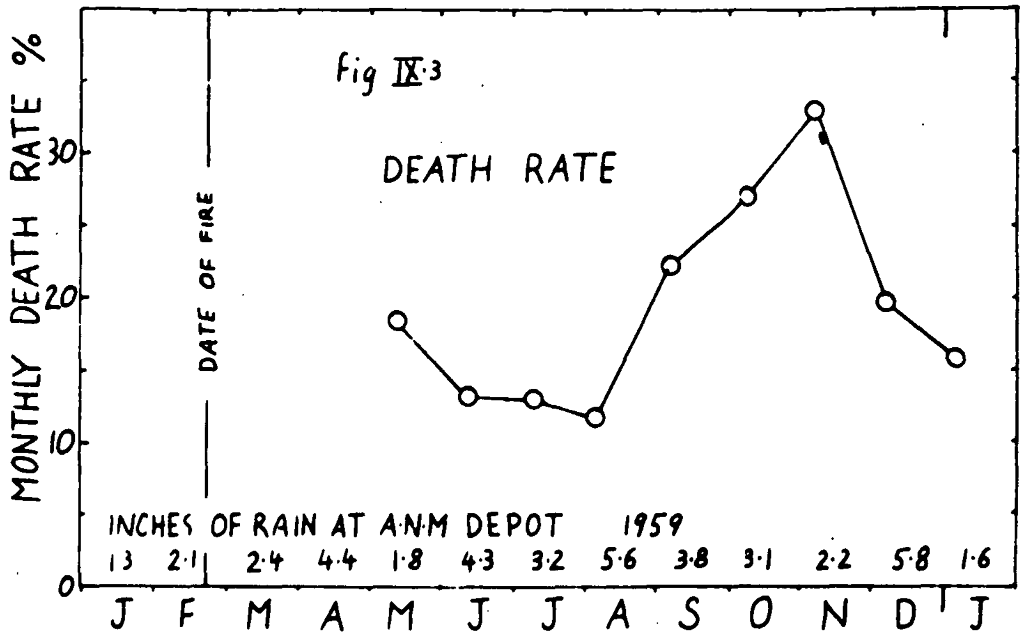


Figure IX. 3 : Monthly death rate expressed as a percentage of the stocking at the previous scoring, plotted midway between scoring dates. Each point is based on a population of 60 to 700 seedlings on 50 to 105 widely scattered half-milacre plots at W54, in 1959.

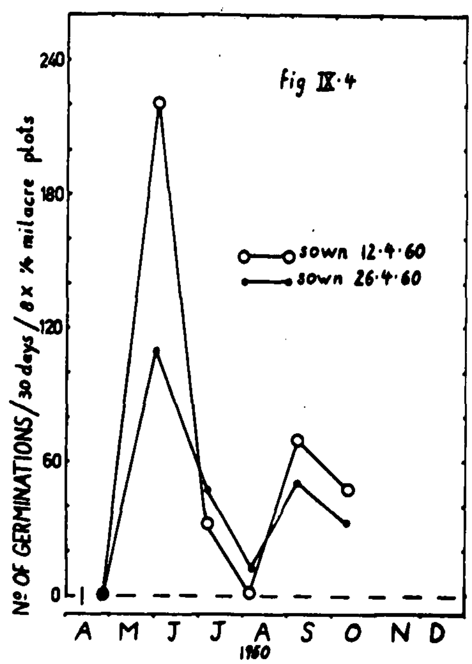


Figure IX. 4 : Pattern of germination from autumn sown seed with a high degree of natural dormancy. Plotted midway between monthly scoring dates.

two cases the ratio was 24 and 32. The very great preponderance of new seedlings in the latter two cases might be ascribed to a very high death rate amongst the old seedlings due to frost lift which had been observed to be particularly heavy on these sites.

It is clear that the spring peak of germinations is very marked and widespread. It was observed in 1959, 1960 and in 1961 both under E. regnans and under E. obliqua. E. delegatensis would have this tendency even without fire (Grose, 1961) because most of its seeds are dormant and need to be stratified by overwintering.

After the burst of germinations in spring, most seedlings present in September/October are recent ones. The proportion of new seedlings is very variable. The spring germinations represent 50% or more of the total germinations. This is remarkable because spring germinations from artificial sowings during March and April (Gilbert, 1958, Cunningham, 1960, Chapter XI) have usually amounted to only 7 to 21% of all observed germinations. The only exception was the rather dormant seedlot which was sown during April, 1960 in the pellet experiment and 27 to 36% of whose germinations occurred in spring (see figure IX.4).

III. WHAT IS THE REASON FOR THIS REMARKABLE BURST OF GERMINATIONS IN SPRING?

The simplest explanation would be time of seedshed. Any seed which is shed after winter cannot germinate before spring time and the closer the sowing is to midwinter, the larger will be the proportion of germinations in spring. Sowings earlier in autumn should germinate to a larger extent before mid-winter if the seedbed is suitably moist.

A second reason for the burst of germinations in early spring is that this time of the year appears to be excellently suitable for eucalypt germinations in the Florentine Valley.

A third reason for the delay in germinations from autumn until spring is that a high proportion of the seed may be dormant when it is shed in late autumn.

Evidence for Dormancy of Seeds.

Firstly, some seedlots of E. regnans are naturally dormant (Cunningham, 1960) in the sense that they germinate very slowly at a temperature of about 65°F. and that their rate of germination can be accelerated by previous moist storage at about 38°F. Some seedlots of E. regnans collected in 1959 and 1960 in Tasmania have exhibited such dormancy.

Secondly, it is known that heating of moist seed can induce secondary dormancy (Cunningham, 1960).

It is possible that a fire which is hot enough to scorch leaves and to kill twigs will cause death or induce dormancy amongst seeds in capsules on the crown. Seeds in green capsules have a moisture content between 30% (Grose, 1961) and 71% (Rowe, 1955). Cunningham (1960) showed that a temperature of 130°F. maintained for at least 6 hours killed most or all seeds which had a moisture content of at least 27%.

He also showed that 90°F. on imbibed seed (50 to 100% M.C.) for five hours may induce as much as 40% of the seed to become dormant. Grose (pers. comm.) found that heat insufficient to discolour the capsules on slash near a fire may nevertheless reduce the viability of sound seed from 98% to 26%. These findings suggest that a considerable proportion of the seed on scorched crowns could be either killed or made dormant.

Plentiful germinations can often but not always be seen under completely scorched crowns. This means that heat strong enough to scorch foliage is nut usually fatal to the seed crop. Crown scorch varies in intensity and it may be expected that some intensity less than a crown fire may cause many deaths amongst the seeds. If seed which was killed by heat can be recognized by its dark, pulpy contents (Cunningham, 1960) then the results of a squash test on twelve seedlots collected from the lightly scorched branches of twelve different E. regnans trees show that light scorching is not usually very harmful to the seeds. Only 2 to 14% of the seeds had dark endosperms compared with 4 to 7% in two control seedlots.

On one tree of E. obliqua whose crown was partly scorched, seed was collected from green branches; 45% of this seed had dark endosperms and would not germinate even after stratification. It could be that fire causes the production of toxic substances which need to be translocated to the seed and can, therefore, affect only the seed which is attached to green branches.

These indications of the effect of fire on death and dormancy of seeds on standing crowns should be tested.

D. SEEDLING MORTALITY

Results from W54 plots (1959).

The results are given in Appendix IV and are summarised in Figure IX.3. Results are not here separately analysed for each type of seed bed because trends in mortality were erratic when based on a fairly small population. The sharp drop in mortality during early December was recorded on all seedbeds. Between March, 1959 and January 22nd, 1960 the burnt seed beds suffered 65% mortality amongst all observed germinations (903) while the unburnt, disturbed seedbeds experienced only 42% mortality amongst the (297) observed germinations. Gilbert (1958) found a similar relative advantage in disturbed as against burnt seedbed when sown in the open during October or April.

Mortality during winter was between 10 and 20% per month. It rose rapidly with the advent of spring and tender new spring germinations to a maximum of 30% in November and then dropped sharply in early December. The lower death rates in Decémber and January are probably the result of ample rain and the older, better established seedling population. A spurt of recent germinations is bound to suffer high mortality if drought or frost lift occur before the seedling roots have penetrated more than one inch. Amongst the dead seedlings which did not disappear between scorings the causes of death could be assigned about equally to fungus, desiccation and defoliation (? by insects). Frost lift, though widespread elsewhere was not very important at W54 in 1959. Desiccation affected only very young seedlings and then only <u>after</u> the winter.

Comparison of survival underneath seed trees as against survival in the open is difficult. Indications are that survival was not much affected by the seed trees either way.

Frost lift proved to be a major cause of seedling deaths on seed beds which were very severely burnt in 1960.

E. RATE OF GROWTH AND VULNERABILITY OF SEEDLINGS FROM BROWSING

Usually, the first pair of leaves expands in September. Then growth is rapid. By October-November many seedlings become tall enough to be browsed. The majority of seedlings then need about twenty months' freedom from browsing before they are established. Protection is advisable from November after the fire until the second July thereafter (see Chapter XII).

Growth rate and hence the period of vulnerability is likely to vary with sites and seasons. The beginning and end of the vulnerable period is about 2" and 24" respectively and its timing is easily verified by inspection in the field for the prescription of control treatments.

F. STOCKING AND ASSESSMENT -

The question of how many seedlings at any particular age constitute satisfactory stocking is not discussed. The problem of interest here is how does stocking (i.e. the number of seedlings per acre) vary with time and what are the best times for regeneration assessments? How soon after the regeneration burn can a reliable regeneration assessment be carried out to determine the chances of success from natural regeneration? How long can the assessment be delayed before its results become useless for the planning of action to supplement natural regeneration by artificial means should this prove necessary?

I. HOW STOCKING CHANGES WITH TIME AFTER BURNING.

Stocking is the combined effect of germinations and deaths.

(a) Changes during the first Year -

During the first year after the regeneration burn the stocking pattern is predominantly determined by the germination pattern which is illustrated in figures IX.1 and IX.3. In 1959 at W54 the stocking rose during April, May and June remained level in Jul+Aug. and then rose steeply to its greatest peak in September. From then on the stocking steadily decreased as new germinations became fewer and fewer and death rate assumed its more and more predominant influence. In 1960, the pattern at Roads 7A and 8W was similar.

The exact timing of the peaks of stocking depends on the seasons. In 1959 and 1960 peak stocking was attained at the end of September. After September the stocking is likely to decrease.

An assessment of the regeneration cannot be carried out before the peak of germinations in spring because the rate of germination in autumn is not predictably related to the rate of germination in spring.

In the years 1959 and 1960 germinations after September were relatively insignificant.

The earliest opportunity for a regeneration assessment occurs, therefore, in October following the burn.

(b) Changes during later Years -

Because of the rapid deterioration of the seedbed after one year and because of the death of seed trees or because of fairly complete seedshed acceleration, germinations during the first year after a regeneration burn are usually so very much more important in number and survival than later germinations that germinations which occur during the second and later years usually need not be taken into practical consideration. Stocking changes during later years can, therefore, be expressed in terms of survival of seedlings present at the end of the first year, or can even be related to peak stocking in the first October.

II. WHEN SHOULD THE REGENERATION BE ASSESSED?

Information from sowings made in autumn is useful for predicting the rate of survival of seedlings from natural regeneration.

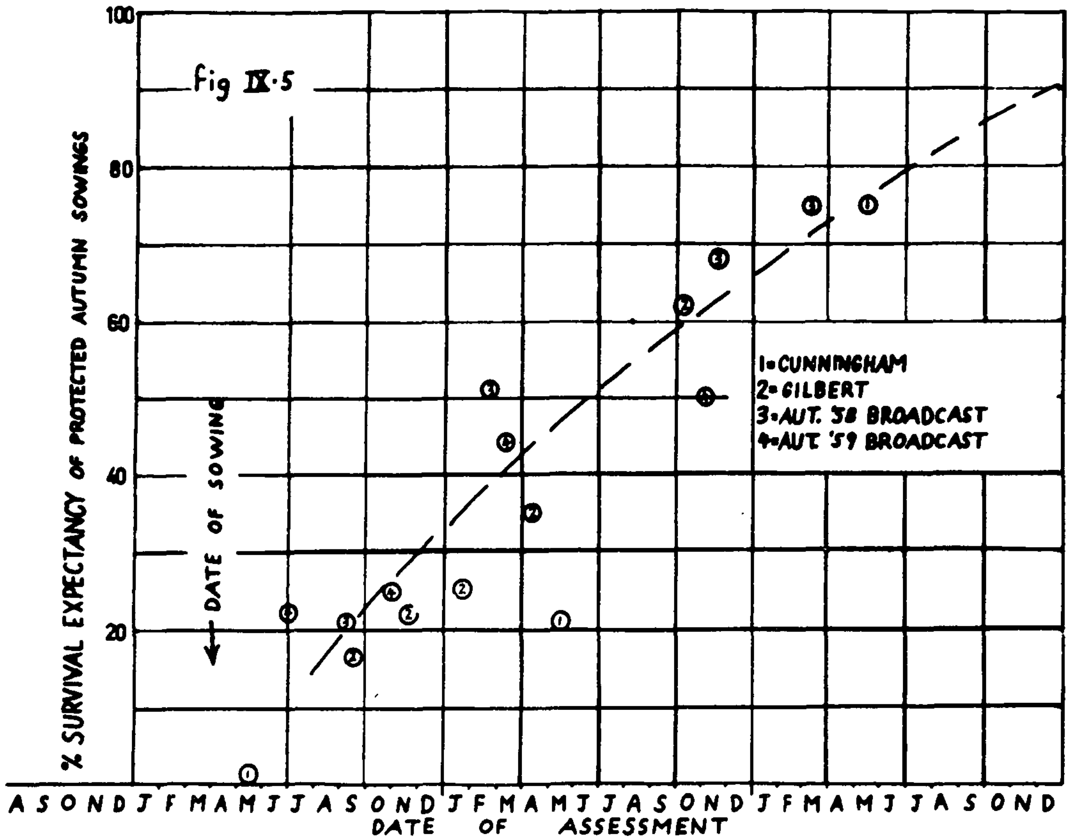


Figure IX. 5 : Assuming that 75% of the plants present two years after sowing will eventually become established, the "survival expectancy" of each sowing at each time of scoring has been calculated by expressing the number of expected survivors as a percentage of the number of seedlings present at the time of scoring. The results come from four March/April sowings protected from browsing and sown on burnt or lightly disturbed seed beds. Two of the sowings are by the author and one each by Gilbert and Cunningham.

Survival expectancy of seedlings to a stage when they can be considered established depends on the age of the seedlings as well as the environment (browsing, weed competition, season). It is, therefore, essential to know the survival rate of seedlings at different ages under specified conditions such as freedom from browsing and lack of excessive weed competition. Such information has been obtained from autumn sowings and is set out in Figure IX.5. Use of this figure, plus a knowledge of what constitutes satisfactory established stocking, enables the assessor to judge whether the regeneration assessed at any given time after the first September following the regeneration burn is likely to be satisfactory. The older the regeneration, the more reliable the assessment becomes. At the same time, the growth of weeds makes complementary artificial regeneration measures increasingly expensive. Assessment should, therefore, be done as early as possible.

Assessment between September and March one year after the burn is reasonably reliable and can still be followed up by broadcast sowing. Deficiencies diagnosed by assessment during the second and third years may be corrected by the more expensive method of spot sowing, provided ferns and shrubs are still sparse. Thereafter, only planting or major site disturbance can correct deficiencies in the level of regeneration.

G. REMOVAL OF SEED TREES -

I. WHEN SHOULD THE SEED TREES BE REMOVED?

The reserved seed trees represent from 20% of the eucalypt timber crop in dense stands up to 100% of the crop in open stands. They are likely to contain one quarter as much usable wood now as is expected to be produced by the new crop at the end of its rotation in 60 to 80 years time. The seed trees must, therefore, be harvested. The question is: when? The major alternatives are either at the end or at the beginning of the new rotation. Harvesting during the rotation, perhaps as part of a thinning programme, is likely to be too destructive to the younger crop.

Over the years, a large proportion of seed trees will be killed by the regeneration burns. Such trees do not compete with their offspring but their wood will probably become unsuitable for pulping after twenty years, irrespective of whether the trees remain standing or fall over. Surviving seed trees may be windthrown or may deteriorate as a consequence of fire damage. The loss of usable wood due to these accidents and due to the suppression of the younger crop is not likely to be fully compensated for by the growth of the seed trees themselves, even when the seed trees are less than 200 years old.

Except in the relatively rare cases when the seed trees are entirely useless, the potential loss of wood involved by delaying the removal of the seed trees for 60 to 80 years, is likely to justify a special logging operation at the beginning of the rotation.

After closure of the seedbed to further regeneration the seed trees are of no further advantage to the new crop, unless they are alive when a second fire occurs before the young trees bear seed.

The <u>earliest opportunity</u> for the harvesting of the seed trees occurs after enough regeneration has appeared and/or when no additional regeneration can be expected because of depletion of the seed source from trees killed by fire or because of closure of the seedbed. If nearly all the crowns of the seed trees are entirely scorched, or if the trunks are deeply girdled by the fire, then nearly all of the seed that can ever be expected comes down within two to four months of the fire. Such trees could be felled during the first winter. If the seed crop assessment has indicated an ample seed supply, the first winter is a reasonable time also for the removal of live seed trees. They can be expected to have shed most of their then mature seed by June. However, if the seedrop is likely to be poor, then the living seed trees should be retained until after the regeneration assessment. If natural regeneration then appears unlikely to be adequate, the seed trees should be removed as soon as possible, preferably before artificial regeneration measures are taken. In other cases, the seed trees may be removed during the second winter.

The <u>latest reasonable</u> date is before the wood of the dead seed trees has deteriorated excessively, before scrub and eucalypt regeneration makes access much more difficult and before the eucalypt seedlings have grown to an excessively vulnerable stage. This date is likely to be within five years if browsing is controlled.

The <u>optimum date</u>, if maximum stocking of seedlings is aimed at must take into consideration the following factors:-

(1) Partial uprooting of seedlings is less lethal in wet weather than it is in dry weather. In spite of slower recovery during the "dormant" season in winter, seedlings should survive best if logging of seed trees occurs in the reliably wet winter period of May to September.

(2) A leafless crown smashes fewer seedlings and clutters up less seed bed than a crown with leaves. Most leaves on exposed crowns are shed within four months of their death, i.e. by the middle of the first winter in the case of trees which were scorched or deeply girdled about March.

(3) Logging disturbance is more likely to kill seedlings than ungerminated seed. However, the burial experiment (Chapter XI) showed that eucalypt seed which is buried deeper than ½ an inch under normal soil will not produce any seedlings. The taller seedlings ((over 3") are less likely to be uprooted or buried than very small seedlings. Most of the damage is likely to result from the pushing aside of felled trees. Seedlings under 2 to 4 feet high are more likely to recover from being brushed over and are less likely to be pinned down. The seedlings will, therefore, be at their least vulnerable stage during the second winter.

(4) If a crown with seed is felled onto a still receptive seed bed it may give rise to further regeneration, rather than just kill existing seedlings. This is the case during the first and second winters.

These factors suggest that the second winter is usually the best time for the removal of seed trees. There is, however, considerable latitude. Many areas may be logged already in the first winter and in most areas, logging may reasonably be delayed for 3 or 4 years.

II. HOW SHOULD THE SEED TREES BE REMOVED?

High leading across felled areas is likely to be most destructive to the regeneration. Therefore, tractors should be used. If the main tracks are kept free from felled understorey trees, tractors can use these tracks again to extract the seed trees. This makes easier work for the tractors and causes minimum damage to seedlings because the compacted tracks are the least valuable type of seedbed and a minimum of log debris is pushed aside for the clearing of new tractor roads.

The seed trees should be felled so that their logs point in the direction of the tractor.

The main principle is to avoid running a tractor onto burnt ground. The damage to the regeneration done by the removal of seed trees is being studied now. Indications are that damage will not usually be excessive.

H. SUMMARY -

Nearly all effective germinations for natural regeneration after burning usually occur before the first summer. Many occur in autumn, most occur in a sharp peak in early spring about September.

The delay of so many germinations until spring time could be due to some delay in seedshed and to a certain amount of dormancy in the seeds.

Mortality underneath the canopy of seed trees does not appear to differ from mortality in the open.

Growth rate is as for sowings made during autumn to early spring (Chapter XI). Seedlings become vulnerable to browsing about November and need protection for about twenty months thereafter.

During the first six months after burning, the stocking pattern is determined by the germination pattern. Stocking reaches a peak about September. Because the contribution of spring germinations is very variable and large, assessment of the regeneration cannot be carried out before October unless the stocking is already ample in autumn or winter. The best time to forecast the success of regeneration is between September and March during the year after the burn. Deficiencies in stocking which are discovered then can still be rectified by broadcast sowing.

In most instances, the best time to harvest the seed trees is during the second winter. Many areas can be harvested late during the first winter and in most areas, the removal of seed trees may be delayed for up to four years.

The logs of the seed trees should be extracted by tractors which re-use the old puddled tracks as much as possible to avoid damaging regeneration on the better seedbeds.

PART C

ARTIFICIAL REGENERATION

CHAPTERS X TO XII

CHAPTER x.

P L A N T I N G .

A. EXPERIMENTAL METHODS

I. PROJECT 1

Aim:

The general aim of this project was a semi-field scale demonstration of methods of artificial regeneration. It was designed to show what level of success can be obtained from the main methods of artificial regeneration in the Florentine Valley, and to give a quantitative estimate of the benefits from the control of browsing.

Numerous additional questions were raised and investigated by minor variations within the overall design and by special scorings. Unfortunately most of the experimental area was burnt accidently in March 1960 before all results were obtained.

Experimental Area:

For economy, all fenced plots had to be within a single large fence. Adjacent coupes W56 and W72 were the only suitable areas available at the time. These coupes are representative of a large portion of the Florentine Valley. The site is at 1600 ft. on a 10 to 20% slope facing SW, with a moderately stony but deep soil derived from dolerite. The area carried a 100 years old rain-forest with 100 and 250 years old emergents of E.regnans and a few E.delegatensis. The coupes were logged by tractor in 1957 and burnt in March 1958. No live understorey remained on the plots. Twenty-one acres of coupe W57 were fenced in May 1958 to a height of 3½ ft. and in January 1959 the height of the fence was increased to 6 ft. to make entirely certain that no kangaroo could cross the fence.

Layout:

The area within the fence and certain comparable blocks outside the fence were surveyed into a grid system with a numbered peg at the corners of each square chain. Where possible all the plots for each main treatment were one acre in size (¼ acre outside the fence) and consisting of ten adjacent one square chain sub-plots running in a line at right angles to the contours.

The main treatments were

Planting)	in Autumn 1958	) fenced (1 acre)
Spot Sowing)	in Spring 1958	)not fenced(¼ acre)
Broadcast Sowing)	in Autumn 1959	)

Only the plantings are described in this chapter.

Each square chain was planted with forty plants. Each plant was identified by an aluminium number tag on top of a peg erected six inches away from each plant. In Autumn 1958 ten out of each forty plants were randomly selected for no manurial treatment. The others were manured with blood and bone sprinkled on the surface in a one foot halo around the plant at a rate of two ounces and four ounces alternately. With the plantings made in Spring '58 and Autumn '59, every second plant was manured at rates alternating between 2 ounces and 4 ounces per plant.

The history of each plant was recorded separately under headings which included: condition of seed bed, browsing-damage, health, frost damage, weed competition, and height of plant.

The condition of the seedlings at the time of planting is described in Appendix X.

<u>PROJECT 2 - PART I</u> -

<u>Aim</u>:

1. To assess the effect of weedgrowth on planting:
(a) through ecological protection against browsing,
(b) through competition.
2. To determine whether manuring with blood and bone affects mortality due to browsing or weed competition.

<u>Layout</u>:

A series of coupes between 0 and 8 years old was chosen to cover the major stages in the early succession of weeds which spring up after logging. The stages which affect the survival of planted seedlings are: (see also Chapter XIII)

(a) <u>The early stage</u>, which starts after the burning or logging and is at first bare of tall weeds but becomes dominated by fireweeds (mainly <u>Erechthites</u>) during the first and second summers and ends about the third or fourth year when fireweeds fade out and are replaced by:

(b) <u>The second stage</u>, which is dominated by <u>Histiopteris</u> and <u>Hypolepis</u> (wet ferns).

(c) The third stage, viz that dominated by Pteridium (bracken) may take 10 years or more to replace the second stage. Its advent is greatly accelerated by repeated fires and the existence of Pteridium in the forest previous to logging.

Dense shrub thickets may also occur but are not considered here. Planting can be assumed to be impossible amongst dense shrub thickets. Ashton (1957) and Gilbert (1958) have shown that E.regnans cannot survive underneath its own wet sclerophyll or rainforst understorey, due to lack of light.

All coupes are between 1,400 and 1,700 ft. in elevation and formerly carried rainforest with emergents of E.regnans plus some E. delegatensis in some instances. L.9 was planted on 9th July 1958. W.72 was planted as part of project 1 in October 1958. The other coupes were planted on 12th December 1958. Not all coupes had been burnt.

Description of coupes planted in project 2.

Coupe	Soil	Date of burning (B) or Logging (L)	Dominant vegetation: in December 1958	Dominant vegetation: in December '59
Fireweed stage:				
W72	Dolerite	March 58 (B)	ground mat of mosses and Mar chantia only.	mainly Erech-thites(sparse)
W69	Dolerite	March 58 (B)	scattered Erech-thites; a few small shrubs.	Erech. very dense
W38	Dolerite	1956 (L)	Scattered Erech-thites & ferns	Erech. Scattered
W43	Limestone	1956 (L)	Numerous fire-weed & fern plants	Fireweeds and ferns fairly dense.
Wet Fern Stage:				
W34	Limestone	1955 (L)	Patchy wet ferns	patches extend-ing.
L.9	Limestone	1954 (L)	Open cover of shrubs, ferns and some fire weeds.	shrubs and ferns becoming denser
W23 R	Limestone	1954 (L)	Many rainforest trees (remnants)	Ferns extend.

(Con't)

Coupe	Soil	Date of burning (B) or Logging (L)	Dominant Vegetation: in December 1958	in December '59
			wet ferns in dense patches.	
W23 L	Limestone	1954 (L)	Fairly dense cover of wet ferns & bracken.	Ferns dense
W18	Dolerite	1952 (L)	dense bra cken in some places, dense wet ferns in oths.	Ferns very dense, bracken extending.
W.4	Dolerite	1952 (L)	wet ferns very dense bracken sparse.	ferns very dense
TS2	Dolerite	1950 (B)	wet ferns and <u>Carex</u> very dense	Ferns very dense; bracken extending.
TS3		1950 (B)	wet ferns very dense	bracken increasing fast.
<u>Bracken Stage</u>:				
Road 10			Ferns (mostly bracken) dense	bracken extending, very dense
Road 11		1934 (B)	very dense tall bracken.	dense bracken

All planting stock was tubed. The stock used at L.9 was prepared by lifting 2 - 3 inches tall seedlings from a nursery bed of heavy soil and then wrapping a tube full of soil about their roots. Though the seedlings used for planting were all alive, only the minority showed by putting on some growth that they became established in the tube. The stock for all other plantings had grown up from seed sown in the tube, was between 3 and 6 inches tall and actively growing when planted out.

Newman planted the 150 plants at L.9 by mattock and crow bar in rows at 15 ft. spacing. The 100 plants at W.72 were scattered over one quarter acre. On each of all other coupes 40 plants were spaced at 12 ft. intervals along two lines at right angles to each other. This wide distribution of plants was necessary to avoid the chance of one animal finding all 40 plants in one bunch and eating them up in one night. Planting along lines was necessary so that plants could be found again amongst the knee to breast deep weeds. Treading paths for the guidance of animals from plant to plant was carefully avoided. Except at L.9, all plantings were made by dibble with minimum disturbance of soil and weeds. Especially dense or open sites were neither sought nor avoided. Every second plant was manured with blood and bone. Manuring was at a rate of 2 oz. and 4 oz. per plant alternately.

Each plant was individually pegged and numbered; a procedure absolutely necessary for the comparability of subsequent scorings.

Scorings were made at the time of planting, a few weeks thereafter, and then only at either end of each growing season. More frequent inspections would have improved the accessibility of the plants to browsing animals, and might have reduced the competition from weeds.

PROJECT 2 - PART II -

Aim:

Part I had shown that undisturbed dense weeds afforded good protection from browsing but that the competition caused excessively high mortality to the planted seedlings. It was then decided to run a small trial to see if the cultivation of a 4 sq. ft. spot plus manuring with 4 oz. of blood and bone was sufficient to establish planted eucalypts amongst wet ferns and bracken and whether browsing of the conspicuous plants would be serious.

Methods:

On coupes TS3, W23 and near Road 11 where dense wet ferns or bracken had caused serious mortality in the earlier experiment, a similar planting was repeated with 40 tubed plants in each case close to and parallel with the previous plantings. However, this time each plant was planted in soil cleared of weeds and cultivated 6" deep over 4 sq. ft. Each plant received four ounces of blood and bone. Plants were pegged, numbered and scored as in Part I. There were no subsequent tendings. Planted on 25.11.59.

In the following section (B) as well as in many other instances in this thesis only summarized results are given. More data and greater detail on methods and results are presented in the Final Report of the Second Australian Newsprint Mills Ltd. Forestry Research Fellowship and several earlier intermediate reports.

B. <u>ENVIRONMENTAL FACTORS WHICH INFLUENCE THE SRVIVAL AND GROWTH RATE OF PLANTED E. REGNANS SEEDLINGS</u>.

I. SEASONAL EFFECTS ON GROWTH RATE -

The Tasmanian climate does not permit a uniform growth rate of eucalypts throughout the year.

Figure X.1 illustrates seasonal differences in height growth of planted seedlings between one and twelve foot tall. Note that:

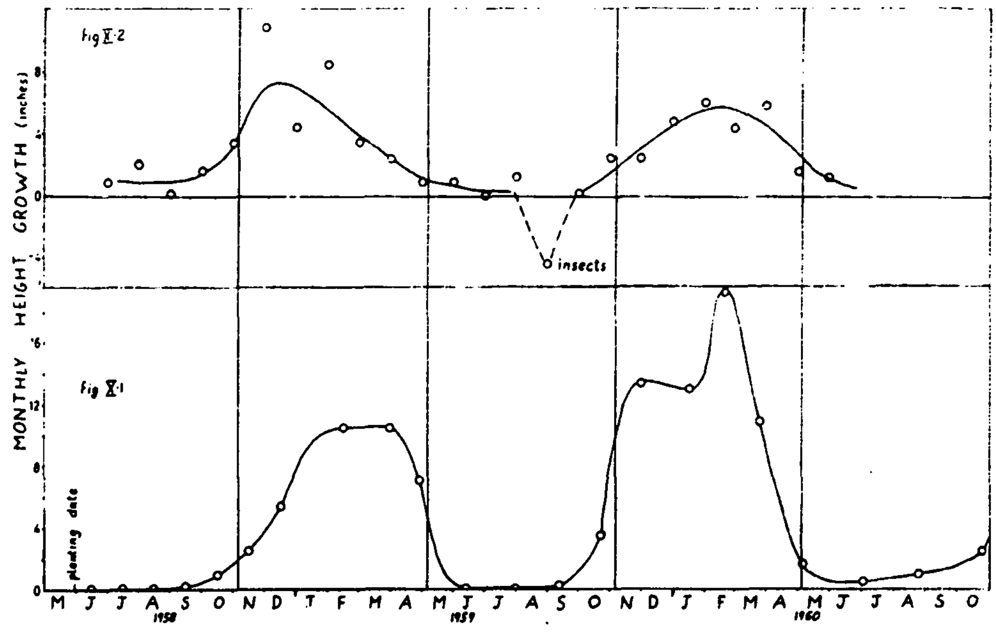


Figure X. 2 : Average monthly height growth based on ten *E. regnans* trees 40 to 50 feet tall. Measured with a theodolite by Bowling in S.W. Tasmania.

Figure X. 1 : Average monthly height growth based on the ten best *E. regnans* seedlings out of forty planted at W56 in May 1958. Fenced. Plotted midway between scoring dates. Some plants were manured.

- During winter, growth is nearly zero.
- Growth slows down very rapidly during April-May.
- Growth recommences in September, and accelerates sharply in October. The growth rate in November 1958 was slower than in November 1959 probably because the plants had not yet become fully established.
- The growing season lasts only 6 or 7 momths, from October to May.
- Established, vigorous plants may grow at an average of half an inch per day for several months.
- Figure X.2 shows that 40 to 50 ft. tall E.regnans trees show the same pattern of seasonal height growth as seedlings.

Diameter growth of the trees in figure X.2 also slowed down to near zero in winter. The summer check and late summer flush tend to be more marked here and may result in false "annual" rings. (Bowling pers. comm.)

Cessation of root growth in winter similar to that reported by Raeder-Roitch (1958a) for the Snowy Mountains is suspected to occur also in Tasmania.

Practically no new leaves are formed from May to August. Immature leaves may increase from one inch in May to full size by July.

Drought during summer may slow down the growth of trees but has apparently little or no effect on the growth of established seedlings. The cessation of growth in winter is probably due to low temperature.

Annual Growth Rate:

The growth rates quoted here were recorded during 1958 to 1961, in the Florentine Valley, on not-puddled soils, with unfertilized tubed stock, which was planted by dibble and protected from browsing and free from serious competition with weeds.

There was a lot of variation in the height of plants at the end of the first year, even when they started off from an apparently uniform batch. But once the plant was established, its growth rate became more predictable.

Table X.1 shows that the annual height growth of E.regnans was about one foot during the first year after planting, about three feet during the second year; and about six feet during the third year.

The extensive stands of E.regnans which re-generated after the wild fires in 1934, show that the average growth rate of the dominants was only 3 to 4 ft. in height per year during the first 30 years.

TABLE X.1 -

ANNUAL HEIGHT GROWTH of E.regnans seedlings planted in tubes on normal, unfertilized soils free from serious weed competition and browsing.

Experiment	Tag Numbers	Date of Planting	Average Height (inches) at Planting	After growing season 1st	2nd	3rd
Spring 58	580-640	17.10.58	3.5"	15.7"	72"	159"
"	1-40	8.10.58	5.3"	20.5"	60"	-
"	161-200	10.10.58	5"	20"	-	-
Autumn 59	1-40	4. 3.59	6.7"	15"	-	-
"	41-80	4. 3.59	Pruned to 3"	18"	57"	
"	81-160	4. 3.59	12"	27"	59"	
"	401-450	18. 5.59	3.7"	16"	47"	
"	451-30	15. 7.59	4.3"	13.1"	40"	
"	541-599	2.10.59	3.5"	17.9"	52"	
Proj. 2	701-740	3.12.58	6"	17"	55"	112"
	781-820	3.12.58	7"	18"	51"	123"
	Average -		5.2"	18.0"	54.8"	131.2"

Note: The number of plants contributing to the average figures quoted are equal to about half of the tag numbers.

III. THE EFFECT OF MANURING WITH BLOOD AND BONE AND THE INFLUENCE OF BURNT AND OF PUDDLED SOILS ON THE HEIGHT GROWTH OF PLANTED SEEDLINGS.

(1) Growth in Puddled Soils -

The general problem of soil puddling by logging tractors is discussed in Chapter XI. In the experiments reported in this chapter only a few plants were planted in puddled soil, but the following qualitative observations are worth noting:

It is clear that no eucalypt seedling - and apparently no other local species either - can thrive in freshly puddled soil. The planted seedling develops symptoms of stagnation within a few months; the leaves turn reddish, or at least pale green, and growth is very slow or nil. Foliage is sparse, and consists of small, thin leaves. B uds, if any, are very weak. No healthy roots emerge from the tube. Indeed even the originally healthy roots inside the tube become blackened and spindly, as a result of the surrounding soil conditions. At tube depth most tractor tracks show severe symptoms of puddling for several years. There is usually complete loss of soil structure, and an evil smell of anaerobic decomposition. The soil is a dense, plastic, amorphous mixture of clayey matrix and churned up organic material. Under these conditions roots may emerge from the tube, but do so to only a very small extent. Such roots are very slender and covered with black, easily rubbed off bark. The surface soil too may be just as forbidding. It often is so dense that a nail can be pushed into it only with difficulty, especially when the soil is dry. If all the soil surrounding the tube is unsuitable for rootgrowth and/or if the tube is impenetrable the plant will become stagnant within a month or two and remain so for years, or die slowly.

Blood and bone can make all the difference between complete stagnation and good growth on puddled soils. One ounce per square foot sprinkled on the surface will ameliorate the top 2 - 3" of soil in one year. Ameliorated soil smells pleasantly, has good structure, is explored by worms and dense rootgrowth and carries a weed growth of mosses and <u>Erechthites</u> just like freshly burnt ground, even though the surrounding, unmanured puddled areas are absolutely barren. If any of the eucalypt seedling's roots reach such soil the stagnation will cease. The seedling's roots must therefore not be prevented from penetrating this surface soil by planting a long, intact tube with its upper brim above the soil surface.

Stagnating plants are amazingly tenaceous. They may survive for more than three years with hardly any growth. If they survive long enough they should eventually benefit from the natural amelioration of the puddled soils, though this may mean the loss of several years' growth. Only few tracks more than five years old cannot grow their pioneer species, namely the eucalypts.

(2) <u>Height Growth on Burnt Soil</u>:

Most of the ground on a coupe is not puddled by tractors, and is normally burnt in preparation for the regeneration of the eucalypts. Intensity of burning may vary greatly. The fire may have burnt all organic material right down to mineral soil, and may even have baked that. At the other end, only the superficial slash may be imperfectly burnt, leaving the humus and even the litter quite intact. The plantings of the present experiments were made on burns of medium or light intensity.

TABLE X.2

The effect of manuring on the height growth of E.regnans seedlings planted on freshly burnt soil and not seriously affected by browsing or weed competition.

(see Page 182a.)

The figures in Table X.2 show that the response to manuring was very variable and not significant within three years of planting. It appears unlikely that manuring with blood and bone at the rate of 2 or 4 ounces per plant will result in any worthwhile improvement in the growth rate or survival of E.regnans seedlings planted on freshly burnt ground.

TABLE X.2

The effect of manuring on the height growth of E.regnans seedlings planted on freshly burnt soil and not seriously a ffected by browsing or weed competition.

Planting	No. of Plants.	Growth During - 1st year	2nd year	3rd year	
Proj. 2	10	11"	33"	72"	F^0
W69	4	12"	26"	66"	F^2
	6	13"	44"	85"	F^4
Autumn 1959	47	11"	30"		F^0
	25	8"	39"		F^2
	21	15"	41"		F^4
Autumn 1959	15	14"	36"		F^0
	8	19"	36"		F^2
	5	2"	27"		F^4
Spring 1958	12	15"	-		F^0
	5	10"	-		F^2
	7	17"	-		F^4
Spring 1958	20	12"	56"	92"	F^0
	10	14"	53"	74"	F^2
	9	17"	66"	89"	F^4

F^0, F^2, F^4 is manuring at 0,2,4 ounces of blood and bone per plant.

(3) Height Growth on Unburnt Soil:

Growth of eucalypts on unburnt and lightly disturbed soils was good and not significantly inferior to growth rates on burnt soils. Compare Tables X.2 and X.3

TABLE X.3

The effect of manuring on the height growth of *E.regnans* seedlings planted on unburnt but not puddled soils free from serious browsing or weed competition.

Planting	No. of Plants	Growth During - 1st year	2nd year	Fertilizer
Project 2	32	8"	28"	F^0
W43, W34.	17	12"	35"	F^2
	14	15"	43"	F^4
Project 1	89	11"	39"	F^0
	38	16"	37"	F^2
	39	18"	54"	F^4

F^0, F^2, F^4 is manuring at a rate of 0, 2, 4 ounces per plant respectively.

Pryor (1960) describes how the baking of soil may double the growth rate of eucalypt seedlings. The soil in which the plantings under discussion were made, was certainly not baked; not even the superficial layer of humus was burnt away. The natural eucalypt seedlings which came up on the areas burnt by hot humus fires in

1960 and 1961 showed remarkably good growth rates. This suggests that Prior's "ash-bed effect" may indeed accelerate eucalypt growth in the Florentine Valley, <u>IF</u> the area was burnt by a <u>humus</u> fire immediately before planting. The "ash-bed effect" is ascribed to the liberation of nutrients (mainly N and P) due to the sterilization of the soil.

Any fire which produces ashes should have some stimulating effect on plant growth (see also Chapter XIII) It is therefore not surprising that the response to blood and bone was not marked on recently burnt soils. It might be expected that the effect of blood and bone is relatively greater on unburnt soils. This is supp orted by the data shown in Table X.3.

It is expected that the response to manuring increases when the supply of nutrients from the soil becomes limiting, i.e. on infertile soils, and when competition from other plants is heavy. Redmond (1953) showed that blood and bone could greatly accelerate the growth of <u>E.regnans</u> seedlings planted on unburnt soils subject to competition by bracken in Victoria. In his experiments three ounces of blood and bone per plant was most suitable. He tried up to 20 ounces per plant and found: the more manure the faster the growth, and the greater the damage by wallabies. The latter conclusion was not borne out by my experiments. (see Chapter XII).

H all (1961) also found that the addition of 4 ounces of blood and bone per plant accelerated the growth of E.regnans seedlings planted on bracken sites cleared by dozer.

The data shown in Table X.4 show that the relative response in height growth due to blood and bone increases as the severity of competition with other plants increases.

However, it must be concluded that, on the fertile soils of the Florentine Valley, the manuring of planted E.regnans seedlings with blood and bone does not produce any worthwhile improvement in growth, if there is no heavy competition from other plants, especially when the site has been burnt very recently.

IV. THE COMPETITION OF PLANTED E.REGNANS SEEDLINGS AGAINST FIREWEEDS AND FERNS.

B ecause of its advantage in ease of initial establishment a planted seedling may succeed where sowing would fail. The range of weed competition which permits sowing is being determined by a special study (Part D). Project 2 aims at defining the upper limit of weed competition tolerable for planting.

Plants of similar stature may compete for space, moisture, nutrients and light.

Photo No. 14 : Device for comparing light intensity under a weed canopy with that above the weed canopy. Weston meter reads light reflected from constant background.

(1) <u>Technique of Light Measurement</u>:

The proportion of daylight intercepted by the overhead canopy of weeds is some measure of the degree of competition suffered by a eucalypt planted amongst these weeds. There is no method of light measurement which gives an entirely satisfactory measure of the competition for light.

The absolute amount and quality of light received at a given point under a weed canopy varies greatly with seasonal changes in the plant canopy, with the angle of the sun, and with the type of cloud cover. A technique was here required which would give a realistic <u>relative</u> measurement of light intensities under various canopy conditions so that firstly other measurements and observations could be correlated with the relatively different degrees of weed competition and secondly so that later observers could recognize the various degrees of weed competition referred to by making light measurements in the prescribed manner.

In these studies a Weston Master III light meter was fixed above and facing a standard white portable reflector. (see Photo No.14) It was found that, in the absence of direct sunshine this method gave a repeatable measurement of the ratio of light intensity below to the light intensity above a given spot of a weed canopy. The reflector was white so that all wavelengths would be reflected and light intensity under dense ferns would give a significant reading on this type of meter.

Without a reflector, even if the meter had been sensitive enough, measurements would have been erratic because of the different backgrounds. Measurements during direct sunshine are extremely erratic because of the chance occurence in space and time of sun flecks. In this cloudy climate, measurement of percentage of full sky radiation should be a reasonable way of determining the degree of competition for light. If measurement during direct sunshine cannot be avoided, an opaque screen screen must be fixed to the side of the reflector so that direct sunshine does not fall on the reflector and the proportion of sky obscured is constant. The measurements of the light intensities below and above a point in the canopy of weeds should both be done in every instance and without interval so that variations in the intensity of daylight become unimportant.

In these studies the light intensities quoted were measured in autumn. Ferns and fireweeds are at their maximum density in summer and autumn.

(2) Competition for Space:

Eucalypts are notorioulsy bud shy. They will not form dense interlacing canopies. On seedbeds suitable for the natural regeneration of eucalypts, the eucalypt seedlings are not usually faced with the problem of having to grow through a dense canopy of weeds. With an equal start, the eucalypts usually outstrip their competitors in height growth. A seedling planted underneath a canopy of dense ferns or bracken faces an unusual problem. Injury to naked buds through rubbing against weeds is considered to be a minor problem here. In fact, E.regnans can grow through a roof of 1½" wire netting without serious harm.

A special problem exists in the case of dense ferns. Outside the protection of the tree canopy, i.e. on cut-over coupes, the fronds of the wet ferns die off completely every year in June - July. These fronds collapse very rapidly and form a fairly complete, dense covering over the ground by October, where there had been a dense standing canopy of ferns in the previous May. Eucalypt plants shorter than 2 or 3 feet are likely to be pushed over and covered up, especially when their stems are spindly through etiolation. The same problem exists under Pteridium, though to a lesser extent. Here the fronds do die off and collapse mainly in winter, especially after snow, but there is no wholesale death as with the very closely related species P. aquilinum in England. A few eucalypt seedlings have been seen to recover from such crushing and smothering. By springtime the crushed seedlings are in very poor condition, with part or all of their foliage and even their bark rotted off. The majority of such seedlings die.

The crushing habit of ferns may decrease the rate of survival of underplanted eucalypt seedlings, but must be regarded to be of secondary importance to competition for light. If open grown for one season, a eucalypt seedling would not be crushable by ferns. Moreover, many, probably most, eucalypt deaths under fern canopy are due to the more direct effect of etiolation.

It is concluded that lack of growing space is rarely the main cause of death or slow growth.

(3) Competition for Moisture:

Established stands of fern on good soils under high rainfall carry a very dense cover of fronds. The top six inches of soil are explored by a maze of rhizomes.

Of 200 seedlings planted amongst dense ferns on 3/12/58 and of 120 planted on 25/11/59 only 1 to 2% died from drought even though the soil was relatively dry, and facing still drier conditions at these times of planting. It is concluded that competition for moisture by dense ferns is rarely fatal even to a newly planted seedling. The effect on growth rate is not known.

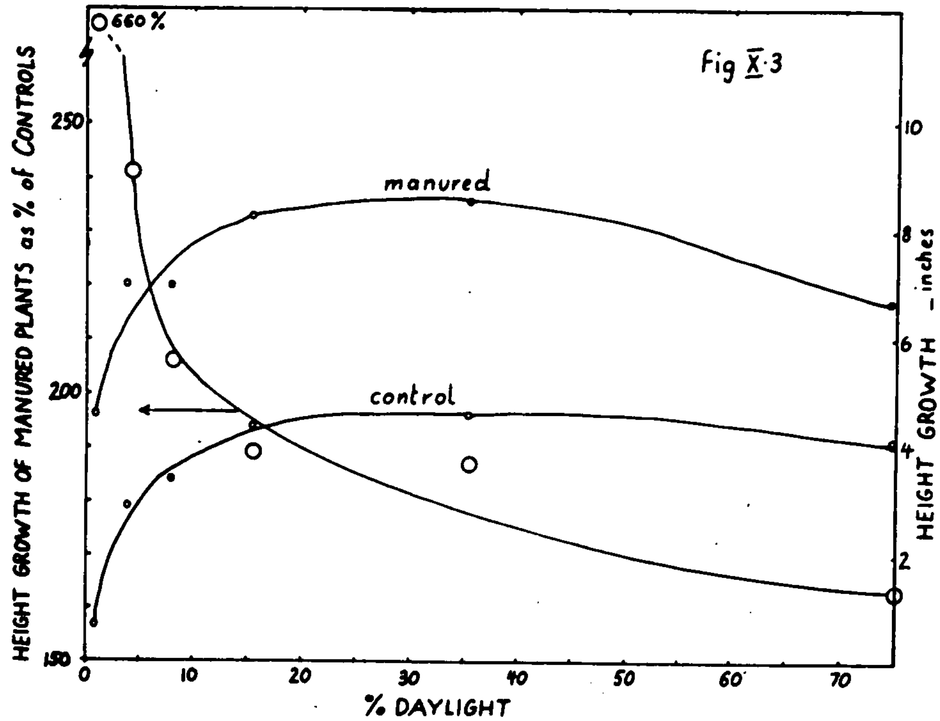


Figure X. 3 : Interaction of manuring and light intensity in affecting height growth of *E.regnans* planted amongst undisturbed weeds, based on table X. 4.

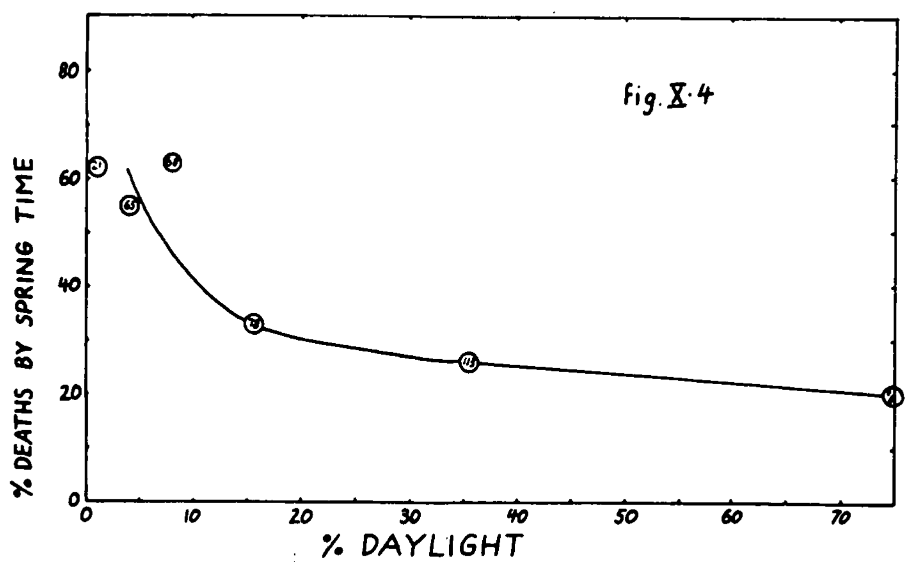


Figure X. 4 : Death rate of *E. regnans* planted on 12.12.58 under undisturbed weed canopies of various densities expressed as the percentage of daylight received below the canopy in April 1959. Half the seedlings were manured. Figures inside the circles indicate the number of plants contributing to the result. Scored in October 1959.

plants was about 4" at all light intensities. However, height growth dropped off rapidly at less than 10% of daylight. Consequently the four inches of growth at lower light intensities represented an increasingly greater percentage in growth acceleration due to manuring.

Between 0 and 10% daylight, 4 oz. of blood and bone produced regularly, and considerably better height growth than 2 oz. per plant.

These data indicate that the slow height growth of E.regnans seedlings due to heavy weed competition, can be considerably improved by the addition of blood and bone. This suggests that competition for nutrients may slow down the growth of E.regnans seedlings on soils which have not been recently burnt and are densely overgrown with weeds.

TABLE X.4

The interacting effects of light intensity and manuring (with blood and bone at 2 to 4 ounces per plant) on the height growth of E.regnans seedlings planted in December 1958 amongst undisturbed fireweeds and ferns.

% of full daylight recorded at the plant in April '59	UNMANURED		MANURED		Height growth of manured plants as % of controls
	No. of plants	mea n growth ± S.E.	No. of Plants	mean growth ± S.E.	
0 - 2	4	.70" ±.71	11	4.6" ±1.8	660%
3 - 5	30	2.8" ±.45	27	7.0" ±1.0	250%
6 -10	28	3.4" ±.80	35	7.0" ±0.90	206%
11-20	41	4.4 ±1.1	42	8.2" ±1.1	187%
21-50	55	4.4"±0.67	59	8.6" ±1.2	196%
51-100	58	4.3"±0.52	40	6.7" ±1.0	156%

(5) Competition for Light:

In this experiment, the height growth of E.regnans seedlings was not significantly affected by variations in light intensity above 5% of daylight. However, the plants in the shade were usually much less bulky than the plants in the open.

Below 20% daylight, and especially below 10%, most plants were badly etiolated even though pure height growth was still comparable to open grown plants. The effect of etiolation was reflected by the death rate after the first winter (Table X.5 and figure X.4). About 60% of plants at less than 10% light died, while the mortality of those in the open was only 20%. This difference would have been even greater if browsing, which is more severe on exposed plants, had been prevented. The mortality of planted seedlings inside the fence was only about 5%.

TABLE X.5

Death rate of E.regnans seedlings according to percentage of daylight received underneath the weed canopy during April 1959. Planted on 12/12/59. F^0, F^2, F^4 is manured at 0, 2, 4 ounces of blood and bone per plant.

% light	DEATH RATE By April 1959		By October 1959		
	F^0	F^2, F^4	F^0	F^2 F^4	F^0 F^2 F^4
0 - 2%	4/7=57%	2/11=18%	7/8=88%	6/13= 46%	62%
3 - 5%	6/29=17%	8/27=30%	26/33=79%	10/32=31%	55%
6 -10%	8/27=23%	3/35=9%	23/36=64%	20/32=63%	63%
11-20%	2/39=5%	2/40=5%	11/37=30%	15/41=37%	33%
21-50%	7/49=13%	3/59=5%	17/49=35%	12/64=19%	26%
51-100	4/49=8%	2/40=5%	10/52=19%	9/41=22%	20%
	12%	7%	44%	38%	

In fact, eucalypts are considered to be relatively very light demanding. Ashton (1957) showed that the compensation point (or need for light) of _E. regnans_ was higher than that of any species in its rain-forest and wet sclerophyll understoreys.

The following are characterisitc symptoms of etiolation in _E.regnans_: Internodes are commonly disproportionately long, are usually very slender and non-woody and bear small, thin, symmetrical, horizontally displayed pale green leaves. Lateral shoots, are absent, lateral buds absent or very weak, and even the terminal bud is very feeble.

Most severely etiolated plants did not survive their first winter, even though the fern canopy becomes lighter in winter. B y spring time the survivors are mostly more or less completely defoliated by the combined activities of "insects" and rot. Brown, soft-rotten leaves can be seen on the plant, and below it. Other leaves are partly or entirely missing, chewed down to the rachis, or even to the petiole. Often even the soft bark is partly chewed away. Plants thus defoliated will usually but not always die by summer. The "insects" responsible have not been seen.

Apparently, the primary cause of such deaths is the etiolation which makes the plant so vulnerable to attack by fungi and "insects" and to crushing by ferns. Both Ashton (1957) and Cunningham (1960) agree that it is lack of light which causes the failure of E.regnans to survive under a dense plant canopy.

Manuring apparently improved survival during summer but not during winter. The death rate of manured plants was not very different from that of unmanured plants even though the growth rate of manured plants was consistently better than the growth rate of unmanured plants.

Section (4) above showed that nutrients may limit the height growth of E.regnans seedlings planted amongst dense weeds. This section shows that competition for light limits the survival of E.regnans, and is hardly alleviated by reducing the competition for nutrients.

It is concluded that planting of E.regnans seedlings amongst undisturbed dense perennial weeds (particularly ferns) is not successful irrespective of whether the plants are manured or not. "Dense weeds" are those which allow less than 10% of daylight to pass through their canopy during the growing season. It can be assumed that shrubby vegetation is at least as forbidding as ferns when growing at similar densities.

V. THE EFFECT OF FROST

(1) Introduction:

Within its own natural range, the regeneration of *E.regnans* after logging can be severely hampered by frost.

On treeless flats and in gullies of the Wallaby Creek Plateau (2,000 - 2,300 ft. elevation) in S.E. Victoria, plantings of *E.regnans* have been partial to complete failures due to frost. Frost hollows have developed after removal and burning of portions of the old *E.regnans.* forest. Bad frost hollows are indicated by the existence of *Poa* grass without bracken. Temperatures down to 4°F have been recorded here; figures below 20°F occur frequently. (Redmond 1953).

Ashton (1957) has shown that temperatures as high as 27°F can kill *E.regnans* seedlings. He also showed that the killing temperature (or frost hardiness) varied greatly according to the hardening experience of the plant and also according to genotype. Trees from frost hollows and from higher altitudes produced hardier offspring.

Similar ecoclines in frost resistance were demonstrated for *E.pauciflora* (Pryor, 1956) and for *E.fastigata.* (B oden, 1958).

In general the destructiveness of frost on plants within their natural range is due to seasonal non-hardiness of plants (Levitt 1958) combined with the out-of-season occurence of exceptionally low temperatures. The latter is a feature of the microclimate (Geiger, 1950) of special situations such as frost hollows, where cold air accumulates.

(2) Occurrence of Frost Temperatures:

The Florentine Valley does not experience such extreme frost temperatures as the Wallaby Creek Plateau. Frosts may occur in any month of the year. In winter the screen minima at the A.N.M. Depot (see Fig.14) may drop to 20°F. Though the winter minima are lowest, it is the frosts in February-March and August-September which have been the most destructive during 1958 to 1960. In the frost hollow of "John Bull" (see figure 14) the lowest grass minimum recorded between May 1958 and March 1961 was 15°F. There were about 5 occasions during this time when the grass minimum dropped below 20°F. The grass minimum temperature at W56 did not drop below 22°F between 4/8/58 and 21/12/59.

General observation shows that some frost hollows do occur in the Florentine Valley, but suggests that they are not severe and are confined to Valley flats. In one case, (the bracken flat at the Road 11/Main Road junction), grass minima up to 10°F lower than on nearby slopes were recorded.

Judging from five sets of measurements by ten thermometers over various periods during June-July it appears that normal types of seed bed such as tractor tracks, charcoal, logging debris and mosses have little or no effect on "grass" minimum temperatures at six inches above the ground. Another few pairs of measurements showed that temperature amongst grass can sink considerably lower than temperatures one inch above bare ground and that deep grass lowers the temperature more than shallow grass. This line of investigation was not pursued because grass does not normally occur where E.regnans regeneration is wanted. Grass frosts can present a serious problem in the regeneration of some forests of E.delegatensis (Grose 1961).

To help explain observed patterns of frost damage a series of temperature measurements were made to determine temperature patterns between the ground surface and five feet height, with or without an intervening layer of bracken or grass.

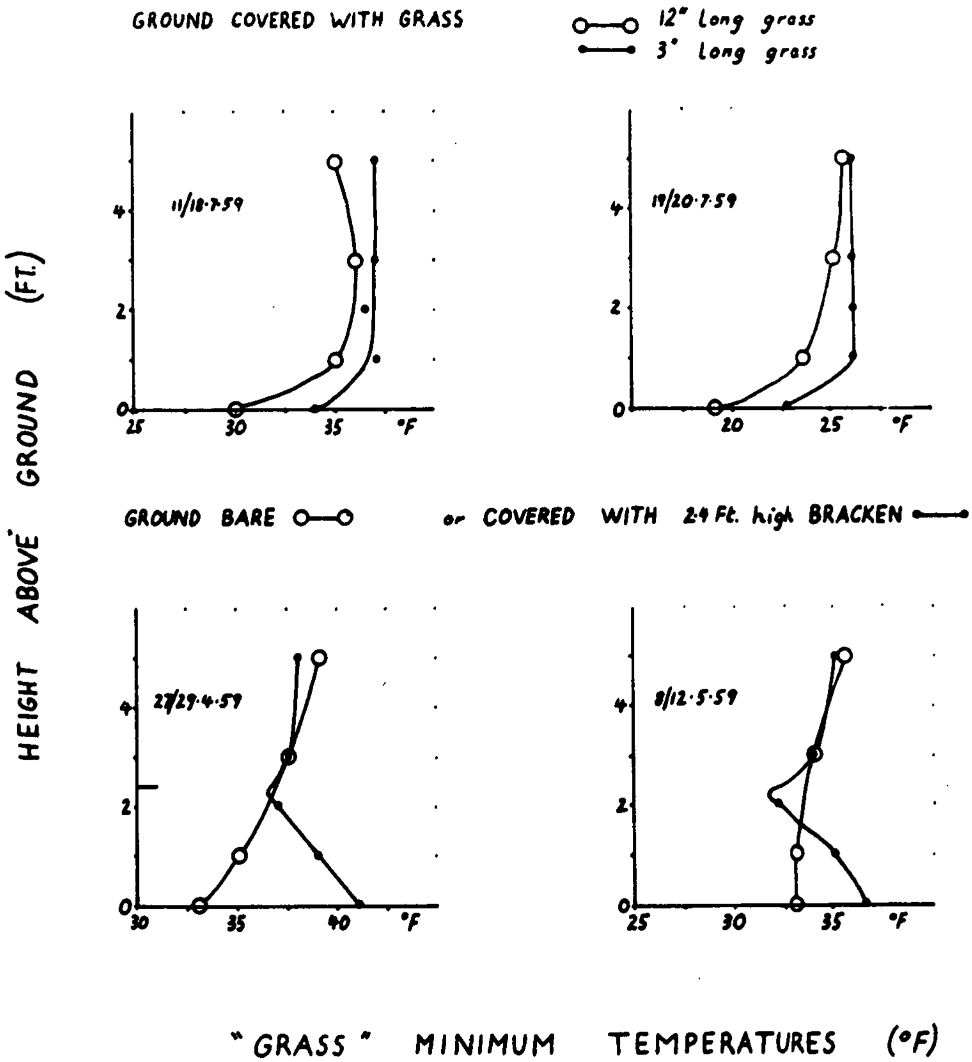


Figure X7. The pattern of "grass" minimum temperatures with increasing height above the ground, and the influence of long (12") and short (3") grass and bracken (2.4 ft) upon this pattern, under conditions of radiation frost. Each pair of curves is based on a simultaneous reading by 9 grass minimum thermometers suspended in the locations shown.

All the frost damage observed was the result of "radiation" frost. The temperature drop was mainly due to loss of heat by radiation rather than due to advection of cold air, though both must occur in frost hollows. "Radiation frosts" can occur only on clear wind still nights. They are most severe in frost hollows.

Two series of grass minimum thermometers were suspended at 3 inches, 1 ft., 2 ft., 3 ft. and 5 ft. above the ground during the winter of 1959 at John Bull, One series was over bare ground, the other series passed through a 2'5" high canopy of bracken. Thirteen sets of readings were taken over variable intervals. Another seven sets of readings were taken on a nearby grassy slope, with one series of thermometers above 1 ft. deep grass and the other series above 3" deep grass. By calibrating all thermometers against each other in cold water it was found that the readings of one had to be raised by 1°F to make them comparable to those of the other thermometers. An additional precaution was taken by shuffling thermometers between different positions.

Detailed results are not presented here. Figure X.7 shows typical patterns obtained after radiation frosts. Minimum temperature at 3" was in all cases 1.5 to 8°F higher under fern than over bare ground. In 10 out of 12 cases the minimum temperature over bare soil was lower at 3" than at 5 ft. (max. difference 6°F). The difference depends on radiation frost. The temperature at fern tip level was usually lower than below or above the fern canopy but not quite as low as 3" above bare ground in the open. It is concluded that the fern canopy protects the ground surface from loss of heat by radiation, and acts as a surface of radiation itself. The temperature at fern tip level was only slightly lower than at the same height in the open. The lowest temperatures occurred just above the radiation surface and increased most rapidly over the first 1 - 2 ft. of height. The gradient was steepest over grass, (because of its additional loss of heat by evaporation, perhaps).

(3) <u>The extent and Pattern of Frost Damage</u>:

Frost lift is dealt with in the chapter on sowing (Chapter XI). Only frost bite is discussed here. Frost bite is the killing of plant tissue during freezing temperatures. The seedling stage is the most sus-

Photo No. 11 : Frost damage on *E. regnans* seedling. Note that old leaves were more frost tender than young leaves. March 1960.

ceptible one because it suffers the lowest temperatures and is probably the least hardy.

(a) The Patterns of Frost Bite -

Frost bitten leaves become flaccid within a few hours. The killed portions dry out and turn pale red brown in two or three days.

Tender seedlings may be killed by frost directly, but woody seedlings are usually not killed directly. Woody seedlings may die slowly as a result of defoliation if the frost kills all the leaves (see defoliation experiment, Chapter XII). The effect of partial defoliation through frost bite on growth is probably not serious. Damaged plants often recover very rapidly.

(b) The Extent of Frost Damage -

Outside the John B ull frost hollow only one case of serious frost damage has been observed. This concerned the plantings made in winter 1958, viz 150 plants planted at L.9 on 6/7/58 and the 40 unbrowsed plants of the W56 planting made on 29/5/58. Apparently both lots of plants were still frost tender when transplanted from the warmer nursery.

In both cases over 60% of the plants suffered fairly heavy frost damage, though apparently no plant was killed directly. Plants manured with blood and bone did not exhibit more frost damage but did suffer a higher death rate (61%) by spring time than the controls (42%).

Frost damage was heavier on the good plants - i.e. those that showed signs of recent growth - than on the stagnant plants. Amongst the good stock, death ra te by spring time was highest amongst the frost bitten plants. Only 30 to 50% of these two plantings survived the winter. Most of the deaths were ascribed to poor stock, browsing and manuring.

The survivors of these plantings suffered very much less frost damage and no deaths during their second winter in the field. The plantings made at various times in the winter of 1959 were made with good, but dormant stock. Frost damage here was neglibible. Mortality was about 5% and not due to frost. Because of its conspicuous nature, frost damage can be seen frequently amongst natural regneration. However, extensive serious damage on natural seedlings more than 2-3 inches tall has not been noticed outside John Bull. On very small seedlings, frost bite cannot be identified so easily. Observations at Road 11 showed that exposed plants may suffer greater mortality in winter than partially sheltered plants. This may be due to frost.

In Tasmania the only real frost problem concerns nursery pra ctice. During the autumns of 1959 and 1960 thousands of tubed seedlings were killed by unexpected frosts in late summer, at John Bull. Nursery practice ca n promote lush growth at times when severe frost can occur.

(4) Observations on Frost Hardiness:

Some plants can respond to their environment by very large variations in frost hardiness. Frost hardiness is capacity to endure freezing temperatures.

The following points made by Levitt (1958) are of interest in connection with the observations recorded here.

(a) Plants are not hardy while they grow.

(b) U sually temperatures below 40°F are necessary for hardening.

(c) Etiolated, chlorotic plants are unable to harden.

(d) Nitrogenous fertilizers reduce frost hardiness.

(e) Any treatment retarding growth (e.g. undersupply of water) increases hardening.

(f) In evergreens, very young leaves are most sensitive, but young yet fully developed leaves are hardier than the older leaves.

(g) Hardiness usually increases with the age of the plant.

In 1958, 1959 and 1960 the most dramatic frost damage at John Bull occurred in February and March of each yea r. About half of the foliage on seedlings less than five feet tall was killed. The killing temperature was 17°F grass minimum in one case. Though the minima in the subsequent winters were lower the additional damage was comparatively negligible.

The only other dramatic frost kill during three years occurred in early August 1960. It was confined to seedlings on one particular bed which had favoured early commencement of growth. On all other beds there was little or no sign of recent growth and almost no frost damage. Recent growth is recognized by the shiny surface of the youngest leaves.

Absence of recent growth did not always combine with frost hardiness. In early March 1960, hundreds of tubed, stagnant seedlings were severely damaged while vigorously g rowing seedlings in an adjacent bed were almost untouched. Both types of seedlings were up to seven inches tall. Simultaneous grass minimum temperature readings by two thermometers during the following twelve months showed that the temperatures in the two environments must have been within 1°F of each other when the tubed seedlings were damaged.

It appears therefore, that vigorous seedlings of <u>E.regnans</u> are more hardy than poor seedlings. During winter dormancy, <u>E.regnans</u> seedlings are very much more hardy than during the growing season. Killing temperatures do occur during the growing season, but are almost confined to frost hollows.

In winter the non-glaucous leaves of <u>E.regnans</u> may become covered by a continuous 1 to 2 mm. thick layer of ice and suffer no damage. (Hoar frost consists of ice spicules; not a layer of ice).

(5) Conclusions:

Frost bite is not a serious problem in the Florentine Valley. T he only hazards are nursery and planting operations. Plants must not be exposed to unseasonal frosts, i.e. while they are actively growing. This means that overhead shelter must be provided in some nurseries during nights when radiation frosts are expected while the plants are frost tender. It also means that tender plants should not be transplanted into the field during winter. Most damage in the nursery is likely to occur in February-March. The most dangerous period for transplanting from the nursery into the field is probably autumn - April, May, June and perhaps spring time.

VI. OTHER MISCELLANEOUS FACTORS.

E.regnans seedlings cannot survive prolonged *flooding*. Floods are rare in areas with *E.regnans* forests and are in any case confined to valley flats.

Snow is also unimportant here, because it rarely lasts more than one or two days. Snow accelerates the collapse of ferns, therefore may contribute to the mortality of eucalypt seedlings under the ferns. Snow does annually cause some breakage of leaders and limbs of eucalypt saplings, especially where the stems have been weakened by a grub which tunnels in the living wood.

<u>Insects</u>, or some agency with a pattern of damage similar to insect damage, deal the death blow to many etiolated plants.

Most of the deaths observed amongst seedlings between 2 inches and 2 ft. tall and free from browsing and excessive weed competition were traced to ring-barking just below soil level. The typical frass at the ringbark suggests that some larva is responsible. Only 1 to 3% of all planted seedlings were affected in this way.

It is suspected that insects are responsible for the decapitation and consequent death of numerous cotyledon stage seedlings. (see Chapter XI). In most years, young, established seedlings of <u>E.regnans</u> in the Florentine Valley are remarkably free from insect pests compared with the sapling and tree stages. However, observations in the years 1960 and 1961 suggest that defoliating insects can occasionally cause considerable mortality amongst 1" - 6" tall <u>E.regnans</u> seedlings.

The top two or three feet of a sapling are sometimes defoliated. Complete defoliation and consequent deaths have not been observed. However, the defoliated top often dies back, thus resulting in a reduction of height growth. This "broom-Top" effect is sometimes observed in the majority of saplings on areas of several square miles.

C. EFFECTS OF PLANTING PRACTICE

I. TYPE OF PLANTING STOCK

The reproduction of eucalypts by vegetative means is often feasible for genetic purposes (Pryor, 1957; and Station de Recherches Forestier de Rabat 1957), but none of the techniques developed so far are cheap enough for the production of ordinary planting stock. Therefore seedlings must be raised from seed.

Eucalypt seedlings are much harder to transplant than most pines unless methods involving a minimum of injury to the root system are used. Ashton (1957) found that E.regnans seedlings at 4 to 6" height have a tap root 8 to 15" deep and laterals 3 -8" long. Methods of raising eucalypt planting stock therefore usually involve restriction of roots to shorter lenghts and provision for transferring the seedling together some or all of the soil it was raised in.

It is not possible to take advantage of wildlings which often occur in dense patches, and transfer them to understocked areas.

The main types of planting stock are:-

- Open rooted
- Root-balled
- Tubed or potted.

(1) Open rooted stock:

"Open rooted" means that the seedlings are raised in a bed and are transplanted without soil.

Methods of raising open-rooted eucalypt stock have been investigated elsewhe re. (Hall 1961).

The author made a small trial to explore the possibility of using "Root-stumps". This involved the lifting of seedlings without any special efforts to preserve the root system. The shoot was then severely pruned to compensate for the loss of roots. This was done on 18/9/58, i.e. at a time of the year when defoliation is least harmful (see Chapter XII). 50 "root-stumps" were planted immediately after lifting them from the nursery. Only half of these survived. Another 50 were stored in wet humus for four days before planting. All seedlings were planted with a handfull of wet humus about their roots. None of the roots were allowed to dry out between lifting and planting. Less than 1/4 of these plants survived. These poor results discouraged further investigation along this line.

(2) Root-balled stock:

This method involves the lifting and transplanting of a seedling together with an undisturbed ball of soil so that some of the fine roots are preserved and are spared exposure to air and the need of immediately re-establishing effective root-soil contact. The seedlings may be raised in a variety of ways to ensure profuse root development within a small root ball and to ensure cohesion of the soil of the root ball.

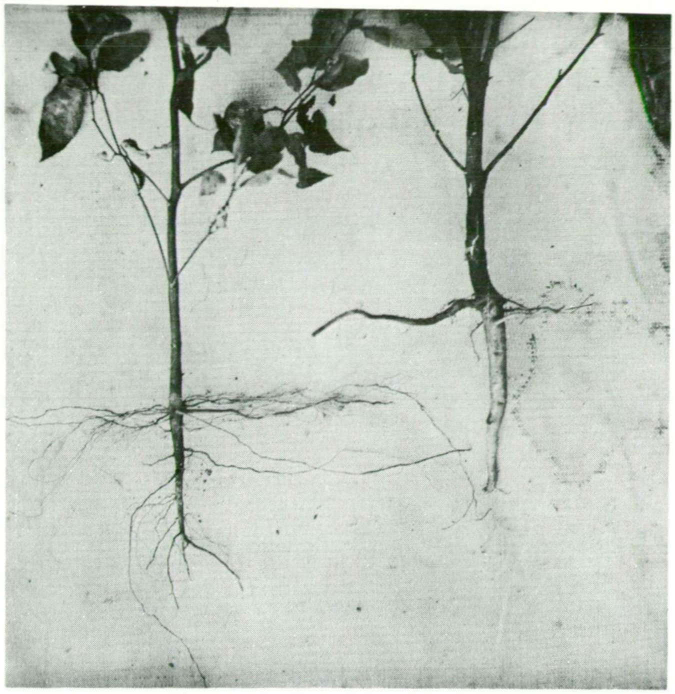
The author obtained 226 root-balled plants by chopping them out of a heavy, clayey nursery soil by means of an axe. There was no previous treatment. The root balls were trimmed to 2" x 2" x 2". The seedlings were 3 to 8" tall. 60 seedlings were replanted at John Bull on 10/9/58. 46 seedlings were planted at W56 on 16/9/58 after several days' storage. Another 120 were planted a t W56 on 10/10/58. The root balls were kept moist until planting. Cohesion of root-balls was excellent.

The survival of 94% was satisfactory. Height growth was normal.

(3) Potted or Tubed Stock:

For this type of planting stock the seedlings are raised singly in a container of soil. The container may be removed before planting (earthern-ware pots, sheet metal tubes) or planted with the seedling (peat pots, plywood tubes). The feature of all pots is that root growth is restricted to the transplantable soil.

Most eucalypt planting stock used in Australia is tubed. The tubes in these experiments were made of untreated Pinus radiata ply of 1/40 inch thickness. The tubes were 6" long, 1½" in diameter, made of two turns of ply, and open at both ends. Most of the seedlings were raised by Edwards' (1956) method (the tubes were sown directly, and watered at least in the early months by standing continuously in 1 - 2" of water). The rest of the tubes were planted with cotyledon or two-leaf stage seedlings. Most watering was from overhead. Hall (1961) and others have described methods of raising tubed eucalypt seedlings.



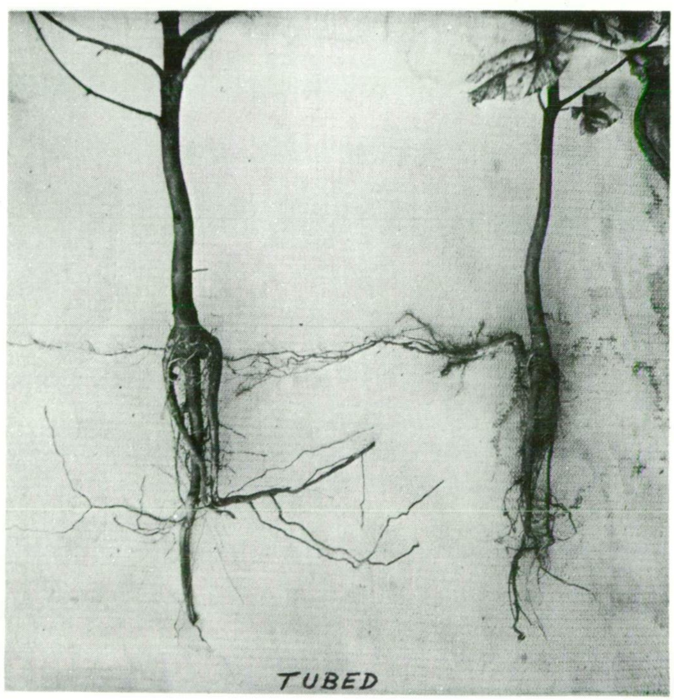


Photo No. 12 and 13 : Root growth of *E. regnans* with and without tubes 1½ years after planting. Note eagerness of laterals to grow horizontally at the earliest opportunity i.e. after emerging from the tube.

(a) The effect of tubing on root growth -

<u>E.regnans</u> seedlings have two clearly distinct types of main roots, viz the laterals and the sinker. U sually there is only one "sinker" root. The <u>sinker</u> is the prolongation of the stem, is sometimes even thicker than the stem, tends to grow vertically downwards, is the first developed root and usually the biggest root at least until the age of 2 years. The laterals are indefinite in number, usually between 3 and 12. The majority of laterals arise from the sinker within one inch of each other, forming a rosette from about half an inch below the root collar. In combination the laterals usually predominate the root system from an early age (half a year). The main laterals have an astounding tendency for horizontal growth. They are surface roots and will remain surface roots as long as possible. Meeting an obstacle they may turn at right angles when required in any direction, even upwards, and resume horizontal growth again if necessary at right angles, as soon as the opportunity arises. (see photos Nos. 12 and 13).

<u>In normal soils</u>, roots soon emerge from the tube and grow healthily. The sinker naturally continues its vertical downwards growth. The laterals may penetrate cracks in the tube if present, or else emerge by downwards, or even upwards growth if the tube is planted deep enough to be covered with half an inch or more of soil.

Restriction of laterals might lead to multiplication of sinkers. The stability of tubed plants is usually adequate though at first not quite as good as in normal plants with their laterals near the soil surface instead of below the tube.

When the soil immediately below the tube is puddled, root growth is obviously and seriously restricted. Some slender, blackened roots may emerge from the bottom of the tube. None of these are vigorous. If the walls of the tube are intact and protrude above the soil surface no healthy root can emerge from the tube and the seedling becomes stagnant. If the brim of the tube is buried, or if the walls have cracks, some laterals may emerge and take advantage of any ameliorated surface soil that may be present or will eventually develop. The presence of the tube may therefore help to induce or prolong stagnation of a seedling planted in puddled soil. Nearly all tractor tracks remain puddled for years. They amount to about 20% of a coupe's area.

(b) The effect of tubing on survival and height growth -

Tubed stock is the most reliable and successful type of planting stock. The 96% survival after one year of tubed seedlings planted in spring '58 at W56 can hardly be bettered.

TABLE X.6

The growth of tubed stock planted by dibble compared with the growth of seedlings from broadcast and spot sowings after these had achieved a height equal to that of the planted seedlings.
All plants were unmanured and on not puddled soil.

Type of Plants	Experiment (W56)	Height on 1st Nov.	Height Growth by 8th March
Tubed	Spring '58	5.7"	8.8"
	Autumn '59	3.7"	10.2"
Broadcast sown	Autumn '58	6.0"	13.0"
	Spring '58	7.7"	7.3"
	Autumn '59	5.2"	2.3" x
Spot sown	Autumn '58	6.2"	10.8"
	Spring '58	7.5"	15.2"
	Autumn '59	1.0"	12.5" x

x Note that the autumn '59 broadcast sowings were retarded by severe weed competition but that the spot sowings of the same date did very well. This is ascribed to weed competition.

It is likely that tubes will retard the growth of planted seedlings if the roots can emerge only through the bottom of the tube and if the soil at this depth is not suitable for eucalypts.

Raeder-Roitsch (1958) reports that some eucalypt seedlings were retarded in growth by tubing even when the tube was removed before planting the seedling in the field. Nevertheless, table X.6 shows that the planted seedlings suffered little or no set-back due to being tubed and planted by dibble. The height growth of the sown seedlings was based on the tallest seedling per sample plot or spot. Since the height growth of dominants is better than the average, their comparison with all of the planted seedlings is less than fair to the planted seedlings.

(4) Tubed versus root-balled stock:

Table X.7 shows that early growth rate of tubed plants planted at the same time was a little faster than that of root-balled stock. The table also shows that root-balled stock which started off about eight inches tall achieved a greater height in one growing season than stock which started off at three inches, even though the taller stock did die back a little at first.

TABLE X.7

Initial Growth Rates of Tubed Compared with Root-balled stock. Only unmanured seedlings on unpuddled soils are included here.

Type of Stock	No. of seed-ings	Date planted	Planting height	Height in-crease by 9.4.59
Tubed	19	10.10.58	4.2"	15.3"
	16	10.10.58	5.3"	12.9"
Root balled	36	10.10.58	2.3"	8.8"
	41	18. 9.58	4.4"	9.8"
Plants above 5"	12	18. 9.58	7.7"	9.6"
" below 6"	29	18. 9.58	3.1"	9.8"

Tubed stock is easy to plant and reliable in its survival. Root-balled stock should be much cheaper to raise, but may with lower survival and higher cost of planting work out at the same price per seedling established in the field.

9 However, it should be useful insurance policy to have a bed of a hundred thousand plants suitable for use as root-balled stock at all times. This would cost very little and would supply urgently needed planting stock if the tubed stock should fail in any one year, or if there is not enough due to unforseen demand.

II. CONDITION OF THE PLANTING STOCK

The two conditions investigated were, firstly the effect of the tallness of the seedlings when they leave the nursery, and secondly the effect of stagnation contracted by the stock while in the nursery.

(1) Effect of the Initial Height of the Planting Stock:

(a) Survival -

Of the approximately 1,000 seedlings planted under freedom from browsing and excessive weed competition only so few died (5%) that an analysis for the effect of initial height upon survival was neither possible nor necessary. All plants which were 1 to 24" tall when planted survived well. The main cause of death was ringbarking at the rootcollar by an insect larva.

In the presence of browsing the bulkier seedling has an advantage because it is less easily defoliated completely. Amongst weeds, tall planting stock is probably superior to short planting stock. Drought is rarely if ever serious enough to favour small planting stock.

(b) Height Growth -

Is the rate of growth of a seedling while still in the nursery any indication of its rate of growth after planting in the field?

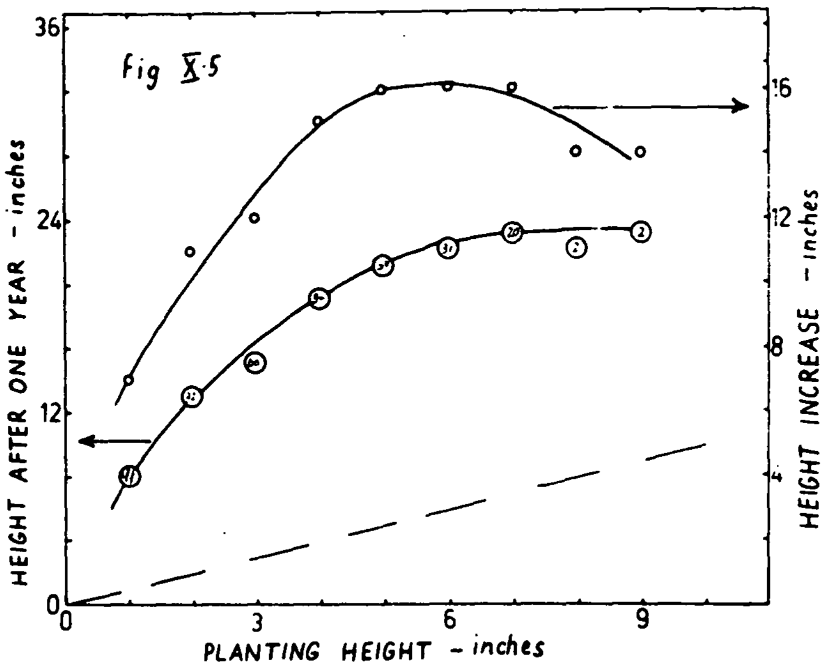


Figure X5 : The relationship between height of tubed planting stock and the first season's growth in the field. Plants not browsed, in not puddled soils, planted in spring '58 and autumn '59; half were manured. The figures inside the circles indicate the number of plants contributing to the result.

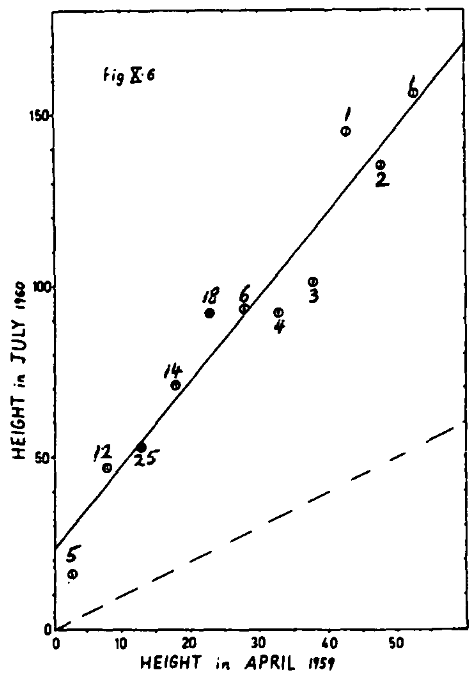


Figure X6. The relation between growth in the first year and growth in the second year after planting. Based on W69, W43, and W72 plantings none of which were fenced and half of which were manured. Figures in circles indicate number of plants contributing to the result. Completely defoliated plants are not included here.

The Tasmanian Forestry Commission has found that this is true to some extent in the case of _Pinus radiata_.

In these experiments various uniformly raised and trea ted batches of tubed _E. regnans_ plants were analysed for height growth according to their height when planted.

The results were summ arised in figure X.5 and by the following conclusions:

Planted seedlings of originally ~~of~~ the same height grew into a wide range of heights within the first growing season, varying from nought to fifteen times their original height. Nevertheless, a trend was apparent. T here was a fairly regular improvement in growth rate during the first year with increasing height of planting stock over the range of one to six inches. One inch tall stock was decidedly poorer than taller stock. Seedlings which were taller than 6 inches (200 seedling) grew at very irregular rates but were (on the average) not superior.

Less than one hundred seedlings were available to study height achieved after two growing seasons in terms of planted height. The few figures available showed that the original one inch stock was still decidedly the shortest, but otherwise planting height had very little effect on height after two years.

Different batches of planting stock which owed their height differences largely to nursery treatment conformed to the same pattern. Plants much taller than six inches tended to suffer from stagnation during the first growing season. For this reason, the 15" stock was no taller than the 5" stock after one year in the field. Redmond (1953) reports that 13" stock was superior to 5" stock for planting amongst tall bracken.

A different analysis showed that height growth during the first growing season in the field is a very much better indicator of subsequent growth. Figure X.6 is a summary of this analysis.

It is concluded that only the very shortest stock (1") might be worth discarding before planting.

(2) <u>Stagnation caused in the Nursery</u>:

<u>Symptoms</u>

A plant is here called stagnant if it shows very little or no growth during the growing season provided water and light are adequate. A stagnant plant can be recognized by its pale green or purplish, undersized foliage, and by a lack of expanding buds. These symptoms are similar to those developed by plantings in puddled soils and by natural seedlings on exposed roadside cuttings. In the latter case the appearance is more blotchy, and the symptoms disappear during summer.

Occurrence

Stagnation very commonly occurs at the cotyledon and early two-lea f stages. It may also occur at later stages. Sta gnation in the nursery can be a major problem. Most of the 200,000 tubed plants raised by the local nursery during 1959 and 1960 became stagnant. Many of them at a stage too small for planting out.

In the field, planted stock does not become stagnant except in puddled soils. In fa ct moderatly stagnant stock resumes active growth and normal symptoms within two growing season months after being planted in burnt or lightly disturbed soil.

Sown seedlings on puddled soil usually stagnate at or very soon after the cotyledon stage. Sometimes there is widespread stagnation of very young seedlings even on freshly burnt soil.

A number of observations suggest that if a seedling is forced to overwinter at the cotyledon stage (e.g. from a late autumn germination) it is likely to grow more slowly in the following growing season than seedlings which germinated at the beginning of that growing season. Nearly all germinations from the autumn '58 broadcast sowing at W56 appeared before midwinter. Nevertheless the spring sowing later in 1958 overtook the autumn sowings in height growth within one growing season - see Chapter XI.

Causes.

Stagnation occurs under a variety of circumstances. Its causes are usually unknown. General observation and successful remedies which have been found suggest that there may be different causes in different cases. In puddled soils it is probably the lack of aeration or perhaps the toxic products of anaerobic decomposition which causes stagnation. Conditions are similar when seedlings are waterlogged by standing water. Excessively high temperatures may apparently stagnate very young seedlings. Perhaps the looseness of the soil in some tubes is related to stagnation. It is very likely that stagnation can be caused by nutrient deficiencies, either because of the poverty of the soil, or because of the inability of the plant to make use of the nutrients. It is easily conceivable that a six to twenty-four inches tall seedling can exhaust the small volume of soil in the tube and that daily watering from overhead can leach the soil excessively.

The symptoms of stagnation described above are commonly associated with nitrogen deficiency in the literature.

Baur (1959) blames the lack of mycorrhiza for the development of similar symptoms of stagnation by E.grandis when raised on pure rainforest soil. In one experiment at Maydena, the addition of top soil from the

E.regnans forest did not cure the stagnation of 200 seedlings treated at the nursery.

Remedies

The following empirical remedies may elucidate the causes:

(i) Transplanting of moderately sta gnant stock into the field usually relieves stagnation in one to two growing season months. Superficial application of blood and bone only slightly accelerates the end of stagnation. The plantings made between 17/5/59 and 2/10/59 (179 moderately stagnant plants) were scored for leaf colour. Most lea ves turned green by 11/11/59. In recovering, the original reddish or pale green leaves turned dark green and increased to normal size.

(ii) Several thousand very small stagnant tubed seedlings were planted in the spring of 1961 in a nursery bed of good soil where they commenced very vigorous growth within a few weeks.

(iii) Seedlings in puddled soil recover from stagnation when some roots reach ameliorated surface soil.

(iv) Ashton (1957) reports that he manured tubed seedlings in the nursery to prevent them from turning red.

(v) Hall)pers. comm). says that tubed nursery stock can be weeded by applying sodium nitrate, and that subsequent watering (once or more) with one ounce of ammonium sulphate per gallon of water can cure "stagnation".

(vi) The author had 200 tubed plants which had been stagnating in the nursery at 3"-6" height for a whole year. These plants were split up randomly into four equal lots and treated as follows in January 1950:

- no treatment, watering only,
- watered once every week for six weeks with a solution of E.D.T.A. plus nutrients
- watered twice at monthly interval with nutrients only
- watered twice at monthly interval with E.D.T.A. only.

All plants stood in trays which contained a 1-2" depth of water.

The controls continued to stagnate. All other treatments resulted in good growth, in larger, dark green leaves, and in the formation of vigorous buds on all the plants treated. "E.D.T.A. plus nutrients" resulted in the most spectacular growth, namely 12-18" in three months.

The two other treatments did not differ from each other after three months and grew about 6 inches each. The "E.D.T.A. only" treatment responded a little earlier than the "nutrients only" treatment.

E.D.T.A. (Ethylenediaminotetra acetic acid, disodium salt) is a sequestering agent. It was presented in a mixture with Fe ions. It may have acted by making cations more readily available to the seedlings. The Fe was not included in the nutrient solution which consisted of an otherwise complete set of macro and micronutrients.

(vii) A different commercial set of plant ntrients without E.D.T.A. applied several times by overhead watering failed to have much effect on several thousand stagnant plants at the A.N.M. nursery.

III. METHODS OF PLANTING

The best method of planting for any one case depends on the type of stock (tubed, open-rooted etc)., on the topography and the accessibility of the site to machinery, and on the type of soil. In the Florentine Valley, the use of planting machines is usually impossible because of all the stumps, fallen tree trunks, and often, because of rock. The many stones and roots make the use of a spade very difficult. The same reasons combined with the clayey nature of the soil make the use of the cylindrical spade impossible. Usually either the mattock or the dibble will be the best tool to use for planting.

THE MATTOCK:

The mattock is most versatile. It can be taken anywhere, can be used with any type of planting stock, and is suitable for stony soils as well as soft soils, and for open sites as well as sites overgrown with weeds. It is however, the most laborious tool. There is no objection to planting by mattock from the point of view of the plant. The soil is cultivated thus improving tilth, and reducing root competition. Freshly cultivated soil as such has no attraction to the browsing animals encountered here (Mollison 1959). This is contrary to the experience with eucalypt plantings in Victoria, (Rolland and Heisler, pers. comm).

THE DIBBLE:

The author designed and tested a dibble as a more versatile alternative to the cylindrical spade for the planting of tubed stock. The dibble can be used under all conditions except in very loose or very compacted soils. Instead of removing a core of soil this tool punches a hole of just the right size for the tube. Because of its point it can avoid or push aside roots and stones.

This is a great advantage in the Florentine Valley where holes are often hard to make by mattock or spade, and then even harder to fill up for lack of soil. Unlike planting by mattock, where there is a tendency not to bury the tubes deep engough, the dibble does make deep planting easy. Planting by dibble, especially under difficult conditions, is very much easier than with the mattock.

A crow bar with a diamater smaller than the tube is objectionable because of the very deep hour-glass shaped hole it makes to admit the tube.

The dibble will tend to compact the soil around the tube and leave a hole below the tube. These objections are serious where the soil is already puddled or compacted as on tractor tracks. On the loose soils which are normal in good forest compaction by dibbling could hardly have a serious effect, and the potential cavity benea th the tube is filled up by soil scraped off the sides of the dibble hole as the tube is pushed down.

Nearly all of the author's plantings were made with the dibble. The comparison in Table X.6 shows that the height growth of planted seedlings did not suffer any significant harm due to the presence of the tube nor due to the fact that the seedling was planted by dibble.

IV. TIME OF PLANTING

In the Florentine Valley stock can usually be planted with reasonable success throughout the year, except possibly during the very dryest month (about February) provided that there is protection from browsing and provided that the stock is hardy when frosts are expected, and provided that shading by weeds is not excessive. The criteria for the best time of planting are survival and early height growth. While the time of planting is not critical if the above provisoes are obtained, an optimum time can be decided from the evidence presented below, especially if, as is usually the case, the provisoes are not fully obtained.

Survival -

In the absence of dangerous browsing, of untimely frost tenderness and of shade, the survival after the first year was above 90% irrespective of planting time, as is shown by Table X.11.

TABLE X.11

First year Survival of Tubed Stock, frost hardy in winter, protected from browsing, and free from excessive weed competition.

Experiment	Date of Planting	No. of Plants	% deaths
Spring '58	10.10.58	115	8%
Project 2	3.12.58	410	6%
Project 2	25.11.59	120	5-10%
Autumn '59	4. 3.59	150	2%
Autumn '59	13. 3.59	84	6%
Autumn '59	18. 5.59	50	6%
Autumn '59	15. 7.59	80	3%
Autumn '59	2.10.59	55	0%

(1) The Influence of Browsing:

Browsing can be lethal to eucalypt seedlings if these are uprooted (1-2" high plants) or completely defoliated (1" to 24" tall plants). The latter event is much more common. It is lethal to most plants if the defoliation occurs durimg February to June - see Chapter XII. The survivors' growth is seriously checked. Defoliation is relatively harmless at other times of the yea r. In the absence of precise knowledge on seasonal variation in the intensity of browsing attack on eucalypts the period February to June must be regarded as the season of greatest danger from browsing.

The bulkier a seedling the less likely it is to be completely defoliated. Even at 12" height a seedling enjoys considerable security if it has several branches.

The great superiority of spring planting as against autumn planting <u>without</u> browsing control is illustrated in Table X.12. The two plantings were on similar sites within three chains of each other and were both browsed most severely during March to July 1959. In addition to their very much higher mortality during the first winter, the seedlings which were planted in autumn were so much retarded in growth as a result of defoliation that they remained vulnerable for at least another year, while the seedlings which were planted in spring grew well beyond vulnerability during the second growing season.

<u>TABLE X.12</u> Comparison of Spring Versus Autumn Planting in Terms of Survival from Browsing.

Date of Planting	17/10/58	13/3/59
No. of plants	60	100
incidence of severe browsing		
age of plants	5-7 months	0-3 months
% severely browsed	68%	89%
height of plants when planted	3.5"(slender)	9"(slender)
when browsed	15.7"(bulky)	9"(slender)
mortality - after 1st winter	13%	54%
after 2nd winter	0%	10%
Total	13%	64%

Note: All but 2-6% of the deaths were due to browsing.

The mortality of seedlings planted in Autumn '58 and exposed to browsing was equally striking. Of the 360 plants planted on 9/6/58, and severely browsed before planting, only 4% survived the first winter.

On 16/3/59 Newman planted some tubed stock at S11. Fourty-nine numbered plants at a spacing of 25x25 ft. were kept under observation by the author. In spite of some control of browsing through poisoning, 92% of all browsable plants were severely browsed by 1/7/59. Consequently the death rate by 22/10/59 was high (31%). Only 56% of the planted seedlings survived till 19/5/60. Only one plant was browsed then. Thereafter there were no more deaths or browsing attack by 3/4/61. The survivors on burnt seedbeds had become established after two years. Survival on tracks was excellent, but nearly all plants were still stagnant near their original height.

In the absence of browsing control, and if control is less than perfect (it always is) it is therefore, advisable to avoid planting seedlings during February to June and to aim at planting at such a time ahead of the danger period that the seedlings have a chance to grow bulky before then. The beginning of the growing season, namely September, is then the best time for planting to avoid the danger from browsing.

(2) <u>The Influence of Frost</u>:

Only hardy stock should be planted out when hardiness is required. This means the beginning and end of winter should not be used for planting unless the seedlings from the sheltered nursery are hardened off first.

When the periods of defoliation danger and likely frost bite coincide (autumn) the danger is in-creased Frost need not kill a plant directly but can entirely defoliate it and thus cause its death indirectly.

(3) <u>The Influence of Weed Competition for Light</u>:

Table X.13 shows that winter is the time of highest mortality amongst plants under heavy competition with weeds, particularly ferns. Mortality may be ascribed to etiolation and to smothering by the ferns which collapse in winter. The dense shade and low temperatures during winter combine to depress the rate of photosynthesis. This rate is further depressed by the continuous film of water on the non-waxy leaves of *E.regnans* which is likely to be maintained during most of the winter under dense weeds, (Thomas pers. comm.) because of the slow rate of evaporation.

TABLE X.13

Comparison of Summer Versus Winter Mortality amongst E.regnans seedlings planted on 4/12/58 amongst Undisturbed Dense Ferns on Various Coup es Unprotected from Browsing.

Coupe No.	No. of Plants	Mortality (% or original No. Planted)		
		3/12/58 - 16/4/59 first summer	17/4/59 - 25.10.59 first winter	26/10/59 - 14/6/60 second summer
TS3	36	36	56	8
TS2	38	10	47	10
W4	39	15	23	15
W18	30	3	43	20
W23	40	20	40	2
W23	37	27	33	11
Road 10	38	13	71	3
Road 11	40	10	30	28
Total	298	12%	43%	12%

Note that browsing contributed about one third of the above mortalities. Most plants escaped serious browsing because they were hidden amongst dense weeds.

Table X.13 shows that planting in December amongst very dense undisturbed weeds is unsatisfactory. The high mortality during winter suggests that planting in autumn or early winter would have been even much less successful because the plants would then have had no chance at all to become sturdy before the hazards of winter became serious.

Note that the "dense weeds" here refers to wet ferns and bracken. Shrub thickets are at least as difficult as dense ferns. None of the plantings made amongst fireweeds died from competition.

Where weeds are dense, it would certainly appear advisable to plant at such a time that plants have a chance to become sturdy, before winter. Planting at the beginning of the growing season (September) is therefore best for overcoming weed comp etition.

(4) <u>The Influence of the Dormant Season:</u>

H eight growth during June to September is almost nil. Seedlings planted during this dormant season do not commence height growth before the advent of the growing season. If root growth during the dormant period is also nil, overwintering in the field will not only fail to benefit growth but will needlessly expose the seedling to its greatest survival hazard. (browsing, frost, etiolation in winter).

The data presented in Table X.14 confirm that seedlings planted earlier in the dormant season do not benefit by the extra 4 to 5 months in the field.

TABLE X.14

Comparison of Height Growth by Seedlings Planted at Different Times During the Dormant Season. Only Unbrowsed, Unmanured Seedlings on Burnt soil are Included Here.

Date of planting	Height when planted	Months Since Planting	Height Growth by 7/3/60
2/10/59	3.5"	5	9.8"
15/7/59	4.3"	7½	5.7"
18/4/59	3.7"	9½	9.8"
13/3/59	5.7"	12	16.0" (a)

(a) Note that the seedlings planted in March were not stagnant, while all others were moderately stagnant at the time of planting.

The March planting benefited by some growth before the dormant season, and probably by the fact that the planting stock used then was not stagnant at the time of planting. The lower growth rate by the midwinter planting might be significant. Any injury sustained at this dormant time could take a long time to heal and may expose the plant to infections.

It is concluded, that planting during the dormant season does not benefit growth rate, but increases the threat to survival compared with planting at the beginning of the growing season.

(5) Conclusion:

For planting in early and late winter (about June and September) planting stock must be hardened off beforehand. With protection from browsing and in the absence of serious weed competition, tubed plantings are successful at any time of the year except perhaps during the driest months of unusually dry years.

With planting stock that is more easily injured (root-balled and open-rooted), planting during the dormant season should probably be avoided.

The less perfect the freedom from browsing and from serious weed competition the more important it is to avoid planting between February and August and to aim at planting during September to November.

D. THE PROBLEM OF OLD UNDERSTOCKED COUPES

There have been and always will be areas where initial regeneration measures, natural or artificial, failed to produce satisfactory stocking. If the understocking is not recognized until after broadcast or spot sowing have become impossible, planting is the only hope of rectifying the deficiency without major site preparation.

For the purpose of planting, the following stages in the early secondary succession on logged coupes may be recognized. (see also Part D).

The fireweed stage. This is dominated by mosses on the ground layer, and by the biennial *Erechthites* in the aerial layer.

The wet fern sta ge. This stage is dominated by *Histiopteris* and *Hypolenis*. When well established there is no live ground cover under the ferns. This stage begins at age 3 to 5 years after burning.

The dry fern or *bracken stage*. This is usually dominated by *Pteridium*, often to the virtual exclusion of all live ground cover. This stage begins. between age 2 and 10 years depending on the vegetation, previous to the burn.

The shrub thicket stage. This is usually dominated by *Pomaderris*, *Acacia* or *Zieria*. Its advent is delayed or prevented by browsing unless the relatively unpalatable *Zieria* is abundant. It may begin at the age of 3 years. Where well established, it does not permit the survival of a ground cover beneath it.

Table X.15 sets out the rate of survival of *E.regnans* seedlings two years after planting in Project 2 Part I.

71% of seedlings planted at the fireweed stage have survived. Most of the deaths were due to browsing, none were due to weed competition.

The survival of 33% amongst wet ferns on coupes aged 3 to 8 years was not satisfactory. Some of the deaths were due to browsing; most were primarily due to suppression.

TABLE X. 15

Survival on 9/11/60 of tubed *E.regnans* stock planted on 12/12/58 amongst various types of uhdisturbed weeds on various coupes.

Coupe No.	No. of plants planted	% survival after 2 years
Fireweed stage		Average 71%
W72	99	86%
W69	40	50%
W38	40	35%
W43	40	93%
Wet fern sta ge		Average 33%
W34	40	53%
W23R	40	22%
W23L	40	35%
W18	40	33%
W 4	40	42%
TS2	40	20%
TS3	40	28%
Bracken Stage		Average 9%
Road 10	40	5%
Road 11	40	12%
L 9	150	47%

The survival of 9% amongst bra cken was extremely poor.

Whereas nearly all of the survivors in the first group (fireweeds) had become est ablished two years after planting mortality will continue at a high rate in the other two groups.

The seedlings at L9 were planted amongst a fairly sparse four year old (4-8ft) stand of Acacia. Most of the deaths here were due to frost, excessive manuring and due to the poor condition of the planting stock. Thickets with as little living ground cover as under dense ferns have not been tested. Seedlings planted amongst shrubs have not only the task of survival, but must also overtake their much taller competitors which are capable of relatively unlimited height growth. Thickets are considered to be unplantable without clearing.

Table X.16 indicates that the reduction of competition with dense ferns by cultivating a small spot did not improve the survival of planted seedlings.

The radius of the cultivated spot was equal to about half the height of the wet ferns, and one fifth of that of bracken. The cultivated soil did not carry any fronds until the second year. Nevertheless the ferns at the edge leant inwards with the effect that clearing amongst the tall bracken gave almost no improvement in light conditions. B ut clearing the shorter wet ferns was a little more effective.

The advantage of improved lighting was nullified by increased browsing attack on the seedlings which were made conspicuous and accessible by cultivation. Cultivation or weeding must therefore be accompanied by the control of browsing if any benefits are to be obtained.

TABLE X.16 The effect of Cultivation on the Survival of E.regnans planted amongst dense ferns (TS3, W23) or dense bracken (Rd.11).

Fourty tubed seedlings were planted on each area, for each of the two treatments. The Cultivation destroyed all rhizomes on a patch 2 ft. x 2 ft. in area and 6 inches in depth.

method of planting:	by dibble only				after cultivat.			
date of planting:	12.12.58				25.11.59			
date of scoring:	14.6.60				2.11.60			
area	TS3	W23	RD.11	Mean	TS3	W23	RD11	Mean
% of plants with less than 11% of daylight. x	38	63	28	42	10	35	30	26
% of plants severely browsed	45	25	8	26	33	65	13	37
% survival	40	40	63	48	28	43	80	50

x Measured in April.

The cutting of weeds at intervals subsequent to planting is often standard practice elsewhere. This practice is very difficult on old coupes in the Florentine Valley because the plants are very hard to find again because of the fast growth of weeds, and because of the wide, and necessarily irregular spacing. Liberation cuttings should be useful perhaps twice during each of the first two growing seasons after planting, say in December just before the new crop of ferns is fully developed and in March/April, at the end of the growing season. When the liberating is done with this frequency, the planted seedlings are probably found again more easily.

Conclusions:

Eucalypts are very light demanding and cannot develop under a weed canopy that is so dense that practically nothing grows underneath it. Nearly all of the ground under dense shrub thickets, dense wet ferns and dense bracken is bare of live ground cover. The presence on the ground of significant amounts of light demanding mosses (*Funaria*, *Ceratodon*, *Polytrichum*) or herbs and grasses is probably a good alternative to light measurement as a guide to the plantability of a site.

Eucalypt seedlings should not be planted in spots which receive less than 20% of daylight.

If the planting is decided on within five years of the regenerating burn, it should be possible to find enough open patches on most understocked coupes to place the supplementary plants so that they have a reasonable chance of success without special treatments. However, some old coupes will be difficult, and the adoption of the following measures in combination should be useful:

1. cut down the woody growth, if and where necessary.
2. clear the ferns or bracken (and cultivate to destroy the rhizomes) on small patches.
3. plant with a mattock, and use 4 ounces of blood and bone.
4. prevent browsing until the plants are established. i.e. for one or two years.

Alternatively, existing regeneration may have to be sacrificed and the whole area cleared by fire or by bulldozer.

E. SUMMARY AND CONCLUSIONS FOR CHAPTER X.

In Tasmania the growing season for E.regnans lasts only 6 or 7 months. There is almost no growth between April and October.

Planted seedlings grow about one foot in the first year, and three to four feet per year thereafter.

There is little advantage in lightly burnt over unburnt soil. Manuring with blood and bone does not greatly accelerate height growth within three years of planting. Growth in puddled soils (tractor tracks) is severely restricted.

On puddled soils manuring is likely to make all the difference between stagnation and normal growth.

E.regnans seedlings planted amongst undisturbed dense weeds (particularly ferns) suffer heavily from the competition. The collapse of the ferns during winter tends to bury the etiolated seedlings, usually with fatal results. The relatively very great response to manuring shows that competition for nutrients amongst ferns is keen. The mortality at less than 10% daylight is very high irrespective of manuring. This suggests that light is the more limiting factor amongst dense ferns. Deaths due to drought are rare.

Frost bite in Tasmania is a hazard only in nursery and planting operations. While they are actively growing, plants should be protected from unseasonal frosts. This means that overhead shelter should be provided in some nurseries at nights when radiation frosts are expected during the growing season. It also means that tender plants should be hardened off by exposure before transplanting into the field in autumn and spring.

Flooding, snow and insects are only minor problems with seedlings of plantable size.

Root-balled stock has been tried with success and should be a useful means of supplementing tubed or potted stock in emergencies.

The restriction of tubing on rootgrowth is serious only when planting in puddled soils. Over 90% of both tubed and root-balled stock planted in the field became established and grew normally.

Tubed planting stock which is only one inch tall is decidedly slower in growth over the first two yea rs in the field than taller stock from the same batch. Apart from this, the initial height of the planted seedlings had little effect on subsequent development in the field.

Stagnation can be a very serious problem in the nursery. Stagnation may be cured by transplanting into the field or by fertilizing.

Under the conditions of the Florentine Valley the best method of planting is usually by a dibble which punches a hole just big enough for the tubed seedling.

Tubed stock can be planted successfully at any time of the year except perhaps in the driest months of "drought" years, provided that the seedlings are not faced with unseasonal frosts, browsing, or heavy weed competition, while vulnerable. To the extent that these provisoes are not fully obtained it becomes important to avoid planting between February and August and to aim at planting during September to November.

Planting under undisturbed weeds so dense that very little or no grouhd vegetation grows beneath them is unsuccessful. In the caxe of coupes which are dominated by dense wet ferns or by bracken the survival of planted seedlings may be improved by manuring, cultivating by planting in spring, by control of browsing and by avoiding the denser patches. Shrub thickets and very dense, tall bracken may have to be burnt or dozed for successful planting.

Unless otherwise stated, the above conclusions apply to unbrowsed plantings not on puddled soils and free from excessive weed competition.

CH APTER XI

S O W I N G.

A. INTRODUCTION

Sowing of *E.regnans* has been studied by several workers. Powles (1940) worked on areas mostly dominated by bracken, (in Victoria). His spring burns gave rise to poorer natural regeneration than his autumn burns. March to May was the best time for broadcast sowing on burnt bracken seedbed if the most rapid and complete germination is aimed. at. Bracken did not prevent germination but seriously reduced survival where it was dense. Survivors took five years or more to emerge above the bracken. Even though mortality amongst autumn sown seedlings was up to 90% during the first winter, he favours autumn over spring sowings because of possible summer droughts. Spot sowing had not any advantage over broadcast sowing on freshly burnt ground.

Carr (1954) confirmed Powles' findings that sowing under scrub, or on litter gave much fewer observable germinations that sowings on mineral soil or on burnt ground.

Rolland+Heisler (pers. comm). found that September - October were the best of the spring and summer months for spot sowing. Application of blood and bone depressed germinations on spo ts and was of doubtful value to height growth and survival. There was no need to cover the seed with a layer of soil.

During the cool moist years of 1955 ~~and~~ to 1957 Mount (pers. comm.) found that the best month for spot sowing in the Florentine Valley was September, then came October, and then February and April, if percentage of established spots is the criterion. Mainly due to seed robbery and browsing, only 5 to 22% of the 4,000 spots he sowed became established.

Two attempts to regenerate dense bracken areas by broadcast sowing (a) after disturbance by tractors, and (b) after clearing by fire have been unsuccessful.

Gilbert (1958) describes in detail the course of germinations from various experiments carried out in the Florentine Valley during 1955 ~~and~~ to 1958. 70 to 97% of all observed germinations occurred within three months of various sowings all followed by favourable weather. Germinations had pra ctically ceased 9 months after autumn sowings and 15 months after spring sowings. April sowings germinated a little more rapidly, but usually somewhat less completely than October sowings. The observed germinations amounted to a very variable proportion of the viable seeds sown, and ranged from 0.4% without the use of insecticides on ground covered with unburnt slash, to 50% with D.D.T. dusted seed on mineral soil. Normally between 2 and 20% of seed which is dusted with D.D.T. can be expected to germinate on burnt or disturbed mineral soil.

Spraying the ground with dieldrin or dusting the seed with D.D.T. gave three times and two times respectively the number of germinations obtained from the bare seed.

Mineral soil gave the best germination and survival; unburnt slash the poorest. Survival was reduced by exposure to browsing by native game, and by shading from dense fireweeds or rainforest tree remnants. Without protection from seed robbing insects and from browsing game tree percents ranged from 0.2 to 4.2 usually about 0.5. Tree percent is the percentage of viable seeds producing established seedlings. Protection of seed and seedlings may multiply these figures several times, up to a tree percent of 6%. Depending on the weather soon after germination, the degree of weed competition, and the intensity of browsing, between 5 and 50% of cotyledon stage seedlings survived to become established.

Cunningham (1960) studied the fate of seed and early survival of seedlings intensively. He found that insects may remove over 80% of the seed if the sowing is followed by weather unfavourable to germination. Of the seed not found by insects over 80% germinates within one year. The other 20% is probably killed by high seedbed temperatures and by fungal attack. High seedbed temperatures during summer may cause exposed seeds to become dormant, thus delaying their germination until autumn.

Few seeds overwinter. Browsing was not a serious cause of deaths. Drought and high temperatures during summer usually killed only young, cotyledon stage seedlings. Most deaths occurred during cool, moist weather and could be ascribed to etiolation, fungi and frost heave. Once beyond the cotyledon stage, the life expectancy of seedlings increased very rapidly. Germination and survival percentages were of a similar order to those found by Gilbert (1958). Germinations observed on disturbed seedbed were five times more numerous than those on ground undisturbed by logging and occupied by litter and weeds (Blechnum fern and Tetrarrhena grass).

In terms of tree percent, sowings in October 1955 and 1956 were twice as good as sowing in March 1956. Cunningham nevertheless suggests that sowing should be done in autumn, because it is then likely to meet with more reliable success, even though fewer established plants are likely to be obtained on the average.

Successful establishment of field scale regeneration of E.regnans from sowing had been very limited in 1960. Powles (1940) was moderately successful in restocking portion of several hundred acres of sown bracken country in Victoria during the 1930's. Gilbert (1958) soed 0.6 acre plots in November 1955 and April 1956 by broadcasting and spot sowing unprotected seed on unprotected seedbed. Success was only partial. It took 1½ lbs.

of seed to produce 500 established seedlings. Lately in 1960, large scale sowings have been made by A.N.M. in their concession area. Results from these will be referred to below.

Taking into consideration the basic information described above, and the probable intention of A.N.M. to plan large scale sowings the author made a number of field scale sowings during 1958 to 1960. These sowings are part of Project 1 referred to in Chapter X. The basic aim of these sowing experiments was to find out and demonstrate the level of success obtainable from large scale sowings if the seed is dusted with D.D.T. and if the seedlings are protected from browsing.

B. EXPERIMENTAL METHODS

The experimental details and results of four small scale series of experiments are given in sections D, E, and F below.

In section C the results of project I are summarised together with some relevant data from ~~two~~ experiments at Road 7A ~~and at Road 11~~ which the author carried on since early 1958 from his predecessor J.M. Gilbert. The details of the methods and results of these three experiments are given in Appendix IX. A summary of the methods is given below:

Project I:

- Two methods of sowing: Spot sowing and broadcast sowing.
- Three seasons of sowing: Late Autumn 1958, Spring 1958; early Autumn 1959.
- Each of the above six treatments were applied to one acre inside the fence at W56 and to one quarter acre outside the fence.

All seed was dusted with D.D.T. prior to sowing. There were 400 spots sown per acre in the spot sowings. All spots were numbered. Each acre of broadcast sowing was sampled by about 200 systematically located, numbered, permanent sample plots of 1/4000 acre. Scoring was done at variable intervals at c ritical times. The trends of observed germinations and deaths were not subject to sampling error because the same patches of ground were re-inspected on each occasion. The position of all seedlings was marked with a coloured nail.

~~Road 7A Sowings (made by Gilbert):~~

~~These sowings were similar to those of Project I but no insecticide was used and none of the seedlings were protected from browsing.~~

Road 11 Sowings (made by Gilbert):

This was a small scale sowing on 27 milacre plots using seed which was dusted with D.D.T. The seedlings were not protected from browsing.

C. SUMMARY OF EXPERIMENTAL RESULTS

I. GERMINATIONS -

(a) The Pattern of Germinations:

Gilbert (1958) and Mount (1961) showed that in the Florentine Valley significant amounts of germination can occur during any month of a moderate year. This finding can now be qualified by results from the sowings made during 1958 to 1961:

Due to almost continuously dry surface soil, and probably also due to secondary dormancy induced by high seedbed temperatures (Cunningham 1960) some summers may have several months during which germinations are very slow. Most of the germinations from spring sowings may thereafter appear in two distinct bursts, viz in spring, and in autumn. This was noted with both sowings made in October 1958. Of the observed germinations from the spot sowing: 72% occurred in spring, during 1½ months; then there was a lull followed by another peak in autumn amounting to 23%. There was a final minor burst of 5% next spring.

This tendency was not evident during the cool, moist summers of 1955/56 and 1956/57, in the Florentine Vall ey (Gilbert 1960) but was found at that time in Victoria where 15 to 20% of seed sown in spring germinated after the summer. (Cunningham 1960).

Gilbert found that 86% of all germinations from two mid-April sowings occurred by mid-winter. There was no distinct peak of germinations in spring. The broadcast and spot sowings made in March 1959 are in fair agreement with this.

However, sowings made in late April 1959 and natural regeneration following burns in late summer or autumn of 1959 and 1960 showed a different and distinct pattern. There was a peak of germinations in autumn, a lull during mid-winter and a sudden burst (lasting about one month) during late August/ea rly September. The "spring" germinations amounted to:

27% of all observed germinations from seed sown on 12/4/60;
36% of all observed germinations from seed sown on 26/4/60;
48% of all observed germinations from seed sown on 25/4/58;
about 50% of all observed germinations from natural regeneration.

It appears that temperatures in mid-winter may limit germinations. The proportion of germinations which occur after mid-winter will then depend on the time of sowing of the seed, the duration of weather favour-able to germination between sowing time and mid-winter, and on the degree of natural dormancy in the seed.

It should therefore be remembered that while in some years 80 to 90% of germinations occur within 3 to 4 months of sowing, in other yea rs a considerable proportion of germinations may be delayed by the intervention of a hot, dry summer period or by a cold winter. In the latter cases, two clearly distinct generations of seedlings can be observed in autumn or in spring respectively.

(b) <u>The Proportion of seed which germinates</u>:

Because the intervals between scorings were relatively long and of unequal duration, the observed germinations give underestimates to various degrees of the actual total number of germinations from the different sowings. Though strict comparisons are therefore not justified, some gener al conclusions can be drawn.

The observed germination percents were remarkably uniform, viz between 8 and 20 percent, or excluding the two extremes: between 15 and 17%. This agrees well with the figure of 15% germination obtained on the average from three different sowings of seed sown on dieldrin sprayed plots of mineral soil and burnt slash seedbeds (Gilbert, "Lord's plots"). However, 10 to 20% germination is more than was expected from large scale sowings. The only other large scale sowings were with seed unprotected from insects at Road 7A, where a germinations percent of 1.9 to 2.6 was obtained.

The observed germinations from broadcast sowing (8%x , 15% 16%) were not significantly poorer than those from spot sowing (15%, 16%, 17%).

x The death rate observed on Autumn '58 spots suggests that the actual germination percent from the autumn '58 broadcast sowing was near 16%, rather than the 8% observed 4½ winter months after sowing.

The germination percent from neither broadcast nor spot sowing decreased with increasing age of seedbed during the first year after burning. At the end of one year nearly all of the burnt seedbed was covered by a shallow, sparse cover of mosses and some Marchantia. During the second year the mosses became very much denser. This is decidedly detrimental to broadcast sowing. On Gilbert's "Lord's Plots", where ground cover was relatively slow in becoming established, the germination percent actually improved from 7.3% from the first autumn's sowing to 21.2% from the second autumn's sowing.

II. DEATHS

The mortality was highest at the cotyledon sta ge (usually over 50%) but decreased rapidly with increasing size of the seedling. In the absence of browsing and severe weed competition, only very few seedlings died after developing a first pair of vigorous leaves. Cunningham (1960) made similar observations and found that less than 10% of all the deaths he observed occurred after the seedlings had grown over one inch tall. Figure IX.5 illustrates the increasing survival expectancy with increasing time since sowing. In this case the population of seedlings at any one time is made up of individuals at various stages of development.

Most deaths appear to be due to fungi, frost lift, drought, and defoliation by animals.

(a) Deaths caused by Fungi:

The great majority of deaths ascribed to fungi occurred at the cotyledon stage. Taller plants succumbed much more rarely except when they were badly etiolated. No attempt has been made to identify the responsible fungi. It is known that in the laboratory, in the glass house, and in the nursery fungal attacks may be very severe and can be controlled by fungicides. The fungi appear to be of the damping-off type, i.e. are only weakly parasitic and attack mainly slowly growing, immature tissues - such as the cotyledon stage plants during winter.

Fungal death is particularly severe under dense shade, e.g. amongst fireweeds. Fungal attack may be the direct cause of the eucalypts' total failure to regenerate in the shade of their own rainforest understorey. Three to twelve inches tall seedlings planted amongst dense ferns survived well during summer, though growing only very slowly and becoming etiolated. The great majority of such seedlings (at less than 10% daylight) died during the first winter mostly as a result of fungal attack as was evident from their rotten leaves and stems.

It was impossible to assign a case of death to every casualty in the field. In only a small proportion of cases where the seedling was still visible, brown and flabby, could fungal attack be blamed with some justification. In many cases of death, the seedling disappeared between scorings. It is suspected that fungus may be blamed for most of these disappearances.

Ashton (1956) showed that fungal attack on E.regnans seedlings increased with decreasing light intensity. Cunningham (1960) and Gilbert (1958) also assigned a large proportion of the deaths they observed amongst E.regnans seedlings to fungal attack. It is possible that some of the deaths ascribed to fungi are really due to injection of the leaves with water in moist, sheltered situations, (Grose 1961).

(b) Deaths due to Frost-lift:

Frost lift is the most spectacular cause of seedling deaths. Its frequency and occurrence is easily recognized by inspection of the lifted top soil at the right times. Its effect on the seedlings is clearly visible after the thaw.

Frost lift affects mainly those plants whose roots are less than two inches long, namely those at the cotyledon stage. Its effect may be:

I To lift the entire plant out of the soil and leave its roots entirely exposed on the soil sur face.

II To expose the roots only partially.

III To tear off the plant above the root collar by pressure from the ice crystals against the cotyledons while the roots remain anchored.

The fate of several hundred frost lifted seedlings has been studied by keeping records of especially marked seedlings. It was found that many lifted seedlings may show no ill effects for several weeks if the weather remains continuously cool and moist. However, root growth is apparently very slow in winter and none of the completely exposed roots re-entered the soil. Consequently nearly all lifted seedlings died by spring time. A small proportion of the partially lifted seedlings survived. All decapitated seedlings died.

In the years 1958 to 1960, most frost lift occurred in July and August.

The amount of frost lift damage which occurs depends on the following four factors: Firstly, presence of very young seedlings which are susceptible to frost lift; secondly, occurrence of frost; thirdly occurrence of wet, loose soil; and finally, lack of a sheltering canopy of plants.

Only the seedlings which germinate in late autumn and in winter are small enough to be lifted when frost occurs. Hence the sowings made in spring did not suffer any harm from frost lift. Only the autumn sowings were affected.

Frosts which lift the soil occur several times each winter in the Florentine Valley, mostly in July and August.

The top soil is wet throughout each winter, but the looseness of the soil depends on a number of factors. Spot sowing especially creates loose soil. Thus from the sowings made in March 1959, 14% of the spo t sown seedlings were lifted by early July, while only 2.3% of the broadcast sown seedlings were lifted. Twenty percent of the April 1958 spot sown seedlings were seen lifted by late July 1958. Secondly, the texture of the soil surface is strongly influenced by the type of fire which cleared the ground. In some areas about half of all seedlings were seen to be lifted where the soil surface was very crumby due to a ~~fiew~~ fire which had burnt the humus away. At the same time the frost lift on areas where the humus was still intact was usually mild or absent. Thirdly, the looseness of the soil depends on disturbances by logging, and also on the degree to which the ground has been revegatated by a mat of mosses, liverworts and herbs.

Frost lift can be severe only where the ground is able to loose its heat rapidly by radiation. Thus a canopy of taller plants can reduce or prevent frost lift. The fireweeds on burnt ground developed much better inside the fence at W56 than outside the fence. Hence the spot sowings on burnt ground inside the fence suffered only 3% of frost lift while the comparable sowings outside the fence suffered 19% of frost lift.

In summary, frost lift can cause many deaths amongst those seedlings which are very small during July and August. Frost lift is most severe on expo-sed sites with loose top soil. Fortunately, it is precisely these sites which favour the eucalypts on most other counts.

Foliar damage due to frost is apparently rare on very small eucalypt seedlings. The effect of frost on seedlings of plantable size is discussed in Chapter X.

(c) Deaths due to Drought:

Detailed studies of drought as a cause of mortality amongst *E.regnans* seedlings were made by Cunningham (1960) in Victoria. He was not able to determine

determine what proportion of the deaths observed during summer were due to drought, but he reached the following conclusions:

(1) Because of the high precipitation/evaporation ratio drought is unlikely during at least the seven winter months.

(2) Summer mortality is severe, but much less important than winter mortality.

(3) Drought dea ths are almost confined to seedlings of the cotyledon or early two-leaf stages; i.e. to seedlings within a few weeks of germination in late spring or summ er. Drying out of the top soil to depths greater than one inch is probably of little importance because of the rapid penetration of roots during the growing season and because of the rarity of such drought.

(4) Drought is a major cause of death. Its effects cannot be rea dily distinguished from those of fungi and high surfa ce temperatures.

The author's experiments and observations agree with these findings.

Two scorings were made to obtain some idea of how severe drought deaths can be at a time of maximum stress. January 1959 and December 1961 were unusually dry months, as is also evident from the existence of uncontrollable fires at that time. The mortality amongst a batch of 520, one to two months old, seedlings (from spring 1958 spot sowing) was only 9% per month during December 1958/January 1959. The mortality amongst another batch of 530, one to four months old, seedlings (Autumn 1960 pellet trial) was only 7% per month during November and December 1960. These death rates are low compared with those which are found amongst young seedlings in winter.

There was one case of high death rates due to drought. This was a batch of 164, one to four months old, seedlings which had germinated amongst a dense cover of fire mosses (Autumn 1960 pellet trial). The death rate during November and December 1960 was 24% per month. The seedlings in the moss were much less developed than those on freshly burnt ground. The dead seedlings were the smallest, and proved to have very poor roots which had failed to penetrate through the now dry moss to the soil below. The dense mosses while moist apparently had permitted germination of the many seeds suspended above the soil. Seedling growth was then inhibited, perhaps because of difficult access to nutrients.

Deep humus may have a similar effect, though growth is not inhibited. The humus may dry out to the depth of several inches. Drought deaths of natural regeneration on mounds of humus at Road 8W were conspicuous in January 1961, but did not reach serious proportions.

(d) Defoliation by Animals:

Defoliation of 2" to 24" tall seedlings due to browsing by native game is a serious cause of deaths, and is described in Chapter XII. Very young seedlings at the cotyledon stage are also often partly or completely defoliated apparently by very small animals such as insects or slugs. The complete defoliation of a very small seedling usually amounts to decapitation and only a stem without buds is left behind, which is bound to die. Insect attack on seedlings beyond the cotyledon stage is rarely fatal because complete defoliation is rare.

Decapitation of very small seedlings has been observed during 1959 and 1960 in widely scattered localities. Its severe occurrence tends to be patchy and confined to recently burnt ground. It has been recorded at monthly inspections of fixed plots as a major cause of deaths throughout June 1959 to January 1960, and May 1960 to January 1961. At these times (on W54 and Road 8W respectively) decapitation accounted for about one fifth of all deaths. Observations during the other months of the year are lacking. It is notable that there is no obvious correlation with variation in conspicuous insect activity. The rate of decapitation was similar during winter and spring time.

III. GROWTH

Seedlings which are at least 6" tall can be considered to be established if they are not expo sed to browsing or intense competition from taller weeds. Otherwise the minimum height of established seedlings is 24". A summary of the results of growth studies is given in Table XI.1.

TABLE XI.1

Height growth of sown *E.regnans* seedlings free from browsing and excessive weed competition.

Experiment	AGE Mths.	Gr. seasons	Stocked sample plots or spots with seedlings at least: 6" tall	24" tall
Spot sowings At W56				
Sown on: 28.10.58	7	1	17%	0%
28.10.58	12	1	17%	0%
27. 4.58	12	1	14%	0%
8. 3. 59	12	1	43%	0%
28.10.58	17	$1\frac{3}{4}$	86%	29%
27. 4.58	18	$1\frac{1}{4}$	27%	2%
28.10.58	24	2	93%	67%
Broadcast sowings at W56				
Sown on: 11. 3.59	12	1	11%	0%
7.10.58	13	1	59%	-
7.10.58	17	$1\frac{3}{4}$	89%	23%
23. 4.58	19	1	14%	0%
11. 3.59	20	2	43%	0%
23. 4.59	23	$1\frac{3}{4}$	75%	20%

At one to two years after sowing a few plants are much taller, and many plants are very much shorter than most of their contemporaries. Extremes and even averages of plant heights are of less interest to the forester than a knowledge of the proportion of plants above a critical height and the adequacy of their distribution. H ence stages of regeneration development are here described by the percentage of stocked sa mple plots or spots carrying plants at least 6 and 24" tall.

The sowings made in autumn had no advantage in height growth over those made in the following spring five to six months later. Indeed, by the end of the first growing season, the later broadcast sowing was well ahead of the earlier sowings. It seems that young seedlings experiencing continuously favourable conditions grow faster than others which had an equivalent duration of favourable conditions which were, however, interrupted by unfavourable periods.

The broadcast sowing made on one year old, burnt seedbed (Autumn '59) grew much more slowly than the sowings on more recently burnt seedbed. This is attributed to weed-comp-etition, particularly by mosses and <u>Erechthites</u> which develop strongly after one yea r following a burn.

The late <u>spot</u> sowing (Autumn '59) on the other hand grew remarkably well. Apparently spot preparation removed excessive competition at this stage while partial shading by adjacent weeds actually assisted height growth.

When sown within half a year of the burn, spot sowings had no advantage in height growth over broadcast sowings. In fact when sown in spring the broadcast sowing grew faster than the spot sowing. Loosening of the soil for spot sowing at the beginning of the drier season seems to be disadvantageous.

Early height growth was slow. With the remarkable exceptions of the spring '58 broadcast sowing and the autumn '59 spot sowing, only 10 to 20% of sample plots or spots carried seedlings at least 6 inches tall by the end of the first year.

Most plants became established during their second growing season and then began rapid growth. Once a seedling is at least two feet tall it will increase in height by at least 3 ft. per year. (see Chapter X).

The ra te of height growth varies considerably from place to place and from year to year. All the above sowings were made on sites which were burnt relatively thoroughly, but the fires were not hot near the ground and nearly all the humus remained intact. It is obvious from general observation that early height growth on sites burnt by humus fire in 1960 and 1961 was often much better than that reported above. The good growth following the 1960 and 1961 fires could be due to better growing seasons and due to release of more nutrients and due to partial sterilization of the soil.

IV. ESTABLISHMENT

Table XI.3 summarizes the rate of survival of germinated seedlings and the proportion of viable seeds which produced established seedlings from the sowing experiments at W56.

With the exception of the autumn 1958 spot sowing, the survival of germinated seedlings was generally good and in the order of 30% up to the age of 20 months.

Spot sowings had no advantage over broadcast sowings except when the ground was occupied by weeds. One year after burning most of the burnt ground was thinly covered by fire mosses and some *Marchantia*, plus a considerable density of *Erechthites* and *Pomaderris* seedlings. Under these conditions the clearing of small patches of ground was of advantage. The relative advantage of spot sowing over broadcast sowing is expected to increase with increasing density of weeds.

At 21 months after sowing, the broadcast sowings made immediately after the fire were no more successful than the broadcast sowings made a year later. However, the delay of one year has put the later sowings at a disadvantage in height growth relative to the competing weeds, and it is likely that mortality will continue at a relatively high rate for the later sowings. The elimination of browsing has permitted a very dense growth of *Pomaderris* and *Acadia* in this area. (W56).

The figures in Table XI.3 indicate that for practical purposes a tree percent of 2 can be assumed if the seed is sown under favourable conditions, dusted with D.D.T. and if the seedlings are protected from browsing. This applies to both spot and broadcast sowings made in autumn or early spring within one year of burning.

(Tables XI.3 and XI.4, see page 185).

Table XI.4 summarises the results from very extensive sowings of *E.regnans* in the Florentine Valley. Cunningham (1960) has suggested that if at least 30% of milacres are stocked with established seedlings, the area can be considered to be satisfactoryly regenerated. Assuming that 40% stocking one yea r after sowing is equivalent to 30% stocking three yea rs later, then it can be seen from table XI.4 that about three quarters of the broadcast sown areas and about half of the spot sown areas have succeeded.

TABLE XI.3

Comparison of survival from various sowings at W56.

Sowing	Age at final score	% survival of observed germ's.	Seedling percent	x probable tree percent
Broadcast on: 23. 4.58	22 months	27%	2.3%	2%
7.10.58	17 "	28%	5.0%	4%
11. 3.59	20 "	38%	5.3%	2%
Spot sown on: 26. 4.58	18 "	8%	1.1%	½%
27.10.58	24 "	18%	3.3%	3%
8. 3.59	20 "	47%	8.3%	7%

x arrived at by using the percentage of sample plots or spots with seedlings at least 6" tall.

TABLE XI.4.

Summary of Results from large scale sowings made by ANM in the Florentine Valley.

Sowing	Area sown	% of areas with a milacre stocking of at least: 30%	40%
Broadcast sowing 1960	581 acres	90%	80%
1961	791 "	91%	67%
Spot sowing 1960	323 acres	77%	52%
1961	345 "	43%	49%

Note: All E.regnans; seed dusted with D.D.T; broadcast sowing at about 1.2 lb. of seed/acre within one year of the regeneration burn; spot sowing at about 900 spots per acre with roughly 50 viable seeds per spot, usually on the more difficult sites where broadcast sowing was less likely to succeed because of the presence of weeds. The areas were assessed at variable times, after sowing (usually about ½ year) by the inspection of milacre quadrats systematically spaced at 1x4 chains.

V. CONCLUSIONS

The effect of browsing is dealt with separately in Chapter XII.

The great majority of germinations usually appear within three months of sowing; germinations are practically complete within 12 to 18 months. If sowing is followed closely by a cold winter or by a hot, dry summer most of the germinations occur in two distinct generations, viz soon after sowing and after the winter or summer respectively.

About 15% of the viable seed will germinate if dusted with D.D.T. and sown on reasonable seedbed at a favourable time.

Ten to twenty percent of the germinated seedlings will survive to establishment age if protected from browsing, and if broadcast sown within half a year of burning; or spot sown within one year (and perhaps later).

A tree percent of 2% may be relied upon for practical purposes.

If 1,000 randomly distributed, or about 300 well distributed seedlings are the minimum stocking requirement (Cunningham 1960) and if one pound of seed contains 100,000 viable seeds then a minimum of half a pound of seed must be sown per acre broadcast - provided the seed is dusted with D.D.T., the seedlings are protected from browsing, and provided the sowing is done at a reasonable time on reasonable seedbed.

There was no consistent difference in germination percent from spot sowing at a rate of 130 as against 260 viable seeds per spot. The higher rate had much more effect on number of seedlings per stocked spot, than upon percentage of successful spots. Since only one established seedling is required for each successful spot, an increase in the rate of sowing above a certain optimum will result in rapidly diminishing returns for increased expenditure of seed. With a tree percent of 2% fifty viable seeds per spot are a reasonable maximum rate when the labour cost of spot preparation is high. About 70% of the spots sown at a rate of 130 to 260 viable seeds per spot become established. One might hazard a guess that only 50% of spots will become established if sown with 50 seeds each. To obtain 300 established spots per acre about 0.3 lb. of seed is needed, i.e. about half the amount required for broadcast sowing.

If poor seedbeds (logs, stumps, heavy slash, and badly puddled soils on landing and on main tracks), are avoided, spot sowing has no advantage over broadcast sowing on seedbeds less than one year old. The saving of seed can equally well be achieved by "patch sowing", i.e. sowing suitably distributed patches of good seedbed without the clearing and cultivation of spots.

Spot sowing is superior once the ground mat of mosses or Marchantia has become continuous, thick and dense, i.e. from 1½ years after the burn. A sparse, thin ground mat may be of advantage. On seedbeds older than one year, broadcast sowing may be impossible, while spot sowing is likely to succeed until competition for light by ferns and shrubs becomes excessive.

Time of sowing:

Except in extreme years (hot, dry summers and perhaps very cold winters) sowing of eucalypt seed if protected from insects can be done at any time of the year with hope of reasonable success. There is evidence that even in the more usual temperate years certain seasons are more favourable for sowing than others. Since extreme years cannot be forecast it is necessary for uniformly good success to time all sowings properly.

Both Cunningham (1960) and Gilbert (1958) found that the tree percent from spring sowings (October '55 and '56) was twice as high as that from autumn sowings.

(March and April '56). In the experiments described above, spring sowing (October '58) was two to six times more successful in terms of tree percent than autumn sowing (April '58, March '59).

A high tree percent is the result of a high germination percent combined with low seedling mortality and rapid growth. The first is ensured if sowing is followed by two to three months of moist and cool, but not cold weather. These conditions obtain most reliably in autumn and early spring. Lower mortality can be achieved if seedlings are given a chance to grow rapidly beyond the cotyledon stage before the attack by (winter) fungi and frost lift and before the possible advent of drought and excessive heat. Germination during early winter, during late spring and during summer should therefore be avoided. It would appear that the ideal time for germinations to occur is just when growth recommences after the winter. This avoids the hazards of stagnation during winter at a very vulnerable stage, and gives the seedlings a maximum chance to become drought resistant before the possible advent of a hot dry period.

In 1959 and 1960 germinations from the natural seedshed in autumn reached a very prominent peak in early September and late August respectively after a two months' winter lull. These seedlings continued to develop rapidly. Apparently the growing season for very young seedlings begins a little earlier than for taller seedlings.

To ensure rapid and complete germination of all seedlots stratification is necessary. Sowing should therefore allow at least one month in the field before the peak of germinations in spring. This makes June/ July/August the ideal time for sowing at least for years with extremes of summer drought or winter frost. September would come next. October and later is hazardous in case of summer drought. March is probably next but requires efficient protection against insects in case the seedbed is not moist and cool enough to permit rapid germination.

D. THE PROBLEM OF PUDDLED SOILS

I. INTRODUCTION

Given the wet climate and hea vy soils of the Florentine Valley, most tractor tracks which are used more than two or three times become seriously compacted and puddled. Puddling is much less serious when the soil is dry, e.g. in late summer. Puddling is reduced by the substitution of highlead logging for tractor logging because the soil is then subjected to less compression and vibration. (McGeorge). When the soils is very wet the churning by tractors may produce a liquid suspension of mud and organic debris more than one foot deep which settles eventually and makes a very dense pavement which rarely cracks when dried, and is so hard that a nail is often difficult to push into it. The smell of anaerobic decomposition shows that aeration at more than one inch depth is extremely poor. The soil is plastic and absolutely without structure.

Tractors ser iously disturb 10 to 50 percent of a coupe's area, usually about 20%. There appears to be little or nothing that can be done to reduce the extent and severity of this disturbance. Except for the immediate vicinity of the loading point, where tracks converge and are used more often, the disturbed soil is fairly evenly distributed. Since the Skagit mobile loader has been introduced the number of loading points per coupe has been increased, and consequently the severely disturbed sites are smaller and more evenly distributed over the coupe. If the areas between the tracks are satisfactorily regenerated it is not important that the tracks remain barren.

The tracks are by far the most easily accessible parts of a coupe and remain free from dense weeds till long after the undisturbed sites are thickly overgrown. For this reason tracks would be an asset if they could be used to improve the stocking of a coupe when this is found necessary several years after the original regeneration treatment. It is fortunate that, eucalypts are amongst the pioneers on disturbed and puddled soils.

Normal broadcast and spot sowings are not successful on recently puddled soils. Germination is good, but the seedlings stagnate (and turn red) at or little beyond the cotyledon stage. Most such seedlings eventually die. A small experiment was carried out to compare some possibilities of making puddled soils suitable for spot sowing.

II. THE PUDDLED SOIL EXPERIMENT

(a) Methods:

In all cases except the control an area of 2 ftl by 2 ft. was cultivated three inches deep. All chemicals were worked into the soil. The roughly cultivated soil was firmed down before sowing. All treatments were done one day before sowing.

"Flotal" - This was applied at 6 ounces per 4 square feet plot, as recommended. "Flotal" is a soil conditioner containing a ferric ammonium organic complex claimed to improve the structure of heavy soils. It is not a fertilizer.

Burning - A wood fire was maintained for one hour on the spot to be treated. The remaining large pieces of charcoal were removed before cultivation.

Manuring - Four ounces of blood and bone were applied to each plot.

Cultivation - No additional treatment.

Control - The soil was not treated at all.

The central one square foot of each plot was sown on 15.12.59 with D.D.T. - dusted seed of *E.regnans* at the average rate of 365 viable seeds each (measured by volume, tested by laboratory germination test).

The plots were laid out in a 5 x 5 latin square with 3 feet wide buffers between the treated areas. There were two replications, both on level ground on deeply puddled dolerite soil near a landing point. One was at W57, half a year after puddling. The other was at W56, inside the fence, one and a half years after puddling.

(b) Results:

The results are summarized in Table XI.5. See appendix VI for the summary of a statistical analysis.

The seedlot used was not naturally dormant. The delay of the first germinations until autumn is ascribed to the hot, dry seedbed conditions during this summer. Only 1.2% of the viable seeds sown was observed to have germinated on the untreated seedbed. The figure for the burnt, manured, and cultiva ted seedbeds was about 5%. The figure of 2.3% after "Flotal" treatment may reflect a reduction of germinations due to this chemical.

TABLE XI.5

Results of Puddled Soil Experiment

Each of the figures is the mean of four one square foot plots. Each plot was sown on 15.12.59 with about 365 viable seeds of *E.regnans*

Treatments	Mean number of seedlings per plot on 4/11/1960			on 5/9/60
	No. of green seedlings	No. of seedlings taller than 1"	Total No. of seedl.	Total No. of seedl.
Plots at W56				
Control	0	0	4.0	6.4)
Cultivated	0	0	8.2	11.4)
Flotal	0	0	6.4	8.4) ±2.91 (SE)
Manured	2.4	3.4	13.0	19.8)
Burnt	0	0	4.6	13.2)
Plots at W57				
Control	0	0	0.8	0.2)
Cultivated	0	0	17.0	14.0)
Flotal	0.8	0.6	8.0	9.0) ±2.94
Burnt	0	0.2	11.6	20.0) (SE)
Manured	10.8	7.6	14.0	17.2)

The plots were scored three times, namely in April, September and in November 1960. Germinations appeared a few weeks before the first scoring, reached a peak shortly before the second score and probably ceased by the time of the third score. In most cases the middle score showed the highest number of seedlings per plot. The results of the middle scoring were analysed statistically to determine whether any of the treatments had significantly affected the rate of germinations, assuming that the stocking in September reflects the relative rates of germination.

In both sets of plots the untreated ground produced the fewest germinations, but only at W57 was the difference between "control" and "cultivated" significant. The "burnt" and the "manured" plots carried the most numerous seedlings but their difference from the control was not always significant. The manuring did not appear to have depressed the number of germinations.

Survival till November 1960 was fair on all seedbeds, but by March 1962 nearly all stagnant seedlings had died.

Manuring produced the only reasonably vigorous seedlings - (see photo No.15). About 40% of the manured seedlings present in November 1960 were over one inch tall. Some of these exceeded one foot in height by March 1961. There was, nevertheless, a proportion of stagnant seedlings. The manured plots were oases of fire weed in the barren surroundings of puddled soil. The response in the growth of fire weeds

Photo No. 15 : Oasis of *Erechthites* on puddled soil. The spot was manured with 1oz/sq ft. of blood and bone one year previously. Note several healthy one year old *E. regnans* seedlings.

Photo No. 16 : The spot covered by numerous *Acacia dealbata* seedlings was burnt by a small fire one year previously. The fire must have stimulated germination ~~of the ground starred~~ and growth of the Acacia seeds which ~~germination of the ground stared *Acacia* seeds~~. were stored in the ground.

and mosses was not as spectacular in this experiment as it had been in the planting experiments after a superficial application of 1-2 ounces/square foot of blood and bone without cultivation. The structure of the soil on the manured plots was obviously improved.

The "Flotal" treatment was very poor. Two of the "Flotal" plots produced a little growth. There was no obvious improvement in the structure of the soil. Growth and soil structure looked hopeless on all other plots.

The main effect of burning in this experiment was to stimulate the germination and growth of numerous *Acacia* seeds. The number of *Acacia* seedlings on the burnt plots was similar to the unburnt plots, but the *Acacia* seedlings on the former grew very much more vigorously than the seedlings on the unburnt plots. (see photo No.16).

A very hot fire *can* improve the top layers of puddled soil. This may be observed after some slash fires, especially where a burning log has fallen across a tractor track. In such cases the top inch of soil is baked into red crumbs, free of organic debris. Mount (pers. comm.) observed that a little deeper down the organic debris is still present as a horizon of charcoal.

In the Douglas Fir forests of N. America soil puddling presents a similar problem, (Steinbrenner). Ploughing is recommended there. In this experiment as well as in numerous spot sowings, the cultivation produced no worthwhile improvement in the growth of eucalypt seedlings. T he improvement of germination on cultivated as compared with uncultivated soil is ascribed to the ability of seeds to find cracks in the soil to protect them from insect robbers and heat injury.

III. DISCUSSION AND CONCLUSIONS

It is fruitless to employ normal methods of sowing on recently puddled soils such as occur on tractor tracks. To avoid soil puddling ploughing or clearing of the ground by bulldozer should only be done when the soil is too dry to be kneaded into cohesive balls. Recovery from the puddled condition is fastest on the centre ridge and edges of the tractor tracks. Recovery can be recognized by the growth of weeds and by the crumbly structure of the soil. Recovery can be accelerated by the application of blood and bone manure.

A factorial experiment is under way to determine the best method of using blood and bone manure in connection with spot sowing on puddled soils. The effects and

and interactions of the following factors is being studied: Cultivation; manuring at 0, $\frac{1}{2}$, 1 and 3 ozs per square foot; time of sowing; and severity of soil puddling. The effect of blood and bone is probably due to one or both of its main constituents, namely phosphate and nitrogen. Both these nutrients can be obtained more cheaply in inorganic form. It may therefore be useful to find out by experiment whether there is a cheaper alternative to the use of blood and bone. The present use of blood and bone is not expensive.

The poor growth of plants on puddled soils may be due to two factors, namely poor aeration, and deficiency in available nutrients, especially nitrogen. The plants may be unable to use the nutrients because the respiration of the roots is restricted or else because the nitrogenous nutrients may be monopolized by the soil organisms which multiply on the large amounts of organic debris usually present in the puddled soils. This latter idea is being tested by a small 4 x 4 latin square experiment where spot sowing is done on recently burnt soil with the addition of the following four treatments: sawdust only; sawdust plus blood and bone; neither sawdust nor blood and bone; blood and bone only. Perhaps the sawdust will cause a deficiency leading to the stagnation of the seedlings, which can be cured by blood and bone.

Precise recommendations for sowing on puddled soils cannot be made until the results of the current experiments become available. In the meantime, reasonable success can be expected from the use of half an ounce of blood and bone per square foot for spot sowing. The blood and bone should be thoroughly cultivated into the top 1 - 2 inches of soil to avoid the possibility of harmful contact with seeds or seedlings.

E. THE SEED BURIAL EXPERIMENT

I. INTRODUCTION

Knowledge about the effect of a covering of soil on the germination of eucalypt seed is of practical importance for two reasons. Firstly, does a covering of soil improve the pattern, amount and reliability of germination of spot sown seed? Secondly, does the burial of seed due to the logging of seed trees make the buried seed unavailable for regeneration? If burial proved harmless to the seed, then the best time to log the seed trees would be after the seed has shed but before the vulnerable seedlings have appeared. Seed is buried by the action of tractors and dragged logs. Most of the buried seed would be amongst the puddled soil of the tractor track, some of the seed would be amongst disturbed but normal soils off the tractor tracks.

Clifford (1953) has reported that some mature seeds of E.regnans require light for satisfactory germination. Free (1951) tested whether the seed from several eucalypt species could germinate from various depths within the soil. He found that a covering of ¼" of soil was best and that seedlings of the species with the larger seeds could emerge from below ½" of soil. Grose (1957) found that the stratification of some eucalypt seeds decreases their need of light for germination, where such a need exists.

These results indicate that burial of E.regnans seed is likely to be harmful. However, Korpinnen (pers. comm.) has made an experiment which seems to indicate that a four inch covering of soil may delay but not prevent the successful germination of E.regnans seed. The following experiment was designed to clear up the position with respect to E.regnans in connection with spot sowing and the timing of the removal of seed trees.

II. EXPERIMENTAL METHODS

All sowings were made in metal tins five inches in diameter, open at the top and perforated at the base. The soil which was used, came from a coupe on dolerite rock burnt two years previously. Two conditions of soil were tested, namely the soil from a tractor track which had been puddled during the previous week, and secondly the normal soil of loose, crumby structure from the top six inches of the undisturbed ground immediately adjacent to the track. The puddled soil resembled a dense, structureless mass of clay.

Two different seed lots were used, namely "A" and "B". Each was sown at a rate of 156 sound seeds. (measured by volume), per pot, but the former contained a much higher proportion of sound seeds (23%) which would not readily germinate in the laboratory, than the latter (7%).

The seed was sown at six depths, namely at 0", ¼", ½", 1", 2" and 4" below the surface of the soil. To ensure uniformity, the normal soil used to cover the seed was sieved. All soils were pressed down to a firmness which is normal in the field. A one inch grid of superficial grooves was scratched into the surface of the puddled soil to imitate the cracks and niches which occur in the field.

There were two replications of each of the 24 treatments.

The soil surface in each plot was ¾" below the brim. All pots were buried to 2" below the brim in random positions into a 3ft. x 4ft. patch of garden soil so that their moisture regime would resemble that of a normal soil surface. The pots were watered once just after sowing. A 50% shade was provided during the first 6 weeks, but this was then replaced by a complete cage of fly-wire to minimise losses of seedlings due to insects.

The sowing was done on 2/9/1961.

III. Results

The scoring was carried on for six months by cutting off and counting all the seedlings which had germinated during the course of each week.

Germinations from the seed which was buried under ¼" of normal soil appeared during the fourth week after sowing and were 99% complete by the end of the 6th week.

All other germinations did not start until the fifth week. 92% of the germinations from ½" depth appeared in the 5th and 6th weeks. In contrast to the very rapid germination of the buried seed, the germinations of the surface sown seed was more widely spread out; only 21% germinated in the 5th and 6th weeks, and germinations continued strongly up to the 15th week.

In spite of their difference in dormancy in laboratory tests, the two seedlots did not differ in the rate and completeness of their germinations irrespective of depth of sowing.

There were no germinations during summer. It is expected that a further but very minor proportion of seeds will germinate in autumn. This should not change the present picture. It will be interesting to find out what happened to the sound seeds which did not germinate. So far only one pot has been dug up unburied and the seed which was sown at 1" depth was searched for. Several "sound" seeds with decaying endosperms were found. There was no sign of any seedlings which had germinated but failed to reach the surface of the soil.

The total number of germinations is shown in Table XI.6. A summary of some statistical analyses is given in Appendix VIII.

Almost no seedlings emerged from the seed buried in puddled soil. Only three seedlings did manage to emerge from $\frac{1}{4}$" depth by making use of an existing crack in the soil.

TABLE XI.6

Results of Seed Burial Experiment

Each figure represents the total number of germinations observed at weekly intervals during 6 months from a sowing of 156 sound *E. regnans* seeds made on 2/9/1961.

Soil	Seed Lot	Replication	Depths at which the seed was buried						
			0"	¼"	½"	1"	2"	4"	Total
	B	I	36	91	36	1	0	0	164
Normal		II	28	68	16	2	0	0	114
	A	I	24	98	24	5	0	0	151
		II	12	61	39	0	0	0	112
TOTAL			100	318	115	8	0	0	541
GERMINATION %			16	51	18	2	0	0	
	B	I	7	0	0	0	0	0	7
Puddled		II	26	3	0	0	0	0	29
	A	I	5	0	0	0	0	0	5
		II	1	0	0	0	0	0	1
TOTAL			39	3	0	0	0	0	42
GERMINATION %			7	1	0	0	0	0	

Only very few seedlings managed to emerge from seed sown below 1" of normal soil, and none came from deeper down.

By far the largest number of germinations, namely 51% of the sound seeds, came from the seed sown at ¼" depth. This rate of germination was about three times higher than those from the sowings both at the surface and below ½" of the normal soil. The differences were statistically highly significant.

The average rate of germination from sowings at the surface of the normal soil was twice as high as those on puddled soil, but the difference failed to achieve statistical significance because germinations were relatively very high in one of the four pots of puddled soil because some particularly favourable cracks had developed here. The "Puddled Soils Experiment" (see section D above) also showed that the untreated surface of puddled soil is relatively unfavourable to the germination of eucalypt seeds. Germination is prevented presumably because the seeds are likely to remain dry, and can be heated to very high temperatures. Germinations on puddled soils in the field can be quite abundant if the weather is cool and moist and if the surface of the puddled soil is roughened.

IV. CONCLUSIONS AND DISCUSSION

Nearly all seeds buried amongst puddled soil and those buried deeper than ½" under normal soil will fail to produce seedlings for the regeneration of the *E.regnans* forests. It is therefore of no advantage to log the seed trees before the seedling regeneration has appeared.

A covering of ¼" of soil does not inhibit germinations, but on the contrary increases the amount and speed of germination, presumably because its protection against seed robbing insects, against temporary drought, and against excessively high temperatures/due to insolation. It would therefore, seem advisable for spot sowing to rake the seed slightly into the cultivated soil and then firm the soil down by stepping lightly on the spot. This measure should improve the overall success and reliability of spot sowing, at least during seasons which are less than perfectly favourable.

PELLETING OF EUCALYPT SEEDS
FOR PROTECTION AGAINST SEED-ROBBING INSECTS

(Paper presented to "Australian Forestry", 1962)

by K.W. Cremer

SUMMARY

Most eucalypt seeds which are broadcast sown on the surface of the ground are lost to insects. This paper describes the development of a technique for reducing these losses by pelleting the seeds prior to sowing. Seed is expensive and is required in large quantities. The cost of pelleting is only a small fraction of the cost of the seed. Field tests indicate that a pound of pelleted seed may produce 1½ to 2 times as many seedlings as a pound of seed which is dusted with D.D.T.

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I. INTRODUCTION

The germination percent[x] of untreated E. regnans seed sown under favourable conditions in the field in Tasmania is normally between 2 and 10%. Dusting the seed with D.D.T. doubles the germination percent (usually about 15%) even though little of the chemical adheres to the seedcoat after some rain. Spraying of the seedbed with insecticide (Dieldrin) effects some further improvement in germinations (Gilbert 1958). With perfect protection from insects about 80% germination can be expected (Cunningham 1960).

In the laboratory, fungi can seriously reduce germinations. It is therefore likely that the fungi in the field may also reduce the viability of seed. About 50% of E. regnans seedlings die at the cotyledon stage. Most of these deaths are ascribed to fungi, probably seed or soil borne fungi.

The control of seed robbing and fungal attack is therefore likely to multiply the efficiency of seed several times. Seed is expensive (£2 to £15 per pound) and impossible to obtain regularly in large quantities. Inexpensive methods of producing real improvement in the efficiency of seed are therefore most valuable.

The insects responsible for the harvesting of eucalypt seeds include small ants and Dieuches bugs (Grose 1957). Both occur in very large numbers, on logged and burnt coupes of the Florentine Valley in Tasmania, where the following investigations were made. It is likely that the seed is often collected for purposes other than consumption. It is therefore possible that

Footnote : (x) Percent of viable seeds which can be observed to germinate.

a mere alteration of the physical properties of a seed (size, shape, colour, surface, texture) will make it unattractive. Whatever is attractive in the seed should be disguised or counterbalanced by a repellent. Alternatively, a hard or abrasive pellet wall may make the consumption of the seed physically impossible to certain types of insects.

A certain thickness of pellet wall may prevent the relatively short proboscis of <u>Dieuches</u> from penetrating to the endosperm of the seed.

Most insect repellents in common use are either volatile (i.e. temporary) or phytotoxic. Some fungicides, especially T.M.T.D. (Woodbury 1943) have some useful repellency. D.D.T. appears to be the most promising repellent. D.D.T. is a residual insecticide, it repels some insects on contact, and is relatively stable on exposure.

Seed pelleting in agriculture and forestry has been employed for purposes such as protection from rodents, insects, or fungi and for provision of certain growth media. There appears to be no report applicable to the problem on hand, except that by Hall (1961) who is experimenting with eucalypt seeds enclosed in a large amount (about one cubic inch) of matrix consisting of peat, paper pulp, insecticides, fungicides and fertilizers. Hall's success is limited, so far.

II. PELLETING TECHNIQUE

Pelleting implies more than soaking or dusting the seed with a chemical. It implies a coating of some thickness. It is here considered that pellets should be uniform and small in size to ensure singleness of seeds and good contact with the soil. Materials used should be water resistant, but preferably water permeable, non-toxic to the seed or seedlings, reasonably stable on exposure, and the chemicals should be compatible with each other. The pellet should have the strength to withstand handling but should permit easy emergence of radicle and cotyledons.

A "sticker" or glue is needed to ensure adequate adhesion of insect repellents and fungicides to the seed coat. An inert, powdery diluent is needed to dilute the active chemicals so that only tolerable concentrations will adhere to each seed. Chemicals are needed which will protect the seed from insects and fungi without harming the seed or the seedling.

(1) <u>STICKERS</u>

The following stickers, considered potentially suitable, were tested. In each case the seed was wetted with water or with the sticker and was then stirred rapidly with excess powder until the pellets separated out. Uniformity and small size of the pellets was ensured by passing all the material through a sieve of suitable aperture (fly wire). A second sieve of much smaller aperture was used to remove the excess powder. Nearly fifty pelleting techniques were tried out. These are the main ones :-

<u>Starch</u> was discarded because it is water soluble, unstable on exposure, and highly toxic to the seed.

<u>Gelatine</u> (edible) was rejected from the same reasons as starch.

<u>Casein</u> (Containing 7% of the toxic NaF) was found to be

insufficiently water resistant and excessively toxic.

P.V.A. (Polyvinylacetate) was eliminated because the pellets produced were not water resistant.

$CaSO_4$. (Plaster of Paris) used as dust with water only as a sticker did not withstand washing. A dough of $CaSO_4$ with a sprinkling of seeds amongst it can be crumbled up before it sets hard. The resulting pellets were too irregular in size, and many of the seeds were entirely free of matrix.

M.E.C. (Methyl ethyl cellulose) was the only watery glue which produced a reasonable pellet with $CaSO_4$ dust. All requirements were satisfied except that the matrix had no adhesion to the seedcoat. This permitted the pellet shell to split away from the seed in the field. This method of pelleting, while not ideal for this program could well be used to re-pellet successful primary pellets of very small size (those below) to give them the weight necessary for sowing from the aeroplane, to avoid excessive drifting of the seed in the presence of wind.

If the $CaSO_4$ shell could be made stronger it might make a good primary pellet.

Asphalt ("Terolas" made by Shell) was found to be a very satisfactory sticker. It is water soluble but water permeable, non-toxic, easy to use and stable on the ground for 4 to 6 months. The emulsion supplied gave best results after dilution with 5 to 10 times its volume of water. When used undiluted, this sticker caused some delay in germinations.

Latex (water suspension made by Dunlop) is as good as asphalt and has the advantage that it can be stored indefinitely as a glue. Its water impermeability and its 0.5% content of ammonia did not prove harmful. The suspension made by Dunlop had to be diluted for easy pelleting - with 5 to 10 volumes of water.

Rubber (solution in petroleum solvent; "S17" made by Dunlop). This sticker made the biggest and toughest pellets. Its benzene content, though toxic to humans, was not obviously harmful to the seeds. It was harder to use in pelleting and proved inferior to latex and asphalt in the field. Diluting it with a petroleum solvent may reduce these disadvantages.

(2) POWDERY DILUENTS

Lime was found to be toxic. Ordinary talcum powder could not be used because it was not easily wettable. Plaster of Paris was moderately suitable, but tended to be so greedy for water that the stickers dried prematurely. There was a small delay in the shedding of the shell of Plaster of Paris from the cotyledons. Kaolin was the smoothest and easiest to use. It was apparently not toxic or harmful in any way.

(3) INSECT REPELLENTS

Apart from the potentially repellent fungicides, stickers, and powdery diluents, only D.D.T. was tried out. Pellets containing 10% D.D.T. in the matrix produced seedlings of slightly reduced vigour and with few root hairs in the laboratory. ~~A~~ One percent of D.D.T. in the pellet matrix did not affect the seedlings.

The literature suggests that other suitable insect repellents may be very hard to find.

(4) FUNGICIDES

The toxicity of the fungicides as well as all other chemicals mentioned was tested by one or both of two methods. Firstly, about 0.2 grams of seed were sprinkled with about 0.1 grams and 1.0 grams of the chemical in each of two petri dishes with germination pads. Secondly, the promising chemicals were incorporated at various concentrations in various pellets and each tested in two petri dishes. The pads were kept moist and between 60 and 70°F. Degrees of toxicity were as follows: <u>mildly toxic</u>, recognizable mainly by a slight delay in the emergence of the radicle and by a reduction in germination percentages as determined by squash test; <u>moderately toxic</u>, recognizable by short hypocotyl, short epicotyl, or lack of root hairs; <u>very toxic</u>, failure of germinations to appear or the above symptoms in extreme forms.

A pellet which proves slightly toxic in the petri dish is likely to be more normal in the field because the rain would tend to wash the chemicals away from the seed.

<u>Sulphur</u>. Redispersible, colloidal sulphur was used with 75-80% active content. Sulphur was relatively harmless to both seeds and fungi in the laboratory.

<u>Cuprox</u>. The product used contained 50% coper oxychloride. Cuprox used in excess is moderately toxic to the seed. It was not effective in excluding fungi from petri dishes at concentrations which were harmless to the seed.

<u>Zineb</u> was used in micronized form with 65% content of zinc ethylene bisdithio carbamate. Zineb was better than Cuprox but harmful to the seed at concentrations effective against fungi in the laboratory.

T.M.T.D. The formulation contained 80% tetramethyl thiuram disulphide. When used in excess T.M.T.D. was very toxic. At a concentration of 0.07% in the pellet matrix it was harmless to the seed but kept fungi out of the petri dishes. With asphalt used as sticker the root hairs were not as abundant as with latex, and emergence of the radicle was a little delayed.

Mercury. This product called "Baytan" contained 3% of "organically combined mercury". It is highly toxic to humans and seeds. At .0025% concentration in the pellet matrix it was effective in controlling fungi in the petri dish but was almost harmless to the seeds. Pelleting with asphalt appeared to be a little better than with Latex.

FIELD TESTS

The field tests were designed to assess the protection against insects and fungi given to the seed by the pellet types which were found to be most promising in the laboratory. The relative advantage of pelleting was expected to be greatest under the most adverse conditions. Germinations in winter probably suffer the severest fungal attacks. Seed exposed during summer is in greatest danger of being found by the insects before it germinates, often after a long delay.

(1) The Autumn 1960 Field Test

METHODS

Eight pellet types were compared with each other, with bare seed, and with seed dusted with as much 50% D.D.T. powder as would adhere to the dry seed coat.

All pelleting matrices contained 5% D.D.T. The pellets were made up of one volume of seed plus $1\frac{1}{2}$ to 2 volumes of pelleting matrix. Four methods of pelleting were tried viz. MEC with $CaPO_4$; latex with kaolin, rubber with kaolin, and asphalt with kaolin. The matrix used for these pellets contained 4% of sulphur. To compare the different fungicides another four pellets were produced, using Zineb (2%), Cuprox (1%), TMTD (3%), and Mercury (0.03%) respectively to replace the sulphur in the MEC with $CaSO_4$ pellets. The ten treatments were randomly assigned to ten quarter-milacre plots in each of eight blocks.

The blocks were distributed as follows -

Coupe at Road 8W : Blocks 1 and 2 are on seedbed burnt in March 1960.

Coupe W56 : Blocks 3 and 4 are on seedbed burnt in March 1960.

Blocks 1-4 are on normal seedbeds, for broadcast sowing.

Coupe W62 : Blocks 5 and 6 are on seedbed burnt in March 1958 and cleared of mosses and fireweeds. This is normal for spot sowing.

Coupe W69 : Block 7 is a tractor track with crumbling surface soil; Block 8 was burnt in March 1958 but was not cleared of its cover of mosses; (Funaria Hygrometrica and Ceratodon purpureus).

Sowing was at the rate of one ladle of seeds per plot.

Pelleting was done separately for each plot, after ladling. One ladle gave an average of 392 germinations after 58 days at about 60°F in the laboratory. The germinations were slow and represented only 79% of all sound seeds, indicating a high degree of normal dormancy. Because none of the blocks were within 300 feet of the nearest eucalypt tree, and because the rate of sowing was so extremely high, the possibility of germinations from natural seedshed was justifiably ignored.

Sowing of bare seed and of asphalt pellets was done on 26.4.62; all the rest were sown on 12.4.60. Pelleting was done 3 to 6 days prior to sowing. Spare quantities of all pellet types were stored for 5 months and then tested for germinations in the laboratory. There was no obvious ill effect due to storage; because squash tests were difficult, precise data were not obtained on this point.

All plots were scored at monthly intervals until practically all germination had ceased. The position of each new seedling was marked with a coloured nail. All one month old seedlings were removed at each scoring because only the mortality during the first month was studied.

RESULTS

The results are summarised in Table I. A summary of the statistical analysis is given in Appendix VII.

The germinations on recently burnt ground were more than four times as numerous as the germinations on the older burns. The two sites were therefore analysed separately.

Most types of pellets yielded many more germinations than bare or DDT-dusted seed, both on the recent and on the older burns. However, the treatment differences on the recent burn were not statistically significant. This can be ascribed to the great variability of the results, and due to the interference of heavy rain which washed some pellets from some of the plots.

The treatment differences on the older burns were highly significant. L.D.S. and A.D.S. were not significantly different from each other but were very significantly superior to bare and to DDT-dusted seed. This experiment did not prove that DDT-dusted seed is superior to bare seed, but it agrees with the results of Gilbert (1958) and others who found that dusting the seed with DDT doubles the rate of germination in the field.

The older burns have much higher populations of seed robbing insects. It might therefore be expected that pelleting is relatively more effective on the older burns. The experimental data support this, but are not statistically significant on this point.

The results of this experiment are extremely encouraging

TABLE I.

RESULTS FROM AUTUMN 1960 FIELD TEST

This table shows the mean of the cumulative number of new seedlings observed at monthly scorings during the first nine months after sowing expressed as a percentage of the number of sown viable seeds. The 80 plots were each 1/4000 acre in size, and were sown in April 1960 with 392 viable seeds each.

TYPE OF PELLET		GERMINATION PERCENT ON RECENT BURN	GERMINATION PERCENT ON OLDER BURN
1. MEC + DDT + Zineb	(MDZ)	19.6	3.5
2. MEC + DDT + Mercury	(MDH)	33.3	2.3
3. MEC + DDT + Cuprox	(MDC)	23.2	7.1
4. MEC + DDT + TMTD	(MDT)	33.5	3.3
5. MEC + DDT + Sulphur	(MDS)	22.8	5.8
6. Latex + DDT + Sulphur	(LDS)	36.9	11.4
7. Rubber + DDT + Sulphur	(RDS)	25.5	6.6
8. Asphalt + DDT + Sulphur	(ADS)	24.9	13.9
9. DDT dusted seed	(DDT)	19.8	3.4
10. Bare Seed	(Control)	12.6	1.8
Average		25.2	5.8
S.E. of difference between means		8.39	2.35
Significant difference between means			
- at 1% level		23.2(x)	6.5
- at 5% level		17.2(x)	4.8

(x) Analysis of variance shows that the differences between the treatments on recently burnt ground were not significant, while the differences on the older burns were highly significant.

and suggest that the best pellets (Latex, Asphalt) are four to six times as good in terms of germination percentages as the bare seed.

The pattern of the course of germinations is illustrated in Figure IX.4 and was not affected by pelleting. The study of death rates due to fungus was inconclusive because by far the greatest cause of mortality on the experimental plots was due to frost lift. There was no consistent difference in mortalities due to any of the treatments.

Frost lift was very severe on many of the plots, often lifting as many as half of all seedlings. The seedlings were susceptible to frost lift because of their short roots. This was similar on control as well as pelleted seed, and could be ascribed to the very slow growth rates in winter. Nevertheless it was decided to reduce the proportion of all chemicals which might affect root growth right down to the level which had proved harmless in previous petri dish experiments.

(2) The Spring 1960 Field Test

METHODS

This time only four types of pellets were tested and compared with bare and D.D.T.-dusted seed. Three stickers were tested; rubber, latex, and asphalt. The latter two stickers were diluted with 9 times their volume of water. The matrix for each of these pellets consisted of kaolin, 1% of D.D.T., and 0.0025% of mercury. The two most promising fungicides were compared by making an additional asphalt pellet with 0.07% of T.M.T.D. instead of the mercury.

Seven blocks of 6 plots each were sown on 16.10.60. Blocks 1 and 2 were at Gold Creek on seedbed burnt in March 1960. Block 3 was at W56, burnt in March 1960 and was sparsely covered by shallow mosses. Blocks 4 and 5 were at W72, and blocks 6 and 7 at W61, all burnt in March 1958 and cleared of mosses and fireweeds before sowing.

Scoring in both experiments was at monthly intervals. All seedlings were pegged with coloured nails when they appeared. The pegged seedlings were retained for one month to give mortality figures. The seedlings were then pulled out together with the nails.

RESULTS.

The October sowings in the Florentine Valley during each of the years from 1955 to 1959 all germinated promptly and amply before December. However, the Spring and Summer of 1960/61 was so dry that only 12% of all observed germinations came up within eight months of sowing. Consequently most seeds were subjected to a large period of exposure to high temperatures and great insect activity. Most germinations (89%) occurred in May-July. However, probably because of the extreme exposure to heat and seed-robbing insects, the total germinations were very few.

The results are summarised in Table II. The pelleting did not improve the very low germinations percentages obtained in this experiment. In fact, a preliminary analysis showed that none of the treatments means were significantly different from the control. It is remarkable, once again that germinations were much more numerous on freshly burnt ground than on the older burns.

TABLE II Results of the Spring 1960 Field Test

Treatment	% of viable seeds observed to Germinate - On Recent Burn	on Older Burn
Asphalt + DDT + TMTD	2.8	1.2%
Asphalt + DDT + Mercury	3.8	0.9%
Latex + DDT + Mercury	2.6	0.3%
Rubber + DDT + Mercury	4.1	0.7%
Bare Seed	3.3	0.3%
DDT Dusted Seed	6.1	1.3%
Average	3.9	0.8%

A number of significant observations were made a few days after sowing. At W72 large numbers of Dieuches bugs were seen to visit the experimental plots. All types of seeds, pelleted and unpelleted, were being carried about by the bugs. The D.D.T. seemed to have no effect. About 1,000 viable seeds mixed amongst ten times this number of chaff particles were placed on a cloth and exposed at W72 for one month during November 1960. After the exposure apparently all the chaff was still on the cloth, but no sound seed could be found. These observations suggested that insects, Dieuches bugs in particular, can remove very great amounts of seeds; and that present methods of pelleting are far from perfect.

(3) Winter 1961 - Field Scale Test

METHOD

The sowing of this experiment was done by the A.N.M. Company. The aim was to compare standard sowing practice with the most promising type of pellet. A randomized block experiment with three replications was adopted. There were three blocks on freshly burnt soil (one at Road 7A, one at L35, and one at W82). Each block consisted of two adjacent plots of one acre each, except that the Road 7A plots were two acres each.

The control plots were sown at the rate of 1 lb. of seed per acre, and the seed was dusted with D.D.T. and mixed with wet sawdust. The pellet plots were sown at ½ lb of seed per acre. The seed was pelleted with latex diluted in 7 volumes of water, and using a matrix which consisted of 1,000 parts of kaolin, 50 parts of 20% D.D.T, and 1 part

80% T.M.T.D. The entire area of each plot was evenly sown between 27.7.61 and 3.8.61.

The seedlot which was used, contained 107,000 sound seeds per pound; and 83,000 seeds per pound germinated in the laboratory at 65°F in four weeks.

The plots were assessed on 13/17.11.61 by counting all seedlings on milacre plots spaced at half chain intervals.

RESULTS

Germinations began one month after sowing, reached a peak in late October, and had practically ceased by the time of scoring in the middle of November. Judging from repeated inspections of heavily sown, adjacent observation plots, death rates were low. Few plants were killed by draught. By March 1961 both treatments had produced similar crops of very vigorous seedlings averaging perhaps nine inches in height. The pelleting did not obviously affect the survival and growth of seedlings.

TABLE III Results from Winter 1961 - Field Scale Test

	No. of sample plots	% of S. plots stocked	Observed Germination %
PELLETS			
W35	42	67%	9%
Rd. 7A	77	68%	5½%
W85	33	12%	1%
Average.			5.08%
CONTROL			
W35	44	84%	5½%
Rd. 7A	77	72%	4½%
W85	33	18%	½%
Average.			3.47%

Note that Control was sown at double the rate which was used for Pellets.

The distribution of seedlings on the ground suggests that the amount of germinations was very strongly influenced by seedbed conditions and that moisture has been a main limiting factor. Very few seedlings occurred on hard ground exposed to the sun. Most seedlings occurred in moist and shaded hollows, very especially where the soil was loose and crumbly (but not dusty).

The great advantage on the loose, crumbly soil, where a foot can sink 1-6 inches deep, is that the seed is buried. This was confirmed by pulling the seedlings up and noting the depth of the root collar.

It is therefore not surprising that the differences due to sites were much greater than the differences due to treatments.

W.35 has a lot of soft crumbly soil, (more than the two other sites) and had the most abundant germinations. W.82 has very little soft crumbly soil and had extremely few germinations. Road 7A is intermediate.

The relative advantage of pelleted seed could easily have been increased or decreased by chance differences in seedbed conditions. Some scoring of seedbed types was done and it appears that the seedbed favoured the unpelleted seed on the average.

The pelleted seed did in fact produce about one and a half times as many seedlings as the unpelleted seed.

(4) <u>Field Tests made by the Tasmanian Forestry Commission</u>

The materials and techniques used were the same as those described above for the Winter 1961 Test in the Florentine Valley except that all rates of sowing were 50% higher.

RESULTS

Location of Experiment	North. Tasmania	South. Tasmania
Date of Burn	March 1960	January 1961
Area Sown	12 Acres	24 Acres
Date of Sowing	July 1961	September 1961
Date of Assessment	December 1961	November 1961
% of milacres stocked:		
Pellets	28.1%	54% (13/24)
Control	28.6%	61% (14/23)

Proof. These results indicate that pelleting approximately doubled the effectiveness of the seeds. — double quantity of seed on controls?

IV. DISCUSSION AND CONCLUSIONS

At present at least 1,000 lb. of eucalypt seed is being used annually in Australian forestry for broadcast sowing, and this technique of regenerating the most valuable eucalypts is bound to gain increasing favour as the economy and reliability of broadcast sowing are improved.

Pelleting by hand costs about 5/- per pound of seed for labour and materials; i.e. the cost of pelleting is only a small fraction of the price of the seed. The field tests indicate that pelleting improves the efficiency of seed by 50 to 100%. Hence pelleting is worthwhile, especially when seed is scarce.

Protection of seed against insects is extremely valuable but cannot guarantee the success of broadcast sowing unless other factors such as seedbed and climate are also favourable. The above experiments and observations show that the present pelleting technique gives useful but far from perfect protection against insects. There is therefore much scope for further useful research on this matter.

RECOMMENDED PROCEDURE FOR PELLETING

Use latex or freshly prepared asphalt emulsion diluted about seven times with water. Use enough sticker to just wet all seeds. Then stir rapidly with excess powdered matrix consisting of : 1,000 parts of kaolin,

plus 10 parts of 100% D.D.T.

Plus 1 part of 80% T.M.T.D.

or 1 part of 3% organically combined Mercury.

Ensure uniformity of pellets by passing them through a large sieve (e.g. of fly wire, 1/12" aperture), and then sieve off excess matrix through a finer sieve, after rubbing off any loose matrix. Dry the pellets immediately to remove ammonia and water. Do not store the pellets for many months in case long term storage proves harmful.

ACKNOWLEDGEMENTS

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REFERENCES

CUNNINGHAM, T.M. (1960) - The Natural Regeneration of Eucalyptus regnans. Bull. No. 1, School of Forestry, University of Melbourne.

GILBERT, J.M. (1958) - Eucalypt - Rainforest Relationships and the Regeneration of the Eucalypts. Ph.D. Thesis, University of Tasmania.

GROSE, R.J. (1957) - A study of some factors associated with the natrual regeneration of alphine ash. (E. delegatensis). Forestry Commission of Victoria. Bull.No.4.

HALL, M.J. and RICHMOND, K.P. (1961) - Recent trends in eucalypt reforestation in Gippsland, Victoria. A.P.P.I.T.A. 15, 1:35-45.

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CHAPTER XII

THE BROWSING PROBLEM

1. THE CULPRIT SPECIES

Serious damage through browsing by marsupials to eucalypt seedlings has been recognized in several areas of Australia. Gray (pers. comm.) in N.S.W.; Ashton (1957) in Victoria. G ilbert (1961) has shown that browsing may greatly reduce the survival and growth of E.regnans seedlings in the Florentine Valley. He found that the incidence of browsing became frequent when the eucalypt seedlings reached the four leaf stage and increased in severity beyond the ten leaf stage (5"). He observed that "all forest species" are browsed. He concluded that the possum was relatively unimportant because none had invaded his fenced plots on a completely felled coupe.

Mollison (1960) confirmed that possum, wallaby and kangaroo are the only large herbivores present in important numbers in the Florentine Valley. He showed that each of these species can eat large quantities of eucalypt foliage.

The main aim of the fenced area at W56 (22 acres) was to study the benefit of protection from browsing. It was found that possum crossed the fence. This opportunity was taken to assess the relative importance of possums by permitting their activity inside the fence from December 1958 till March 1959. At other times the inside and periphery of the fence were poisoned as soon as any damage appeared, by using strychnine or 1080 on apple bait placed on top of stumps which were accessible to possums and not to wallabies.

Table XII.1 gives an indication of the importance of browsing damage by possum alone, and affords some comparison with the other animals. The plants were scattered over a considerable area: more than six acres inside the fence, and six one-quarter acre plots scattered outside the fence. This mea ns that the results were not due to chance location of a plot within the range of one odd animal.

The figures indicate that possum can inflict widespread and fairly severe damage. In fact, the browsing damage done outside the fence at this time was not much greater than that done inside the fence. If possum densities were similar on both sides of the fence this means that the two wallaby species were less destructive than the possum. This puts the possum into perspective as a major culprit.

TABLE XII.1

Comparison of Browsing Intensity by Possum Alone (Fenced) as Against all Browsing Animals Combined. (N ot Fenced)

Experiment	Date of score	FENCED No. of plants scored	FENCED % of plants severely browsed	NOT FENCED No. of plants scored	NOT FENCED % of plts. severely browsed
Aut'58 spots	12.5.59	851	41%	282	31%
" '58 broad-cast	23/2/59	397	7%	32	0%
Spring '58 planting	6/7/59	286	28%	100	66%
Spring '58 spots	15/5/59	136	52%	72	95%
Spring '58 broadcast	15/5/59	334	15%	187	37%
Aut'59 planting x	16/3/59	140	2%	98	17%
TOTAL		1760	31%	776	40%

Note: In Autumn '58 all the plants were scored. At other times the plants which were less than one inch tall and showed no sign of browsing damage, were excluded from this table.

x Planted only six days before scoring.

B. TYPES OF DAMAGE DONE BY BROWSING

I. DAMAGE TO EUCALYPTS

Up to six inches or even more of a seedling's shoots may be browsed.off. Small seedlings are commonly bitten off at ground level, and sometimes are even up-rooted. Seedlings with few branches or less than two feet tall are commonly completely defoliated, taller or bulkier seedlings more rarely so. Damage sometimes extends up to 4 or 5 ft. above ground level. It is suspected but not certain that the possum sometimes climbs saplings and eats their leaders. In most cases, defoliation of the top of a sapling is due to insects. Gilbert (1958) found that browsing is not extensive until the seedlings have rea ched a minimum size or bulk, namely the 2 or 4 leaf stage. The older leaves of taller plants and the leaves of stagnant plants are apparently less palatable than young and tender leaves. Bitten off portions are usally consumed. Some rare instances where the intact leaves minus part of their petioles lay scattered beneath the defoliated plants have been attributed to possum (see also Pracy & Kean, 1949). Another, more common characteristic of possum is to leave a very jagged midrib and the base of the leaf attached to the browsed plant. In the Florentine Valley the bark of eucalypts is apparently not attacked by any animals other than insects.

The severity of damage by browsing is greatest where the plants are most easily accessible, i.e. on tractor tracks. Accessibility differs only little for possum as against wallaby. Logging slash and weed growth may afford niches of protection. The possum is an able climber but seems to do most of its feeding and defecating on the ground.

II. DAMAGE TO PLANTS OTHER THAN EUCALYPTS

The herbaceous stem of *Erechthites* is often preferred to its leaves. The uneaten leaves can often be found scattered around the damaged stem. With this exception the type of browsing damage is similar on all plants species, namely the tender leaves and shoots are eaten. Tenderness is only a relative criterion within a species. Some very tough species such as *Carex*, *Juncus* and *Coprosma* are browsed intensively. With the conspicuous exception of most ferns, apparently all spedies of plants are palatable. Even the fruiting bodies of mosses, liverworts and some fungi are eaten. The strongly scented *Zieria* appears to be relatively unpalatable.

In a co-operative experiment with Mollison (1960), an assessment was made of the relative palatabilities of the different plant species by inspecting 80 half-milacre quadrats which were systematically located inside and outside the fence at W56 in June 1959.

Outside the fence 36% of all seedlings were browsed, inside the fence only 26%. This ratio of 1.4 to 1 in browsing intensities was similar for all species recorded in significant numbers. (Eucalypts, *Pomaderris* *Acacia*, *Hydrocotyle*), except for *Erechthites* which was 4.7 to 1. This means that *Erechthites* was the only plant which was relatively more heavily attacked outside the fence than inside. *Erechthites* was therefore either more palatable to the wallabies than to the possum or else the *Erechthites* was more heavily browsed because of the relative scarcity of alternative plants outside the fence. It would appear from this assessment that wallaby and possum have similar tastes for several important plant species. On one other occasion numerous, well scattered, browsed eucalypt seedlings were observed hidden amongst entirely unbrowsed plants of *Pomaderris* and *Acacia* inside the fence at W56. This suggests that the possum may at times seek out and prefer eucalypts.

Except for *Erechthites*, 25 to 33% of all the individuals of the plant species mentioned above were browsed. Only 15% of the individuals of *Erechthites* were bfowsed.. This means that *Erechthites* was apparently less palatable than the other species, but all the other species were similar in palatability.

Gen eral observations elsewhere show that the ferns Pteridium, Histiopteris and Hypolepis are the only important, really unpalatable plants. The strongly scented Zieria is apparently less palatable or less vulnerable from browsing. The result is that browsing may cause an area which is regener ating mainly to Pomaderris and Acacia to become dominated by Zieria for many years. This latter point is illustrated by the data given in Table XII.2 which is based on a co-operative project with Cunningham (1961). Two years' browsing changed the proportion of Zieria amongst the woody plants from one fifth to three quarters.

Table XII.2 (see page 308).

The Effect of Browsing on the Survival and Growth of the Scrub ~~Ser~~ spec ies which Regenerate after Burhing.

The effect of browsing on the survival and growth of woody vegetation is dealt with in Chapter XIII. It was condluded that most areas in the Florentine Valley have enough seeds of woody species stored in the soil to produce a dense thicket of shrubs soon after the forest is burnt. Browsing by native animals can greatly delay or even prevent the establishment of a shrub thicket.

Pomaderris is one of the main shrub species and seems to be particularly easy to kill by browsing.

TABLE XII.2

The effect of Browsing on the Composition of the Scrub which Regenerates after Burning.

The number of plants per acre was estimated on 1/12/61 by scoring 10 systematically located milacre quadrats on the burnt ground, and by inspecting the adjacent unburnt forest. All three areas were within 5 to 10 chains of each and had originally carried the same type of forest.

	Number of plants per acre on 1/12/61			
	Olearia	Acacia	Pomaderris	Zieria
xxx unburnt forest	100	100	10,000	0
x burnt March 1961	700	29,000	46,100	18,100
xx burnt March 1959	800	900	2,300	10,400

x Seedlings had just germinated and were scarcely affected by browsing.

xx These seedlings had suffered the effects of two years' browsing.

xxx The browsing pressure after an extensive wild fire which gave rise to the virgin forest was probably not high because the population of animals per unit of burnt area would not be high.

At W56 the three years' browsing reduced the number of *Pomaderris* plants to 2,000 individuals per acre nearly all less than one foot tall, while inside the fence 60,000 individuals per acre were surviving and most of these were 3 to 6 ft. tall. At the same time the browsing outside the fence reduced the survival of eucalypts by only about one half (see below). This means that the eucalypts survived browsing much better than *Pommaderris*. Since competition with *Pomaderris* is probably harmful to the eucalypts, it is possible that a certain amount of b row-sing is in the long run beneficial to the eucalypts.

The effect of scrub on the survival and growth of eucalyp ts and factors, such as browsing, which determine the density and composition of the scrub are discussed in a paper by Cunningham and Cremer (1962).

III. THE EFFECT OF PARTIAL AND COMPLETE DEFOLIATION ON THE SURVIVAL AND GROWTH OF E.REGNANS SEEDLINGS

(1) EXPERIMENTAL DETAILS

(a) Aim of the Experiment:

It had been noted that many eucalypt seedlings die from the effects of browsing, while others made amazing recoveries. An experiment was designed to find out the effects of different degrees of browsing damage and their interaction with time of browsing.

(b) Experimental Methods:

From extensive observations of pegged plants it was found that nearly all browsing damage consisted in complete or partial defoliation, with or without removal of tender shoots. This was imitated by two treatments, namely:-

(a) Complete defoliation, i.e. cutting off all leaves over one inch long - without injury to any buds.

(b) Pruning of the plant to 1/3 of its original height. This treatment left at least 2" of stem which could sprout buds, and usually still retained some leaves.
Decapitation to below cotyledon level is lethal because no potential buds are available then for recovery.

The experiment does <u>not</u> imitate repetitive browsing. Repetitive browsing can often be found in nature and may be more destructive than a single browsing. 240 healthy eucalypt seedlings between 4" and 12" tall were pegged and numbered in January 1959 on each of two areas (John Bull nursery near Maydena, and Lawrence Creek gravel-loam quarry in the Florentine). Treatments were carried out monthly.

Defoliation was alternated with pruning on 20 plants which were randomly selected each month. On each area twenty random plants wer e kept under observation without treatment as controls. In December 1959 it was decided to replicate the defoliation treatment in both areas over the important part of another season, viz until July 1960. A furth er 10 plants were defoliated in September 1960 at Tyenna 4 miles from Maydena. If a plant had grown to over 18" height between the times of selection and treatment, it was rejected in favour of the nearest untreated plant between 6 and 12 inches tall. There was no browsing.

Scoring was at monthly intervals at first, and irregular later on. Each plant had a separate history sheet of height growth, die-back and bud behaviour. In the analysis the pruned plants which were left without leaves are included with the defoliated plants.

(2) <u>EXPERIMENTAL RESULTS</u>

(a) <u>Mortality</u>:

The results are set out in Table XII.3. The trends were so similar on both experimental areas during

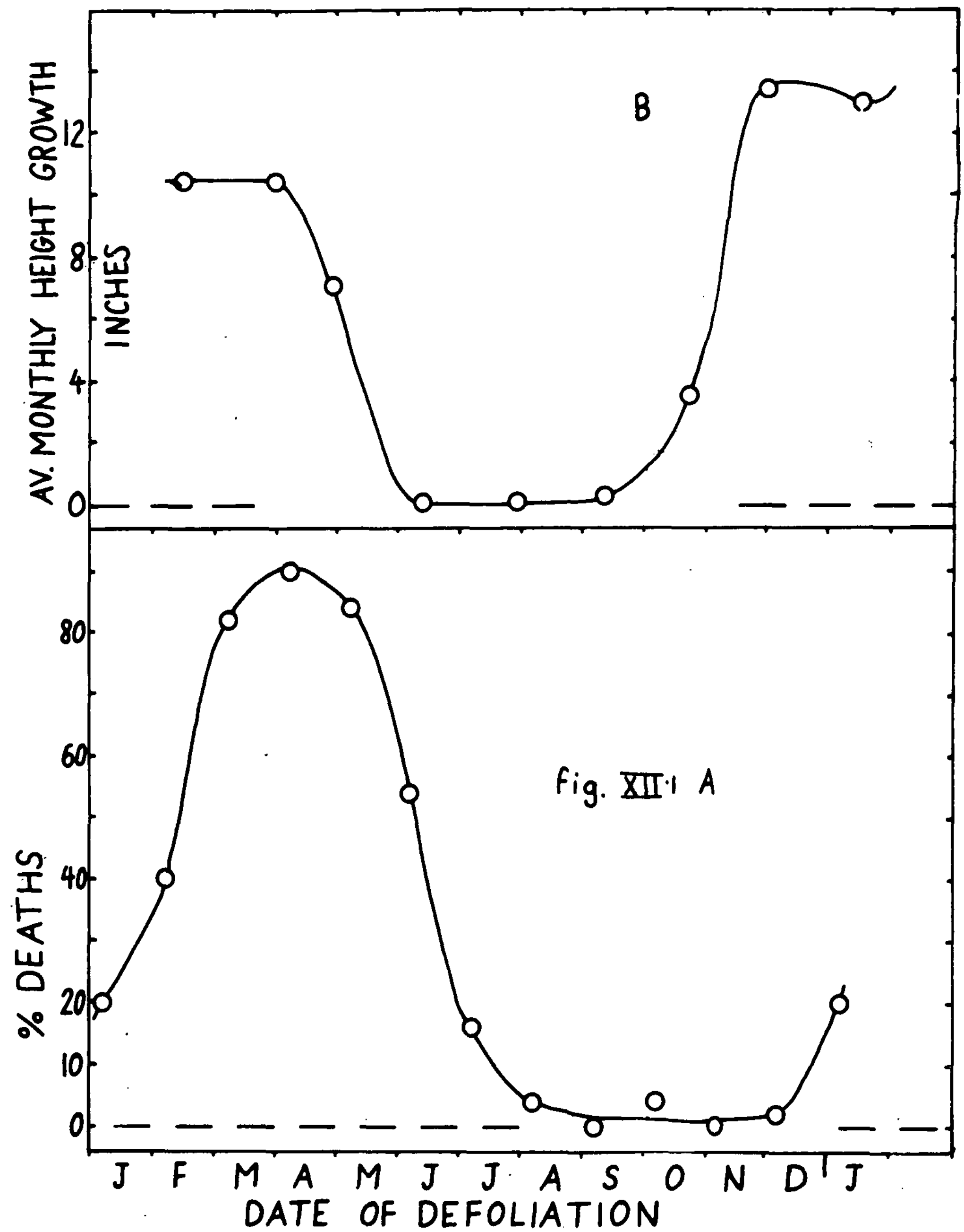
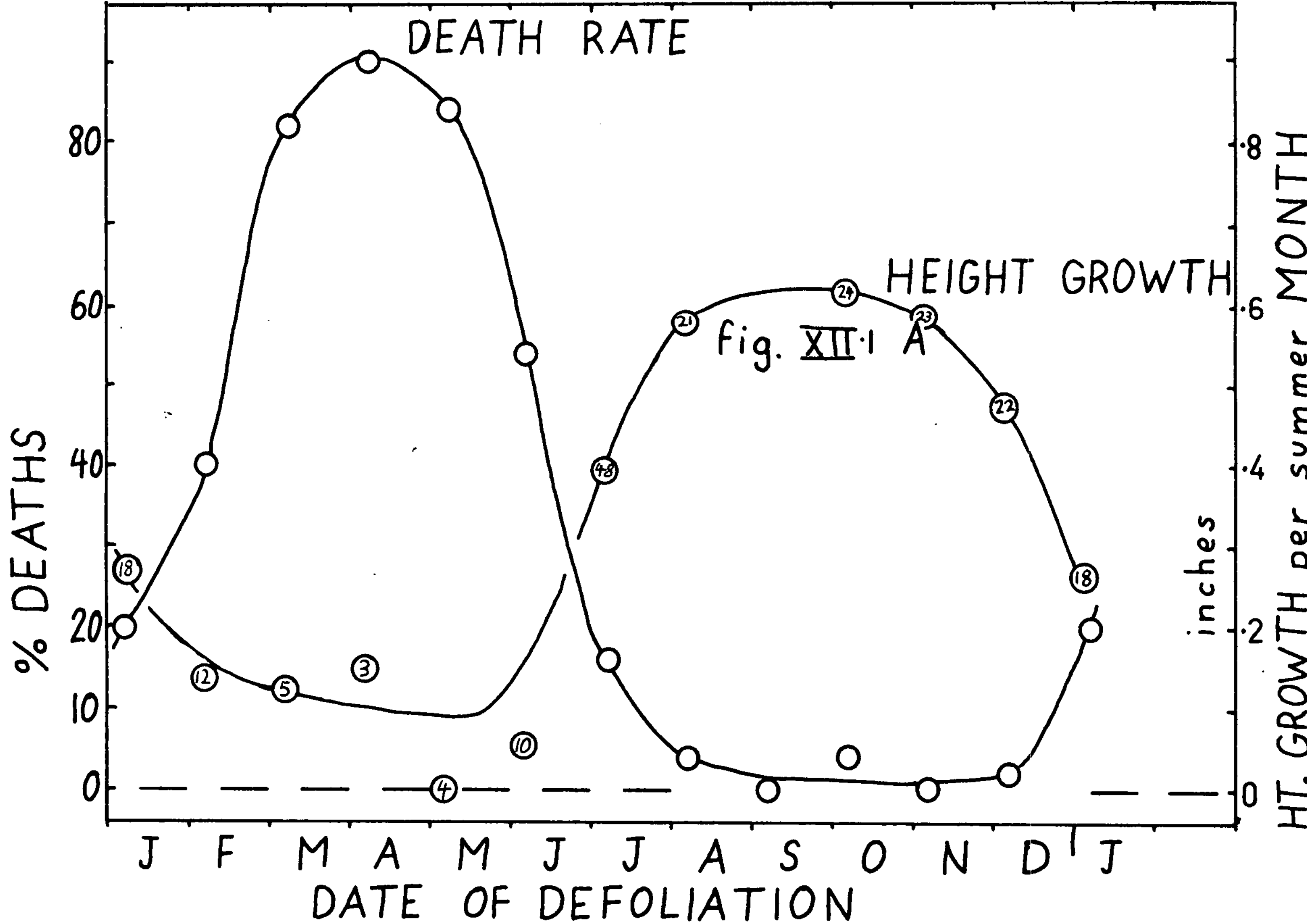


Figure XII. 1 The effect of defoliation during the various months of the year upon death rate of 4–18" tall *E. regnans* seedlings within one year of treatment. Each point is based on about 20 randomly selected plants. Part B shows the extent of the dormant season.

Figure X11.1 A : Height growth. This figure refers to the plants which survived defoliation. It records the mean monthly height growth during the first $3\frac{1}{2}$ to $8\frac{1}{2}$ months of growing season after defoliation. The figures inside the circles indicate the number of plants contributing to each result. Note: The controls which were not defoliated grew at a rate of 1.5 inches per month of growing season.


DEATH RATE
HEIGHT GROWTH
fig. XII·1 A
% DEATHS
80
60
40
20
10
0
·8
·6
·4
·2
0
HT. GROWTH per summer MONTH
inches
18
12
5
3
4
10
48
21
24
23
22
18
J F M A M J J A S O N D J
DATE OF DEFOLIATION

both years, that the data have been averaged for each month and then presented in Figure XII.1.

The experiment shows that a single, complete defoliation can kill a large proportion of seedlings between 4 and 18 inches tall.

The effect of defoliation varied greatly with the seasons. Defoliation during the five months from February to June killed more than half of the seedlings, while defoliation during the five months from April to December was followed by a death rate of only 3%, which was also normal for the untreated plants. It is concluded that browsing during autumn is much more destructive than browsing during spring time.

Provided at least one fairly healthy lea f remains attached to the 4 to 18" tall plants, even very heavy pruning at any time of the year was rarely fatal.

On 9/5/60 fifty 4 to 10 ft. high seedlings of E.regnans on a roadside were cut off at 6" to 12" above ground level. Half of the seedlings retained a few suppressed old leaves, while the other half were completely defoliated. The mortality was 65% and 100% respectively. This shows that even taller seedlings can easily be killed by defoliation, and that retention of a very small, senile proportion of the original foliage is often not sufficient to preserve the life of the seedlings.

It is concluded that, other things being equal:

1. Protection of seedlings from browsing is very

TABLE XII.3

Effect of Defoliation or Pruning on Mortality of 4 to 18 Inches Tall *E.regnans* Seedlings.

Date of Treatment: 5th +_ 2 days in each month of:		Death rate after one year					
		After defoliation			After pruning		
		At John Bull	At Lawrence Creek Qry.	Total %	At John B ull	At Lawrence Creek Qry.	Total %
1959	F	3/10	-	30	0/10	-	0
	M	7/11	-	64	1/9	-	11
	A	9/11	9/11	82	0/9	0/9	0
	M	7/10	13/14	83	1/10	1/6	12
	J	8/11	6/15	54	9/9	0/5	0
	J	1/11	2/15	12	0/8	0/5	0
	A	0/10	1/15	4	0/10	0/5	0
	S	Not Done					
	O	0/10	1/13	4	0/10	0/7	0
	N	0/10	0/13	0	0/9	0/7	0
	D	1/10	0/11	5	0/10	1/9	5
1960	J	2/10	2/10	20			
	F	6/10	3/10	45			
	M	9/10	9/10	90			
	A	10/10	9/9	100			
	M	9/10	9/10	90			
	J	7/10	4/10	55			
	J	5/10	1/20	20			
	A	Not Done					
(At TyennaS		0/10		0		Total	3
Control		1/20	0/20	3			

much more important during February to June, than during August to December.

2. Brushing of eucalypt growth on roadsides is most effective ~~and~~ if done during February to June, and if all or nearly all leaves are removed. Otherwise many of the eucalypts will sucker and grow up again quickly.

3. On plants defoliated during the danger period, die-back began soon after defoliation and continued until complete or until October.

The corollary of these findings is that most leafless plants observed during May to June are bound to die. Most leafless plants seen in September to December will <u>not</u> die if they have several inches of healthy stem. Leafless plants found during January-February and July-August may or may not die. This information is necessary for the correct assessment of browsing damage. It is also important for interpreting assessments of young regeneration on browsed areas.

It was interesting to note that the rate at which the defoliated petioles were abscissed varied greatly with the different times of the year.

(b) <u>Height Growth</u>:

Defoliation during February to June was almost invariably followed by the die-back of the stem. At first the buds, then the stems and even the roots died back progressively towards the root collar which was the least region to die.

Where die-back was not complete, the rate of growth during the first year was very slow. There was also considerable die-back from defoliation during July and August. However, in these as well as the other months outside the danger period of February to June, height growth was much better, though the rate of growth of the control was never equalled. See figure XII.1A. Slow growth following defoliation was characterized by the presence of small, broad leaves. Once a plant had developed leaves of normal size, shape and colour its growth rate was normal.

During their second year after defoliation, all groups of defoliated plants grew at similar rates, and much faster than during the first year: namely at 1.8 inches per growing season month. The controls, which had gained much more momentum now, grew at 4.0 inches per month.

Height growth of pruned plants was much more rapid than the growth of defoliated plants and was about equal to that of the controls, though these were not caught up with. The date of pruning did not obviously affect the subsequent growth rate. Observations elsewhere, indicate that the defoliated leaders of plants which were browsed during the danger period may die back to the surviving leaves lower down the stem.

Gilbert (1961) states that recovery from browsing ... can be very rapid. This statement is true, but must not be understood to imply that browsed plants grow faster than unbrowsed plants. The above data show that complete defoliation can kill or severely reduce the height growth of E.regnans seedlings. Incomplete defoliation or pruning appears to set the plant back by at least the amount of height which was cut off. Thus a 9 inch plant pruned to 3 inches grew about as fast as an unpruned nine inch plant, which grows faster than an unpruned 3 inch plant.

Eucalypts are usually regarded as particularly well adapted to recover from defoliation (Jacobs, 1955). However, there are some other eucalypt species which are similar to E.regnans in their sensitivity to defoliation This is evidenced in a remark by Baur (1959), who reported that E.grandis seedlings when defoliated during March sprouted some tiny adventitious shoots but all died by the following June while the leafy controls nearly all survived.

(3) Discussion:

Eucalypts of all ages can be completely defoliated by natural agents such as insects (e.g. Phasmatids and Roeselia)

Campbell (1960) considers that regrowth of eucalypts with lignotubers (<u>E.regnans</u> and <u>E.grandis</u> do not have lignotubers) is remarkably tolerant to insect attack and that repeated attack over several successive seasons is needed to kill the seedlings. He reports that adult eucalypts of some species are less tolerant of defoliation than others. Even large trees of tolerant species may be killed if defoliation by insects is sufficiently intense and prolonged.

Some eucalypts, such as the thickly-stringy barked <u>E.obliqua</u> can recover conspicuously well from defoliation by fire, while others (e.g. the thin-smooth barked <u>E.regnans</u>) do so much more weakly. (See Chapter VI).

What is the cause of death of defoliated <u>E.regnans</u> seedlings?

The low mortality amongst pruned plants shows that <u>injury</u> alone is rarely if ever lethal.

Both defoliation and pruning stimulate bud growth at all times except winter. All healthy axillary buds (slender, appressed leaves) present at the time of defoliation may commence development. In addition numerous proventitious buds (a pair of tiny, broad, spreading leaflets) may appear on the lower part of the stem. Deaths following defoliation are therefore not due to any <u>inability of buds to commence development</u>.

It is possible that defoliation makes a plant <u>frost tender</u> by stimulating untimely growth. However, the fact that stimulation is similar on both pruned and defoliated plants, indicates that frost is not the primary cause of the deaths which follow complete defoliation. Pruned plants die only rarely.

It is suggested that deaths following defoliation are due to starvation. This theory depends on the following two assumptions:

(a) During periods of rapid height growth eucalypts deplete their food reserves which are not replenished until growth slows down or ceases. This is possible because photosynthesis continues at temperatures below those necessary for growth.

(b) Very immature leaves are incapable of sufficient photosynthesis for their own growth as well as the maintenance of life in the plant. Excised tiny leaves of <u>E.regnans</u> have proved capable of some photosynthesis by their uptake of labelled carbon dioxide. (Thomas, pers. comm.).

A defoliated plant can grow new leaves only if sufficient food reserves are available. Reserves might be present throughout the period of dormancy while being formed and in spring before they are used up again.

Leafy seedlings do in fact grow new leaves throughout the growing season. Leafless seedlings did do so only during the early part of the growing season, viz. from October to January. It stands to reason that a prolonged period without leaves must deplete food reserves. It could be that some species (especially those with lignotubers) usually have more food reserves than others and that mature trees have more reserves than seedlings. Hence, ability to recover from defoliation may vary with the size and species of plants. The high mortality from incomplete defoliation of 4-10 ft. high seedlings at the beginning of the dormant season may be a result of the inadequacy of the few remaining senile leaves to maintain the life of a relatively large plant. See also page 96.

On 22/9/60 four branches, each 1-2 ft. long, of E.regnans were ringbarked. The two branches which had been only 70% defoliated grew new shoots and many leaves by 21/2/61. On the other hand the two branches which had been entirely defoliated produced no new shoots, no buds and only two undersize leaves on one branch and none on the other. The 70 to 100 capsules (1959 age) on each branch were still green and had suffered no abscission due to defoliation. There was only little die-back on the completely defoliated branches. Apparently the reserves on these branches had been insufficient to produce vigorous leaves. Life for the 5 months may have been just maintained by the green surface of the capsules.

C. THE TIMING OF BROWSING ATTACK ON EUCALYPTS

I. SIZE AND AGE OF THE PLANT

A seedling becomes browsable when it achieves

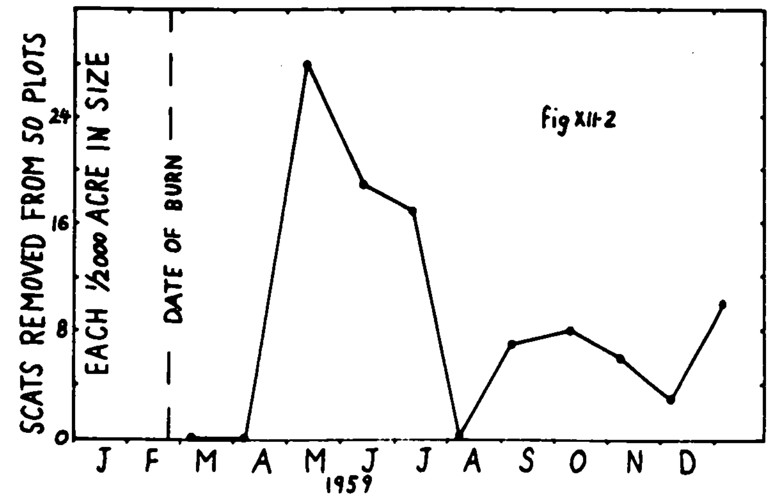


Figure XII. 2. The relative frequency of browsing marsupials at different dates after a burn in February 1959 at W54 estimated by the number of scats removed monthly from 50 fixed half milacre plots. Plotted halfway between scoring dates.

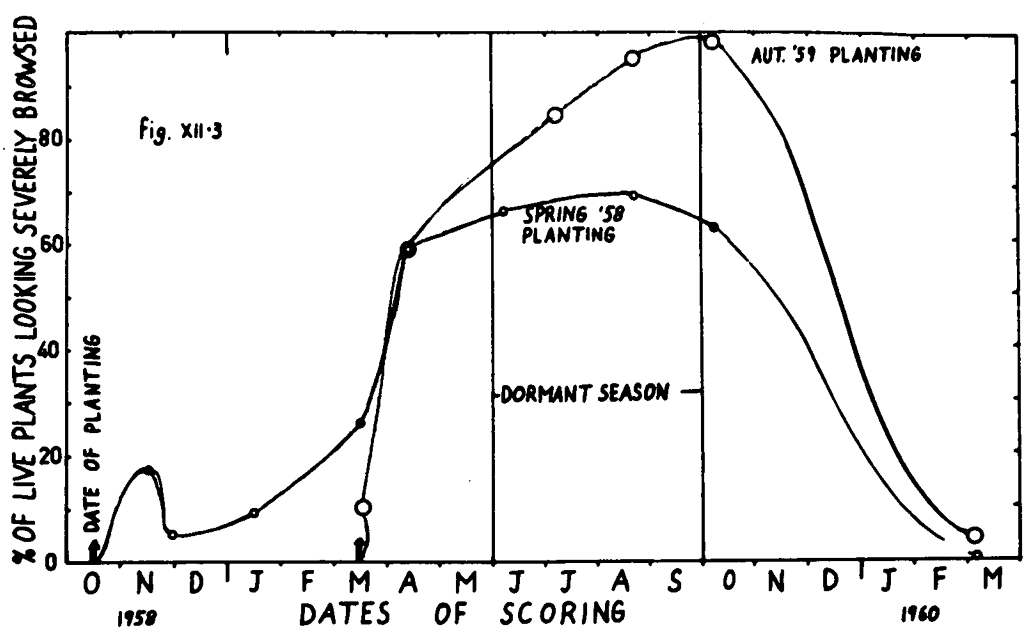


Figure XII. 3. The relative frequency at different times of the year of severely browsed looking *E. regnans* planted at W72. Each point is based on 60 to 100 plants scattered over one quarter acre.

sufficient bulk, namely at the 2-4 leaf stage. (Gilbert 1961). This means that planted seedlings are immediately browsable.

A large proportion of the seedlings which arise after natural seedshed following a regeneration burn in autumn become browsable in November after the burn.

Sowings made in autumn and spring also become browsable about November after the sowing.

Plants remain vulnerable to browsing until they are 12 to 24 inches tall, i.e. until they are 1 to 2 years old.

II. TIME AFTER BURNING

During every month of 1959 all scats of browsing animals were counted and removed from a series of 50 fixed half-milacre study plots at W54. This area was burnt on 23rd February 1959. The results are plotted in figure XII.2 for all species of animals combined. Kangaroo scats were picked up only in May and June. Wallaby and possum scats appeared in high numbers in the 3rd month after burning and have been present ever since.

Evidence from elsewhere indicates that re-invasion by animals of the burnt area may occur within a few days. Even large burns can be penetrated to at least one mile within two months.

There is therefore not enough delay between the burning of a coupe and its re-invasion by browsing animals

~~to browsing animals~~ to permit the establishment of eucalypts from sowing or planting.

The author has no evidence of changes in the population of browsing animals with the progress of the early secondary succession on the burnt coupes. It may be expected that some changes in animal population take place with the advent and passing of browsable plant species in large numbers, and with the openness of the habitat. In most of the areas inspected browsing animals were present in ~~in~~ considerable numbers at least during part of the year for an indefinite number of years (10 or more) both before and after most browsable species have come and gone. Table XII.4 shows that plantings on seedbeds almost free from tall weeds (i.e. at ages 0 to 1 years after burning) were more heavily browsed than plantings on older seedbeds. The seedlings that are hidden amongst weeds so well that they are reasonably safe from browsing usually die from weed competition.

There is therefore no stage in the succession which offers adequate protection from browsing while not offering excessive weed competition.

TABLE XII.4

The Effect of Stage of Weed Development on Severity of Browsing Attack on Planted E.regnans Seedlings.

Planting	Age of Seedbed at time of planting	No. of Plants	% of plants browsed within 1½ years
Spring '58	9 years	60	69% +
Autumn '59	1 year	100	98% +
Pron.2 at W69	1 "	40	60%
Proj. 2 at W38 + 43	2 "	80	25%
Proj. 2 at L9	4 "	150	20%
Proj. 2 all others	4-8 "	400	27%

III. TIME OF THE YEAR

Figure XII.3 shows that severe browsing damage on planted seedlings may commence at any time within one to six months after planting.

The visible browsing damage was greatest in autumn and winter because of the severity of attack in autumn and because of the inability of the plants to recover during the dormant season. During both '58/'59 and '59/'60 summers the plants at W56 were relatively free from browsing attack. The attack during autumn 1959 was not repeated in autumn 1960, even though the seedlings planted in autumn '59 were still well within the reach of the animals.

The evidence presented here of an autumn and winter high, and a summer low in visible browsing damage is supported by similar findings from spot sowings by

Mount (pers. comm.). Some browsing damage to eucalypts is done at all times of the year. The evidence presented is not strong enough to permit neglect of animal control at any time of the year. It does however, emphasize the finding from the defoliation experiment that browsing control during late summer and autumn is more important than at other times of the year.

A seasonal variation in browsing attack can be explained by seasonal variations in animal diet or in animal migrations. Mollison (1960) has some evidence for the latter. He points out that Kangaroo prefers the high country during the summer, but descends into the valleys when the cold snowy winter arrives.

D. THE EFFECT OF BROWSING ON PLANTED SEEDLINGS

I. SURVIVAL

Browsing was responsible for the great majority of deaths observed amongst the planted seedlings.

Except for stagnant seedlings, especially those planted in puddled soils, all eucalypt seedlings seem to be palatable. On accessible sites and with the presence of game, apparently the ohly way to achieve immunity from serious browsing damage is to grow up, i.e. to grow beyond the reach of the wallaby, or to put on so much bulk that complete defoliation becomes unlikely. The seedlings planted in spring '58 were large enough by the end of their first growing season in the field to have the protection of bulk when browsing.attack became severe in autumn. Though 69% of them were severely browsed, 95% survived and grew well beyond the reach of the browsing animals during their second growing season. The seedlings which were planted in autumn 1959 were severely browsed (98%) while they were still small. Only 47% of them survived and most of the rest were so seriously retarded by the browsing that their growth during the following growing season was not enough to afford them much protection. It may be concluded that, with freedom from browsing during their first summer, seedlings which are planted in spring are not seriously endangered by browsing, while seedlings which are planted during autumn are likely to suffer heavily during at least the first two winters.

II. HEIGHT GROWTH

The defoliation + pruning experiment has shown that the effect of browsing depends very much on the severity and on the timing of the browsing attack. Complete defoliation during February to June either kills a seedling or very greatly retards its growth. Defoliation at other times of the year, and pruning at any time of the year are much less likely to be lethal, but will result in some set-back of growth.

In the field, degrees of severity and times of incidence of browsing are so complex that clear-cut results are difficult to obtain. The survivors of one uniform batch of seedlings which were planted in March 1959, the 80 plants inside the fence averaged a growth of 27 inches during the first growing season, while the 27 plants outside the fence grew only 6 inches. This example illustrates the very pronounced effect of browsing on height growth if the plants are very vulnerable and are severely browsed during February to June. The effect of browsing is very much smaller if the plants are bulky, if browsing does not completely defoliate the plants and if browsing occurs outside the period of February to June.

III. THE EFFECT OF MANURING WITH BLOOD AND BONE ON THE SEVERITY OF BROWSING ATTACK.

Not all types of E.regnans foliage are equally palatable to browsing game. The possum, though a climbing animal, appears to prefer the tender leaves of seedlings to the tougher leaves of mature trees. A batch of four hundred tubed seedlings which was accessible only to possum was eaten practically bare, while a freshly fallen ~~off~~ eucalypt limb nearby was entirely ignored. The wallaby may leave stagnant plants entirely unmolested while nearby luscious seedlings are heavily browsed, even if the stagnant plant stood right in the wallaby's path. The success of roadside regeneration, and its apparent relative freedom from browsing, may be largely due to heavy dust on the foliage during summer. Apparently the game prefer clean, tender leaves on eucalypts.

It seems therefofe possible that manuring would make seedlings more palatable. This has been affirmed in the case of E.regnans in Victoria by Redmond (1953) who used blood and bone manure. However, analysis of the author's plantings made at various times and places in the Florentine Valley shows that amongst 467 tubed plants manured with blood and bone, 45% were heavily browsed by the end of their first autumn in the field while an equal number of unmanured plants showed exactly the same degree of browsing damage. Apparently the manure had no special attraction immediately after planting, nor did it make the manured plant more attractive after one growing season. This was true for fenced (possum only) and unfenced plantings. The indifference to manuring in the field may have partly been due to the fact that all tubed stock was manured some time before planting. The root-balled stock had not been manured before planting. In this case 30% out of 60 manured plants were heavily browsed while only 23% out of 106 unmanured plants were similarly attacked. The difference was small and not significant.

This indifference to manuring is not so surprising because manuring did not have any obvious effect on the plants grown by the author. At least dring the growing season almost every plant which was not in puddled soil looked attractive. If enough plants had been planted in puddled soils in such a way that manuring prevented their stagnation, browsing would very likely have been found to be correlated with manuring, because stagnant unmanured seedlings are relatively unattractive.

E. THE EFFECT OF BROWSING ON SOWN SEEDLINGS

Because the fence did not always keep out the possums, a comparison of the survival of plants inside versus outside the fence at W56 gives a conservative indication of the effect of browsing on sown seedlings. The data are summarized in Table XII.5.

Height growth as well as survival were very strongly influenced by browsing.

Plants which are defoliated during February to June usually die in winter. This explains the high death rates outside the fence during winters.

At the time of scoring the survival of fenced plants was generally 2 to 4 times as good as the survival of unfenced plants. At this time, which was 17 to 25 months after sowing, many of the plants outside the fence were still vulnerable to browsing. Hence the difference in favour of fencing is likely to be even greater in terms of established seedlings.

TABLE XII.5

The Effect of Fencing on Sown Seedlings.

(n)F = (not) Fenced

Experiment	Date of scoring in mths after sowing	seedl.% F	seedl.% nF	% of stocked spots or sample plots with seedl. over 23"tall F	nF	Periof of max.browsing mortl. from / to	Monthly death rate at this time F	nF
Aut.'58 B'cast	23	2.3x	0.6x	20%	0%			
Spring'58 B'cast	17	5	3	23	4	15.5.59/29/10/59	1.9	18.8
Aut.'59 B'cast	20	5.3	2.9	0	0	7.3.60/2.11.60	1.6	7.5
Aut.'58 spots	18	1.1	1.0	2%	4%	12.5.59/26.10.59	4.4	9.4
Spring'58 spots	24	3.3	0.8	67%	V.few	15.5.59/29.10.59	10	15
Aut.'59 spots	20	8.3	2.1	27%	0%	10.3.60/20.10.60	2	6
Grass Expt.(b)	25	-	.01	-		sown with grass	-	
(d)	25	-	1.0	-		sown without grass	-	

x Note: These two seedling %'s are not comparable because the germination % inside the fence was much better than that outside the fence.

F. THE CONTROL OF BROWSING

Mollison (1960) states that the browsing animals retire to the perimeter of a coupe during the day. Perhaps a relative reduction of perimeter by an increase in the size of the coupe would reduce browsing pressure. A reduction in perimeter per unit area would certainly make the removal of animals easier.

Control of browsing by control of the animal habitat is not promising. Browsing animals are present in considerable numbers throughout that period of the secondary succession when regeneration of eucalypts by sowing or planting is possible. Weeds sufficiently dense to hide a eucalypt seedling effectively, are likely to suppress and kill it. (Planting Project No.2).

The experiment described below was designed to test whether presentation of a highly palatable alternative food would relieve the browsing pressure from the eucalypts.

THE GRASS EXPERIMENT

I. INTRODUCTION

Grass is highly palatable to wallabies and kangaroos. This experiment was designed to test whether presentation of a highly palatable alternative food such as grass will protect the eucalypt seedlings amongst the grass or at some distance away from the grass against browsing by native game. This is an attempt at the control of browsing damage to eucalypts by ecological manipulation of the site, rather than by removal of the culprit game.

This sort of idea is not new. In Germany, the forester often encourages the growth of alternative food plants and may even present fodder during winter to protect the young plants of valuable tree species from browsing by game. (Haagen, 1961).

Because the animals concerned in this experiment have a range of several acres each, and because of the potentially devastating effect of even one animals that chances to come across a small plot, it was necessary that this experiment should cover the largest possible area of a uniformly accessible site. For study purposes, only a small sample can then be inspected thoroughly. But at least the sample would not suffer from marginal effects and would be unlikely to suffer from mere accidents of location by animals. Ideally, the area should be big enough to cover the range of several animals in case each animal strictly defends its territory.

II. EXPERIMENTAL METHODS

Coupe W62 was chosen. This area of 34 acres was logged in 1957 and thoroughly burnt in March 1958. It is on level ground, on soil derived mainly from limestone and with few logs to hinder the movement of animals. Its former vegetation was wet sclerophyll forest dominated by *E.viminalis* and *E.regnans*.

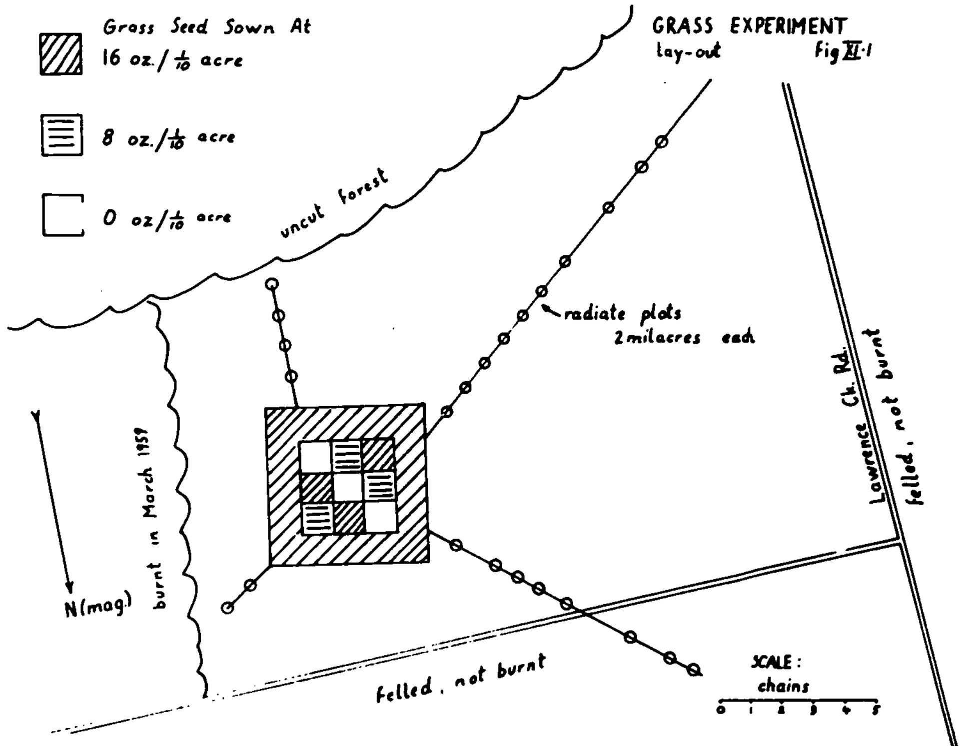


Figure X1. 1 Lay-out of grass experiment.

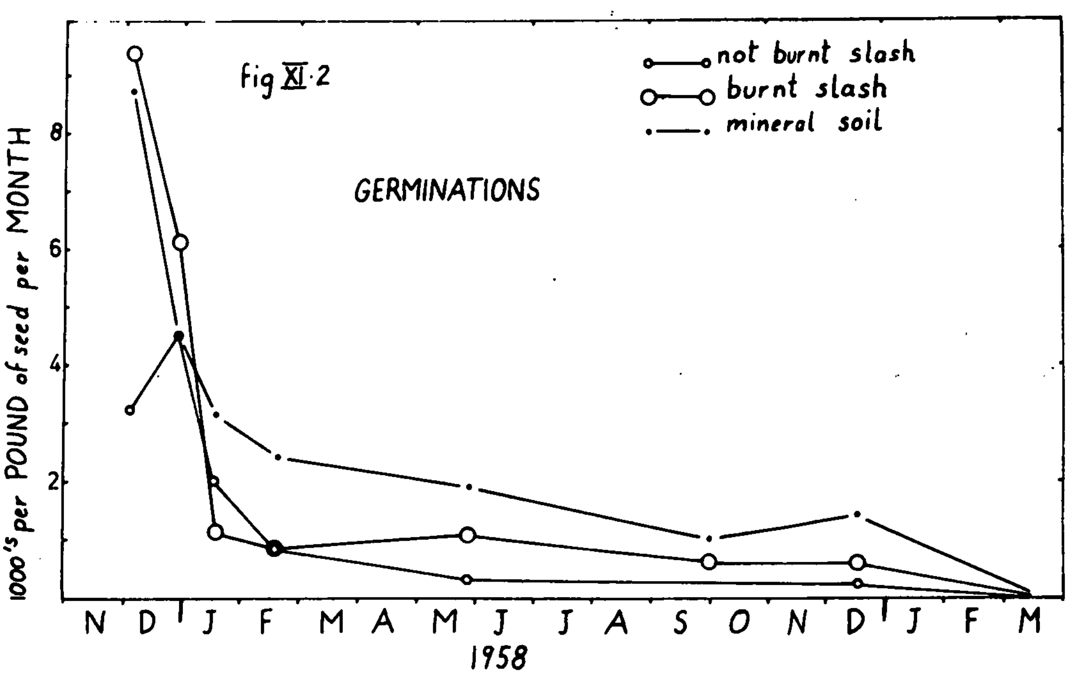


Figure X1. 2 Pattern of germinations from broadcast sowing on 20. 11. 57 on 6 milacres of burnt seedbed, and 10 milacres each on mineral soil and unburnt slash.

There was no significant natural seedshed of E.regnans on the sown area. The burnt ground which was not sown with grass was almost covered by mosses after the fire one year. Erechthites and Carduus, became dense in the summer of 1958/59 and again in 1959/60. Only Carduus died off in autumn 1959. Carduus and Erechthites died back completely in autumn 1960, leaving the site remarkably open and exposed to animals from then on.

Judging by the browsed nature of adjacent forest and cutover areas and by the frequency of tracks and scats there was a high population of wallabies, kangaroos and possums in this area throughout the period of this experiment.

In the middle of this coupe a square 5 x 5 chains (i.e. 2.5 acres) was laid out and subdivided into one square chain lots. The central 9 one square chain plots were treated as a 3 x 3 latin square. The treatments were:-

sowing of 10 lb of grass seed per acre.
sowing of 5 lb. of grass seed per acre.
sowing of 0 lb. of grass seed per acre.

In addition all plots were sown with 3 lb of E.regnans seed. The grass seed was a mixture of Lolium perenne, Agrostis tenuis, Festuca rubra and white clover in proportion by weight of 5:3:1:1 respectively. The surround, one chain wide, was sown with 10 lb of grass seed per acre only. Four lines with plots at intervals of about one chain radiate from the edges of this area. This was to test gradients of browsing intensity away from the grass area. Each radiate plot of 10 links x 20 links (1/500 acre) and its 10 link wide surround (1/500 acre) was sown with E.regnans seed only, at a rate of 3 lb. per acre. The radiate plots were comparable to the burnt seedbed on the latin square. About three quarters of the seedbed on the latin square was burnt. All seed was dusted with D.D.T.

For a further comparison, two square chains of burnt seedbed were sown with 3 lb. of E.regnans seed per acre plus 10 lb. of grass seed inside the fence at W56.

All sowings were done on 4 - 14th August, 1958.

See Figure XI.1 for a diagram of the lay-out.

III. RESULTS OF THE GRASS EXPERIMENT

Within one month of sowing, the clover and at least two of the grass species had begun to germinate. The grass became established in quantity before the eucalypt seedlings grew beyond the cotyledon stage. Inside the fence at W56 the grass (mostly Lolium) became dense and over two feet tall within one growing season. Outside the fence, at W62, the grass became a closely cropped lawn except in places made inaccessible by logs or thistles. The clover persisted in both places but never achieved much importance. Neither eucalypts nor grass did well on the puddled soils of tractor tracks.

The number of animal droppings (scats) found on an area is an indication of the frequency of visits by animals.

TABLE XI.2

The Presence of Grass - the Frequency of Scats - and the Survival of Eucalypts.

Treatment	Number per acre			
	SCATS x		EUCALYPTS on	
	on 28.1.59	on 26.2.60	on 26.2.60	1.12.60
Large plots with grass	13100	12100	1300	25
" " without "	6700	6700	2800	165
Plots on radiating lines: at 1-3 chains	6800	6300	6800	3100
4-6 chains	7000	6400	11300	6700
7+ chains	2900	5300	4600	2900
Plots inside the fence	-	-	9800	burnt

x wallaby, kangaroo, and possum.

Note: the last score is based on a complete count of seedlings on the whole experimental area. For all the other scores the large plots were each sampled by 25 systematically loacted, permanent quarter-milacre sample plots.

Table XI.2 shows that the native game was attracted to where the grass was. There is no evidence that this relieved the browsing pressure from the areas adjacent to the grass.

The table also shows that heavy browsing pressure can have very drastic effects on the survival of eucalypt seedlings. Two years after sowing, only 25 seedlings per acre survived where the grass was, and most of these owed their life to a few inaccessible niches amongst the logging debris. The survival of eucalypts immediately adjacent to the grass plots was distinctly better but still extremely poor. The survival of seedlings still further away from the grass plots was a thousand times better. The stocking here was about 4,000 seedlings per acre, which represents 1.0% of the viable seeds sown. This figure is comparable to, but not better than the rate of survival outside the fence at W56 in Project 1 (see Table XII.5). The survival of the seedlings amongst the very vigorous grass inside the fence was by far the best and represented about 2% of the viable seeds sown. There is no doubt that these figures represent the result of different degrees of browsing attack because germinations had been uniformly good on all plots and amounted to about 45,000 seedlings per acre.

The burnt ground, where the grass was sown, was covered with grasses instead of mosses. *Erechthites* was distinctly sparser on the grass area probably as a result of browsing. Only *Carduus* was not obviously affected. The eucalypt seedlings amongst the very closely cropped grass could have survived only if the animals had avoided them with extreme care, and there was no evidence of that !

The failure of grass as an alternative food to relieve the browsing pressure from the eucalypts growing amongst the grass must be partly ascribed to its habit of growing as a dense, low mat. In addition, the presentation of a highly palatable alternative food attracted greater numbers of animals and actually increased the browsing pressure on the nearby eucalypts on adjacent plots. The presentation of alternative foods on a large scale must save some eucalypts in the long run, if the overall number of animals remains constant. However, the method is not at all promising.

This experiment did, however, point out strongly what had been observed also elsewhere. The abundance of other plants, especially if they are unpalatable, can hide the eucalypts or can make them inaccessible and thus protect them from browsing. The other plants in this case were thistles (*Carduus*) and fireweed (*Erechthites*)

Thus the radiating plots with 0 to 10% of tall weed cover carried 3,300 eucalypts/acre; the plots with 25 to 50% of cover carried 6800 eucalypts per acre; and the plots with 75 to 100% of cover carried 8300 eucalypts per acre, in spite of the adverse effect of heavy competition for light against the eucalypts.

The same effect, or rather the lack of this effect was also illustrated rather strikingly by the following facts: the fireweeds and thistels suddenly died completely all over the coupe at the end of the second summer after the regeneration burn, namely in February 1960. This is a normal event - see Chapter XIII. The effect was that the formerly hidden eucalypts were now most conspicuous and became very heavily browsed. Indeed 55% of them died in the following 8 months compared with a 9% mortality of similar seedlings inside the fence. The browsed, dead skeletons of eucalypts were seen in great numbers in December 1960.

IV. SUMMARY AND CONCLUSIONS OF THE GRASS EXPERIMENT

Grass is highly palatable to native game, and is very closely cropped when exposed. An area with grass will attract the native game. Eucalypts amongst the grass suffer extreme mortality due to browsing. It is doubtful whether eucalypts at a distance of several chains from the grass benefit from the presence of the nearby alternative food. It can be expected that in any case the eucalypt seedlings, because of their relative scarcity and poor ability to recover, rarely if ever form a major portion of the animals' diet, even though the eucalypts are very palatable at least in autumn and may be selectively browsed by the possum, This means that presentation of alternative foods is unlikely to have much effect on the eucalypts.

Sowing grass with or at some distance away from eucalypt seed will therefore fail to protect the eucalypts from browsing damage.

Taller, and less palatable weeds, such as fireweeds and thistles, can protect eucalypt seedlings from browsing attack by hiding the eucalypts and by making them relatively inaccessible. The sudden death of the fireweeds usually after the second summer, may expose the still vulnerable eucalypts to most serious browsing attack at the time of the year when the mortality from defoliation is highest. This means that control of browsing by the removal of native game is particularly important at the time when the fireweeds die back suddenly.

(b) Exclusion, Repelling or Removal of the Browsing Animals.

In the forest, both normal and electric fencing are very expensive to instal and maintain and are not effective against the possum. They cannot be recommended.

Repellents to protect a whole coupe or individual seedlings have received some attention, but without success, (Gray pers. comm.; Rolland+Heisler, pers. comm?) The ideal would be to repel the animals from the entire coupe. Next best would be a systemic repellent which can be incorporated in the seed before sowing, or in the seedling before planting. Other types of repellents appear to be of little use in extensive forestry.

Removal by shooting or snaring or trapping may be effective enough but is expensive unless the meat or fur can be sold profitably. The A.N.M. have found that trapping for fur and meat is unprofitable.

Removal by poisoning has been studied by Mollison (1950). The methods evolved appear to be satisfactory except that an unknown number of innocent species may be killed at the same time as the culprits.

(c) Timing and Duration of Browsing Control:

In the absence of definite knowledge on seasonal variations in animal populations and in diet, browsing control must be timed according to the vulnerability of the seedlings. Vulnerability is greatest at the 2 to 12 inch stage and during February to June. Seedlings above 24 inches are not easily harmed.

In the author's experiments the height growth of planted seedlings was almost nil during the five winter months and about one foot during the first and four feet during the second growing seasons, if the seedlings were not browsed nor stagnated in puddled soils. Protection is therefore needed from the date of planting until July following the first growing season. Planting during the dormant season increases the period of protection needed from 9 months up to 15 months without benefiting the seedlings. Protection beyond July would benefit the below average seedlings. After the second growing season browsing is probably beneficial in reducing weed competition.

Early growth rates of seedlings from sowing or natural regeneration are quite variable. Sowings made between March and October usually reach browsable size by November and should be protected from then on. Commencement of protection should be worthwhile even if less than half of the seedlings have reached browsable size because it is these advanced seedlings which are most likely to become established. They have already proved their superiority and they have an advantage in competition with weeds and drought. Because of their small bulk these seedlings are most vulnerable to browsing.

Amongst the sowings protected at W56 only 10 to 20% of sample plots or spots carried seedlings over 5 inches tall after one growing season. Given protection for another growing season and to the end of the following defoliation danger period (July) a sufficient proportion of sown seedlings should be beyond vulnerability by browsing.

This means that protection is needed from the first November to the second July, i.e. for 20 months. The beginning and end of the vulnerable period should be confirmed in the field in each instance.

G. SUMMARY AND CONCLUSIONS

The species responsible for browsing damage to eucalypt seedlings in the Florentine Valley are possum, wallaby and kangaroo.

Browsing damage consists in removal of leaves and tender shoots. It affects most weeds, except ferns at least as much as the eucalypts. Browsed plants are retarded or killed. Browsing can sometimes prevent *Erechthites* from achieving a very dense climax during the second year after the burn, but will prolong the occurrence of *Erechthites* at lower densities. Except where the less palatable *Zieria* is abundant, browsing can prevent or delay the formation of a shrub thicket.

Complete defoliation during February to June kills most eucalypt seedlings and very much retards the growth of the survivors. Defoliation at other times of the year, and pruning at any time are rarely lethal but do set back height growth a little.

Eucalypt seedlings are most vulnerable when they have so little bulk that they are easily defoliated completely, i.e. when they are between 2" and 12" tall. The

The browsing animals return to a burnt area before eucalypt seedlings from sowing or planting can become established, and remain till after weed competition makes further eucalypt regeneration impossible. There is some evidence that browsing attack on eucalypts is lightest during spring and summer.

Both plantings and sowings benefit greatly in survival and height growth when protected from browsing.

Manuring with blood and bone did not increase the incidence of browsing.

Ecological methods of controlling browsing damage are not promising. The only known satisfactory method of control is removal of the culprit species of animals.

Seedlings should be protected during their most vulnerable stages. Plantings are most vulnerable from the time of planting until July after their first growing season in the field. Sowings made between March and October (i.e. including natural regeneration) become vulnerable about November and remain so till July after their second growing season.

PART D

ECOLOGICAL

CHAPTER XIII

CHAPTER XIII

EARLY STAGES OF PLANT SUCCESSION AFTER THE COMPLETE FELLING OF FOREST AREAS IN THE FLORENTINE VALLEY, TASMANIA.

INTRODUCTION

Most of this chapter is based on a project which was carried out in co-operation with A. B. Mount of the Tasmanian Forestry Commission. The aim of this project was, firstly, to discover and describe the changes in the vegetation which take~~s~~ place on completely felled areas of forest during the early years after the regeneration burn and secondly, to determine the effect of the various stages of vegetation on the chances of obtaining regeneration of *E. regnans* from seed.

This information is required to answer two important questions:-

Firstly: For how long should seed trees be retained after the regeneration burn? The seed trees lo~~o~~se their usefulness after the ground has become so densely overgrown that no significant additional regeneration can become established from seed.

Secondly: For how long after the regeneration burn is broadcast sowing effective? Related questions which are not directly answered by this project are: Up to what stage would spot sowing be effective, i.e. sowing on spots cleared of the ground mat? What stages of vegetation prevent planting of Eucalypts without disturbance of the vegetation?

METHODS OF STUDY

The same experimental framework was used for the solution of both the aims of this project. However, the results from the sowing of the experimental plots will not be available before 1963. Therefore, and for the sake of clarity, the existence of the experimental plots will be ignored in this report and only the plots used for the vegetation study will be described here. It should be remembered, however, that the methods which were adopted to sample the vetetation were largely determined by the requirements of the sowing experiment.

The Sites which were sampled.

All sites carried E. regnans before being completely felled. Attention was equally divided between sites which had carried an understorey of rainforest on the one hand and of wet sclerophyll scrub on the other hand. The rainforest sites were on soils derived from mudstone and from rocky dolerite, but the layout of the plots was not designed to test for any differences due to soil types. On the wet sclerophyll sites the sampling was equally divided between soils derived from limestone on the one hand and from gravelly dolerite on the other hand.

Each sample plot on burnt, undisturbed ground was matched by another plot on a nearby tractor track. The whole available range of burning and soil puddling by tractors was sampled. The vegetation succession on tractor tracks is comparatively slow and very variable according to the degree of puddling. The changes of vegetation on the tracks were so small during the two years of study that a complete analysis of these plots is not worthwhile here.

Ages of the Vegetation and Times of Scoring.

It was intended to study the changes in vegetation from the date of burning until the vegetation is obviously too dense for Eucalypt regeneration, i.e. from age 0 to age 5 or 10 years. The only areas in the Florentine Valley which were available, when the study commenced in September, 1959, had been burnt ½ year, 1½ years, 3½ years and 5 or 6½ years previously. Accordingly, these were the ages chosen for study.

All plots were scored in September/October, 1959 and were then scored again in April, 1960, in September, 1960 and in September, 1961, i.e. ½ year, 1 year and 2 years after the initial scoring. Note that September is at the beginning and April is at the end of the growing season for most plants other than the mosses and liverworts.

Succession on recently burnt ground was so rapid that most of the important trends in vegetation were actually recorded on the permanent study plots within the two years of study. The choice of areas burnt in different years made it possible to conclude the study in two instead of eight years and at the same time, served to give some indication of how the early succession is influenced by the climate in the year following the fire.

Methods of Sampling

No standard ecological technique was entirely suitable for the special purpose of this study of vegetation. However, where appropriate, the terminology of Cain and Castro (1959) was adopted.

The sample unit was a milacre quadrate, i.e. a square plot 1/ 1000 acre in size. The choice of this size was a compromise between the ideal sizes to study mosses on the one hand and tall herbs or low shrubs on the other hand. The choice proved to be satisfactory for the purpose.

Each quadrat was made permanent by surveying its location and by marking its corners with four painted wire pegs, one of which carried an aluminium identification tag. The permanence of the sample plots made sure that the trends of succession which were recorded did actually occur and were not due to sampling error.

Whether the sampling is representative of the sites it is meant to represent, depends on the size and distribution of the sample, which, in turn, depends on the time and resources available for the work. The adequacy and representativeness of the sampling in this study is open to criticism. There was no great advantage in making the sample quantitatively reliable, because - due to variation from site to site and from year to year - exact quantitative predictions of vegetation changes are impossible and in any case, not needed. The main aim of the study was to recognize and describe the stages of vetetation which are significant in Eucalypt regeneration, and to recognize in what manner and approximately how fast each stage of vetetation is changing. This aim was realised.

The sample in each of the two understorey types (rainforest and wet sclerophyll scrub) and at each of the four ages (½, 1½, 3½ and 5 or 6½ years) consisted of 10 milacre quadrats. Where possible, each sample was equally divided between two areas of felled forest.

The sample units (milacre quadrats) were located subjectively with the following criteria: to be widely scattered over and representative of a given area of felled forest (which was usually 30-60 acres); to include on the plots a normal amount of discard logs in case shading proves important; and to cover the available variability in intensity of burning.

Methods of Recording and Analysis.

The description and analysis of the plots was concerned more with the structure than with the floristics of the vegetation and was designed to emphasize those features which were most likely to influence the germination and survival of E. regnans seedlings.

Consequently, the vegetation was described in terms of density and coverage within each of two strata, namely the ground stratum and the aerial stratum. The coverage made by each species, or group of species, is expressed as the percentage of the ground which would be shaded by this species if the sun were directly overhead.

The ground stratum includes all the species of plants which are, more or less, confined to a height of 2 to 4 inches. A dense ground mat of mosses, liverworts and low herbs could present a physical barrier to successful broadcast sowing. The Eucalypt seed may not reach the mineral soil and the roots of the germinated seed may have difficulty in penetrating the mat to reach a better supply of nutrients and moisture in the mineral soil. In the analysis, coverages within the ground stratum are expressed in terms of "available ground", i.e. ground not occupied by rocks nor in immediate contact with discarded logs. On good forest sites in the Florentine Valley, nearly all the available ground becomes completely colonized by a dense ground mat within $1\frac{1}{2}$ to 2 years after burning. The ground mat does not disappear until it is shaded out by the more slowly developing taller vegetation. The available ground is, therefore, always occupied by the following items, singly or in combination: (1) Bare soil, i.e. freshly burnt ground without dense overhead shade.

(2) Ground mat of living mosses, liverworts and low herbs, (3) Shade bared soil, which is available ground so intensely shaded that the ground mat has died or disappeared.

The aerial stratum may sometimes include several layers of plants and is of variable height. It includes all plants above the ground mat. The survival and growth of the light demanding *E. regnans* seedlings depends largely on the absence of excessive competition for light by the aerial stratum. The competition against temporary herbs such as fireweeds is only temporary; the competition against ferns is permanent but limited to a short height and the competition against shrubs and trees is prolonged both in time and height. The fireweeds, the ferns and the shrubs are usually separate and successive stages in the plant succession. They are described separately.

A special form was designed and used so that complete and comparable records were kept of each plot at each inspection.

A chart of the major, easily chartable features was made of each plot at each inspection.

Nearly 200 photographs were taken from 11 ft. vertically above the ground of certain plots at certain times. Some of these series of photographs are reproduced in the text.

Additional Plots to test the Effect of Fencing.

For each 5 sample plots in this project, one additional comparable milacre quadrat was established and completely enclosed in a wire cage to test the effect of prevention of browsing by wallabies and possums.

In addition, another 10 milacre quadrats were located at W.56 inside a 22 acre fence which had been erected soon after the burning of the rainforest understorey in March, 1958. This fence admitted possums for only a few months and excluded all wallabies.

Additional Plots to test the Effect of previous Vegetation on the Succession after Burning.

Mudstone soils usually carry rainforest. A small area of mudstone soils was available at W.57 with a wet sclerophyll scrub understorey burnt in March, 1959. Five milacre quadrats were established here.

Table XIII.I.

Summary of Lay-out.

Showing the number and location of sample plots and fenced experimental plots for each site and age after burning. (Reference to an equal number of plots on tractor tracks is omitted).

Forest Type	Parent Material of the Soil	Date of Burn					
		3/53	10/54	3/56	3/58	3/59	3/58
		Years since burning in Sept. 1959					
		6½	5	3½	1½	½	1½
Rain-forest	Mudstone & rocky dolerite	10+0F (W.6)	-	10+2F (W34-37)	10+2F (W69,72)	10+2F (W57)	10F (W56)
Wet sclerophyll	Lime-stone	5+0F (W.7)	-	-	5+1F (P1)	5+1F (W48)	-
Wet sclerophyll	Dolerite gravels		5+0f (W12)	-	5+1F (W62)	5+1F (W67)	-
Wet sclero-	Mudstone					5+0F (W67)	

Note: Figures in brackets denote coupe names.
1F= 1 plot fenced in September, 1959; except that the plots at W.56 were fenced in April, 1958, at age 0.

A. <u>SUCCESSION ON BURNT GROUND</u>

I. DEVELOPMENT OF THE GROUND STRATUM.

1. <u>The Colonization of freshly burnt, bare ground</u>.

On all the sites studied, the freshly burnt ground was very rapidly colonized by a dense ground mat which consisted predominantly of mosses and <u>Marchantia</u>. This mat covered 30 to 60% of the ground after the first winter, 90% after the first summer and 99% after the second winter, which was one and a half years after the fire. During the first year, the ground mat was very thin and its rate of development was rather variable. However, by age 1½ years, the degree to which the available ground was colonized by a ground mat was very uniform and nearly 100%, except on very exceptionally dry sites such as shallow soils on steep limestone outcrops. During the second winter the ground mat becomes very dense and about one inch deep.

2. Development of the Grount Mat.

In the early years after a fire, *Marchantia*, plus two to four species of mosses dominate the ground mat on large areas, especially on sites of former rainforest. On some sites, the virtual absence of low herbs can be very striking. The relative importance of herbs does, however, increase with time after burning and with increasing dryness of the sites.

(See figure XIII.I (i).

(a) *Marchantia polymorpha*.

In the virgin forest the occurrence of *Marchantia* is infrequent but widespread. After logging plus burning, *Marchantia* springs up rapidly and may cover over 70% of the burnt ground of a coupe at its peak 1½ years after a burn in autumn. (See figure XIII.I a. & b.). It often grows in patches of several square yards and becomes so dense that individual plants overlap each other on all edges. (See photo. No.20).

Marchantia requires a good moisture supply and cannot stand prolonged exposure to hot sunshine. This may account for most features of its very variable pattern of development and distribution. Nutritional requirements may also be important but are less likely to be limiting on freshly burnt sites which are capable of producing a forest of high quality.

On sites which are marginal for *Marchantia*, the occurrence of *Marchantia* is often confined to especially moist depressions and to areas of ground shaded from the sun but not from the rain.

The variability in coverage made by *Marchantia* at its peak of development $1\frac{1}{2}$ years after a fire in autumn is illustrated in Table XIII.2.

Table XIII.2

Percent of available, burnt ground covered by *Marchantia* at its peak one and a half years after burning a forest site in an autumn fire. Each figure is based on 5 or 10 widely scattered milacre quadrats.

Soil	Date of burning	
	March, 1958	March, 1959
(wettest site)		
Mudstone	-	75;73
Heavy dolerite	33	53
Dolerite gravel	17	-
Limestone	22	3
(Driest site)		

Figure X111. 1

Plant Succession after Burning:

Changes in the Ground Layer of the Vegetation.

The coverage made by each species or group of species is expressed as a percentage of the "available ground", i.e. burnt soil which is not occupied by rocks or logs.

Parts (a) - (b)

Each point represents the mean of 5 or 10 widely scattered milacre~~s~~ quadrats. The quadrats were permanent and were inspected five times in the course of $2\frac{1}{2}$ years. The points which are joined to each other represent the result of consecutive inspections of the identical pieces of ground; i.e. they show the changes which actually did take place.

Age 0,1,2,3,etc. is in autumn. Age $\frac{1}{2}$, $1\frac{1}{2}$, $2\frac{1}{2}$, etc. is in spring time. Changes in vegetation which occur in winter were often quite different from those in summer.

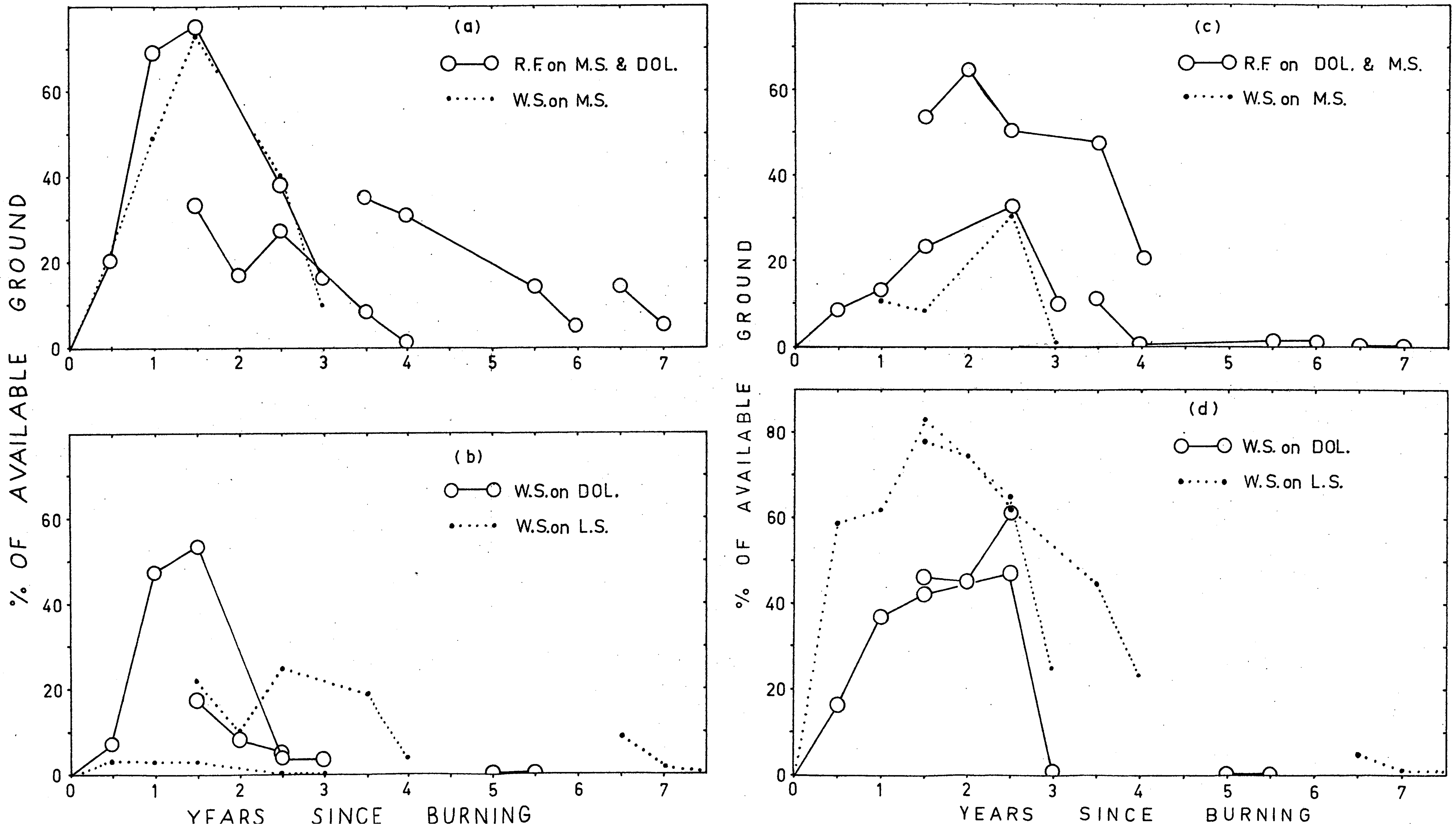
Part (i)

This is the average of all sites and is therefore not quite true of any one type of site. The abundance of *Marchantia* is the most variable component of this figure.

KC/AB.

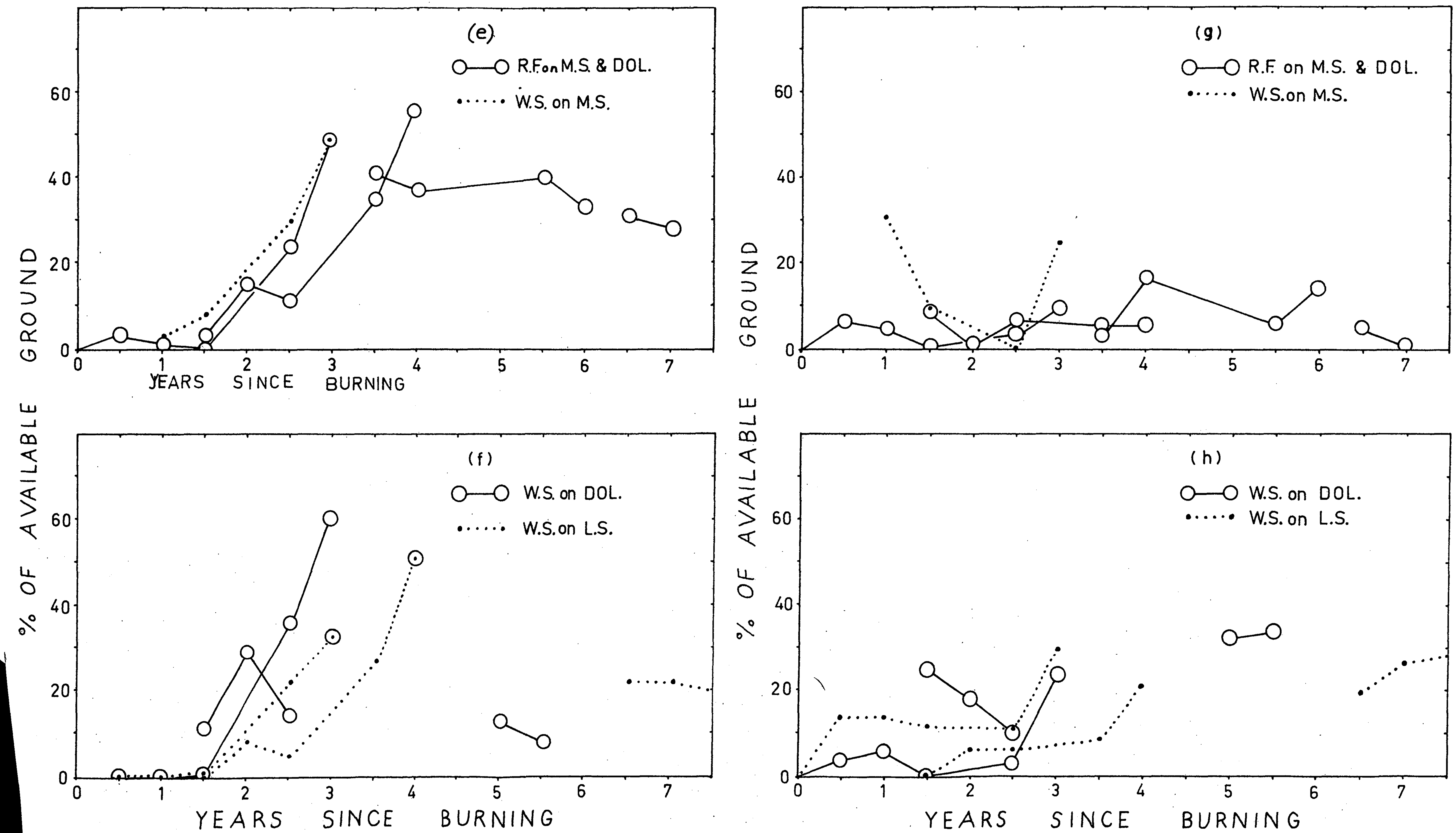
MARCHANTIA a & b

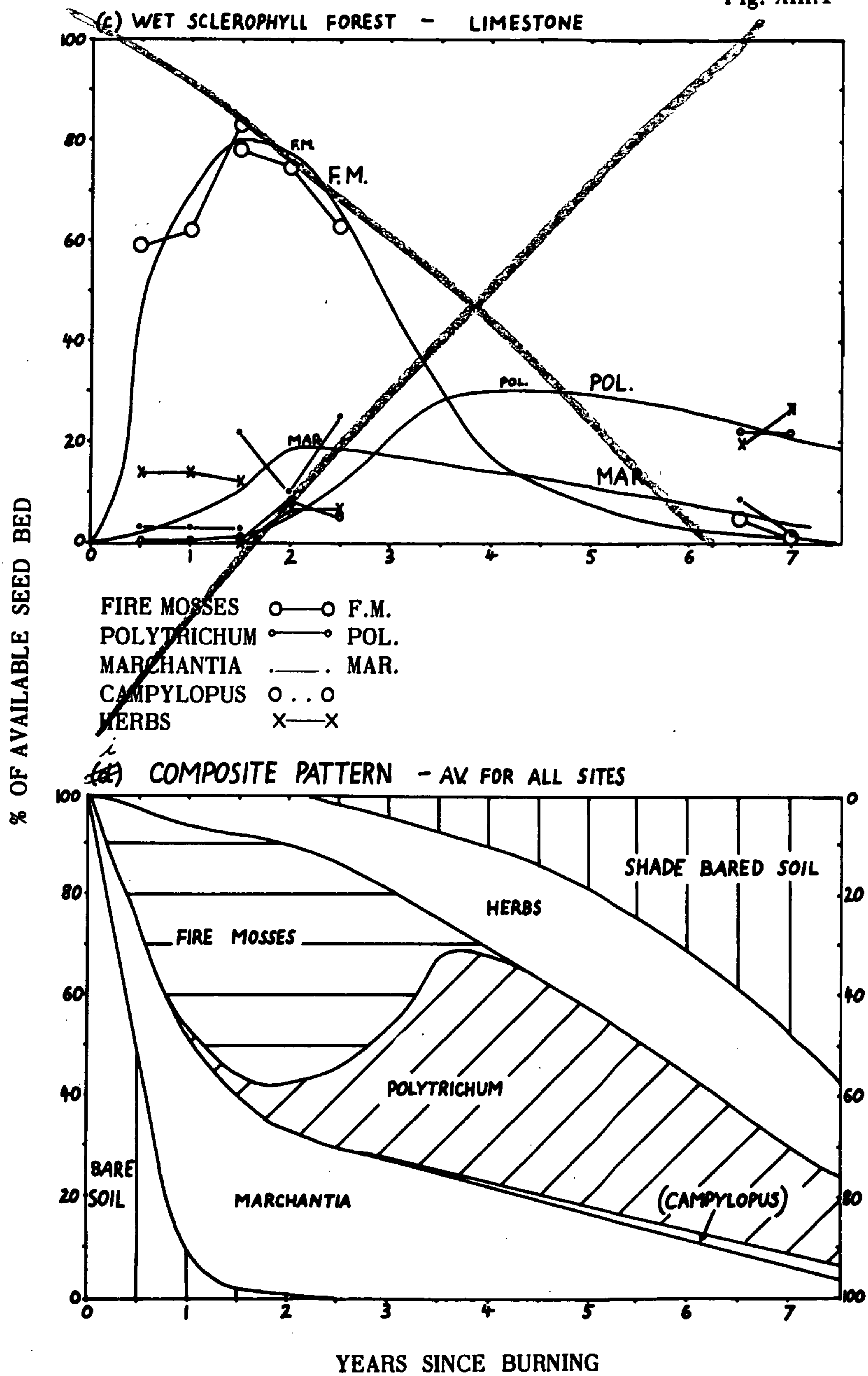
FIRE MOSSES c & d



POLYTRICHUM e & f

BROAD LEAVED & GRASSLIKE HERBS g & h




(c) WET SCLEROPHYLL FOREST - LIMESTONE
F.M.
POL.
MAR.
FIRE MOSSES F.M.
POLYTRICHUM POL.
MARCHANTIA MAR.
CAMPYLOPUS
HERBS
% OF AVAILABLE SEED BED
(d) COMPOSITE PATTERN - AV. FOR ALL SITES
SHADE BARED SOIL
HERBS
FIRE MOSSES
POLYTRICHUM
BARE SOIL
MARCHANTIA
(CAMPYLOPUS)
YEARS SINCE BURNING

Most of the variability in coverage by Marchantia shown in table XIII.I is probably due to differences in the moisture holding capacity of the different soils. Shallow limestone soils are obviously dry; soils on dolerite gravel are excessively well drained when deep but can be wetter when they are shallow and overlie mudstones. Soils on heavy dolerite are very variable. Mudstone soils are usually very wet.

The two years of observations on permanent quadrats were sufficient to record very great changes in the coverage made by Marchantia (see figure XIII.I a & b). Small plants of Marchantia appear by mid-winter following a burn in autumn and may attain 20% coverage by spring time. If the following summer is not unusually dry, the plant individuals increase in size and probably in number. The increase in coverage continues until the next spring, when a peak of as much as 75% coverage is attained. Thereafter, Marchantia declines at a rate which is probably determined by the dryness of the summers and by the degree of competition for moisture by fireweeds and shrubs. On one site Marchantia rose from 0% coverage at age 0 years to 53% at age 1⅝ and fell again to 4% at age 2½/

Where Marchantia was over one year old it tended to die back in summer, especially in exposed places. Marchantia appears to suffer heavily when in competition with dense Erechthites in spite of the benefit from shade. Desiccated plants commonly regenerate from their tips in autumn. Mosses tend to recolonize the dead patches faster than Marchantia. Once the mosses are well established, Marchantia cannot invade them significantly. Hence Marchantia declines after 1½ years. The better drought resistance of Marchantia during the first summer, compared with later summers, might be explained by the fact that later crops overgrow their own dead and, therefore, dry out more easily.

Other liverworts are rare on burnt seed bed and occasional on unburnt and on disturbed soils.

It is likely that the development of Marchantia is strongly influenced by the climate of the first summer. We have no good experimental evidence on this point.

General observations suggest that Marchantia is usually rare on ground where all or most of the humus has burnt away. In all observed cases, extensive mats of Marchantia were associated with a moderate amount of humus. The humus probably improves the moisture supply. This suggests that development of Marchantia can be influenced by the type of fire which cleared the ground.

(b) The Mosses.

Mosses usually make up the greater part of the ground mat which develops after the burning of good forest sites in the Florentine Valley. They may predominate over all the other species of the ground mat on areas of hundreds of acres. There is a distinct succession in moss species but at least in the early stages, the number of moss species on burnt ground is remarkably small. The succession is from the "fire mosses" to Polytrichum and eventually to the mosses which are found in the virgin forest.

The Fire Mosses.

The "fire mosses" are those species of moss which colonize freshly burnt ground in great abundance and are relatively rare on unburnt or not recently burnt ground. They may even grow on pure charcoal.

The early development of the fire mosses is complementary to that of Marchantia. The fire mosses colonize most or all of the burnt ground not occupied by Marchantia. Their absolute coverage is, therefore, as variable as that of Marchantia, but in terms of available burnt ground not occupied by Marchantia the fire mosses were uniform in their early development on all the sites included in this study. Where Marchantia was rare, the fire mosses occupied over 80% of the burnt ground at their peak of development at age 1½ or 2 years. (See figure XIII.1 c & d).

Where the aerial layers of vegetation become dense by the age of 4 years, the fire mosses are shaded out. Elsewhere, the fire mosses are replaced by Polytrichum. The fire mosses usually dwindle to insignificance in the third and fourth years after the fire.

Funaria hygrometrica and *Ceratodon purpureus* are by far the most important of the fire mosses. *Bryum crysoneuron* does sometimes occur but is much less common, and is less typical of burnt ground. There are no other important species of fire mosses in this area. Both *Funaria* and *Ceratodon* may be found in similar circumstances on freshly burnt heaths and bogs in England (Watson, 1955). In the Florentine Valley, *Funaria* and *Ceratodon* usually grow in intimate mixture and are similar in abundance. After the 1960 and 1961 fires, the ground in most areas was dominated by *Funaria* at first and *Ceratodon* did not become conspicuous until one year later. *Ceratodon* is, apparently, less moisture demanding and may sometimes predominate on the drier sites. The fire mosses dry out easily in summer but recover readily from apparently complete desiccation.

The species called fire mosses are vegetatively all very similar. They grow most rapidly in winter. They are widespread but relatively sparse and shallow by the end of the first year after the fire. During the second winter, they become ½ to 1 inch deep (without the fruiting stalks) and so dense that a sown rice grain would rarely hit the soil.

Weaver (1938) states that on forest sites in North America "fires of recent occurrence are indicated by an abundant growth of liverworts and mosses such as *Marchantia*, Funaria, and Bryum, which frequently cover the soil". Similarly, Watson (1955) reports that on heaths in England where fires are frequent Funaria hygrometrica is generally very abundant in the first or second season after burning and that Marchantia is commonly associated with Funaria on such sites. Watson mentions that burnt heathlands are often purple with the countless setae of fruiting Ceratodon purpureus. Richards (1958) also mentions that Marchantia plus Funaria may spring up in great masses after fire on boggy ground in England. These references show that the striking development described above of Marchantia and fire masses on freshly burnt ground is not unique to the Florentine Valley. In fact, the identical species appear to play a similar role in widely separated places of the world and are probably typical of burnt ground in moist, temperate environments with soils rich in humus and acid in reaction.

Polytrichum

Polytrichum juniperinum appears as scattered individuals within one year of burning. It is the main re-colonizer of patches of Marchantia killed during summer. About the third summer it very rapidly replaces the fire mosses and forms extensive, pure patches by age 4, when it may occupy as much as 40% of the burnt ground. It usually dominates the live ground mat from age $3\frac{1}{2}$ years onwards.

Polytrichum mats are almost as dense as two year old fire mosses and are still deeper (1-2"). They do usually not die off in summer. Their rootlets are efficiently anchored in the soil. They decline only by being shaded out. Their retreat is relatively slow and depends on the rate of development of the aerial cover (See figure XIII.I e. & f.).

Polytrichum is not confined to burnt ground and may form extensive mats on unburnt and on disturbed ground.

Other Mosses.

The mosses not only dominate extensive areas of burnt ground but use very few species to do so. Apart from the fire mosses and Polytrichum only Campylopus introflexus is of any importance. This moss may appear in the second year after the fire. It develops best on rainforest mudstone soils, but did not exceed 8% ground coverage on the study plots. It also occurs in the virgin forest and can form extensive cushions on unburnt disturbed soil.

Other mosses typical of the virgin forest are rare on recently burnt ground but are more common on disturbed and on unburnt soils.

(c) Herbs of the Ground Mat.

Herbs are least important on rainforest sites. The most common herb is Hydrocotyle hirta. On rainforest sites the herbs exceeded 10% coverage in only one year. On wet sclerophyll sites the herb coverage was frequently between 20 and 34%. While the species recorded were similar on all sites, some species were more typical of wet sclerophyll sites. These are Viola hederacea, Oxalis corniculata, Acaena sanguisorba and grass-like species. Other species which were recorded on or near the study plots are: Australina pusilla, Galium australe, Asperula conferta, Dichondra repens, Gnaphalium japonicum, Geranium dissectum and Epilobium spp.

It should be noted that some of these species are confined to the ground mat only because of browsing by native animals.

In exposed places on the drier sites, the Polytrichum of the ground mat may be replaced by low herbs after some years if the aerial cover does not become dense.

3. Development of Shade-bared Soil.

When the live ground mat is shaded out by ferns or shrubs it gives way to "shade-bared" soil. Polytrichum and Hydrocotyle are the last of the ground cover species to disappear. Most areas under dense ferns or shrubs are practically bare of living ground cover. The rate of development of shade-bared soil depends on the aerial cover which is very variable. Fire weeds may grow densely enough to bare the soil in patches. These patches are recolonized when the fireweeds die.

The extent of shade-bared soil after age 4 shown in figure XIII.1 (i) is less than normal because of biased selection of study plots at this age. Evidence of burnt seed bed at this age was difficult to find except in the patches relatively free from aerial cover.

4. <u>Some Factors which influence the Development of the Ground Stratum</u>.

(a) <u>The stimulating Effect of Fire</u>.

Colonization of unburnt ground by mosses and <u>Marchantia</u> is very much slower than on burnt ground. The fire mosses are practically confined to burnt seed beds. The growth of <u>Erechthites</u> is far superior on burnt soils.

A succession of fire mosses and <u>Erechthites</u> can be obtained on disturbed and even on puddled soils by the addition of blood and bone manure. Manured spots on tractor tracks become luxuriant oases in the barren surroundings of puddled soil (see Photo. No.15).

A similar effect can be achieved by a prolonged very hot fire on tractor tracks. The fire burns away the churned up organic matter in the top inch of soil and leaves a surface of bricked crumbs.

On the other hand, if the mineral soil is exposed by removing the mat of fire mosses two years after burning, the original succession of fire mosses and <u>Erechthites</u> is <u>not</u> repeated. The site behaves like ordinary lightly disturbed soil. If the moss cover plus humus is burnt by a second fire the original fire succession is repeated.

During the first winter, i.e. while drought is not limiting, a humus fire is followed by more rapid colonization by mosses than a surface fire.

This may be due to the fact that a humus fire burns a lot of extra fuel in a very hot fire right close to the soil.

The above observations and experiments show that the nature and rapidity of the colonization of burnt ground is due to the stimulating effect of fire. The stimulation by fire may be due to release of plant nutrients, the sterilization of the soil and the increased availability of nitrogen.

Burgeff (1943) states that Marchantia grows in all sorts of wet places and occurs in great masses on burnt ground, especially on burnt bogs and that it thrives on a rich mineral nutrient supply.

(b) The Effect of fencing against native browsing Animals.

The felled areas of forest in the Florentine Valley are intensively browsed by wallabies (Protemnodon rufogrisea v. frutica, and Thylogale billardieri) and possums (Trichosurus vulpecula fuliginosus). The effect of browsing control depends on whether control begins before or after most of the palatable species are eliminated.

Herbs are the only component of the ground mat which may respond to fencing. Inside the 22 acre fence at W56 the response by herbs was absent or very small. Elsewhere some of the fenced milacre quadrats on freshly burnt seedbed showed a marked, temporary expansion of Hydrocotyle overtopping the mosses. Though their fruiting bodies are browsed, the development of mosses and Marchantia does not appear to be directly affected by browsing.

The aerial strata, namely fireweeds and shrubs, benefit greatly by protection from browsing. The advent and spread of shade-bared soil is, therefore, accelerated by several years, if the area is protected from browsing from the date of burning onwards, e.g. at W56, burnt in March 1958 and fenced in June 1958, the aerial shrubs became so dense that about half of the burnt ground was bare again by age 3 years while shade-bared ground on the adjacent, unfenced, comparable W72 was negligible.

The increased competition for moisture due to the earlier development of the aerial strata may cause the earlier disappearance of Marchantia.

(c) The effect of seasonal Climate.

A warm winter probably accelerates the spread of mosses and Marchantia. The hot, dry summers of 1959/60 and 1960/61 probably had the reverse effect, especially on Marchantia. Herb, fern and shrub growth is almost nil in winter but very rapid in a relatively hot summer.

(d) Effects of the previous Vegetation.

The propagules for the main species of the ground mat (i.e. the spores of Marchantia and the mosses) are presumably abundant on both wet sclerophyll and on rainforest sites. The special series of quadrats on mudstone soils under former wet sclerophyll forest shows that the previous vegetation did not significantly influence the development of the ground mat directly.

On the soils derived from mudstone, the ground mat on the site formerly occupied by rainforest was similar at least up to age 2½ years to the ground mat on a site which had been wet sclerophyll forest (See figure XIII.1 a,c,e & g.)

The greater abundance of shrub propagules and the presence of the fire resistant Pteridium on wet sclerophyll sites causes the earlier establishment of a dense aerial cover and hence shade-bared soil irrespective, probably, of soil types.

On the drier soils in the wet sclerophyll forest, herbs are relatively more abundant both before and after burning than on the wetter sites. It is likely that the composition of the herb cover on the drier sites is affected by the survival of roots and seeds from the previous vegetation and by the seedshed from the adjacent unburnt areas of vegetation.

II DEVELOPMENT OF THE AERIAL STRATA

The aerial strata vary more from place to place than the ground stratum because they are profoundly influenced by the previous vegetation and by the intensity of browsing after the burn. There are three distinct stages in the early development of aerial cover on burnt ground. They are firstly the fireweed stage, secondly the fern stage and thirdly, the shrub stage.

1. The Fireweed Stage.

This stage is usually dominated by Erechthites prenanthoides; Senecio has been seen to become dominant on mudstone, on conglomerate and on alluvial soils protected from

Photo No. 17 : Dense clump of *Erechthites* in March 1960 growing on a spot cultivated in March 1959 on an area burnt and fenced in March 1958. The photo shows that *Erechthites* finds it relatively difficult to establish on burnt seed bed more than one year old

Photo No. 18 : The same plot photographed on 10.11.59, on 26.4.60 and on ~~25.4.61.~~ Wet sclerophyll forest site on limestone burnt in March 1959. Note scattered young *Erechthites* and *Pteridium* and 80% moss cover in first spring. Note rapid expansion of fireweeds and ferns by end of first summer. Note that most fireweed is dead by end of second summer. *Pteridium* and *Zieria* are expanding, and will make complete canopy in another year's time.

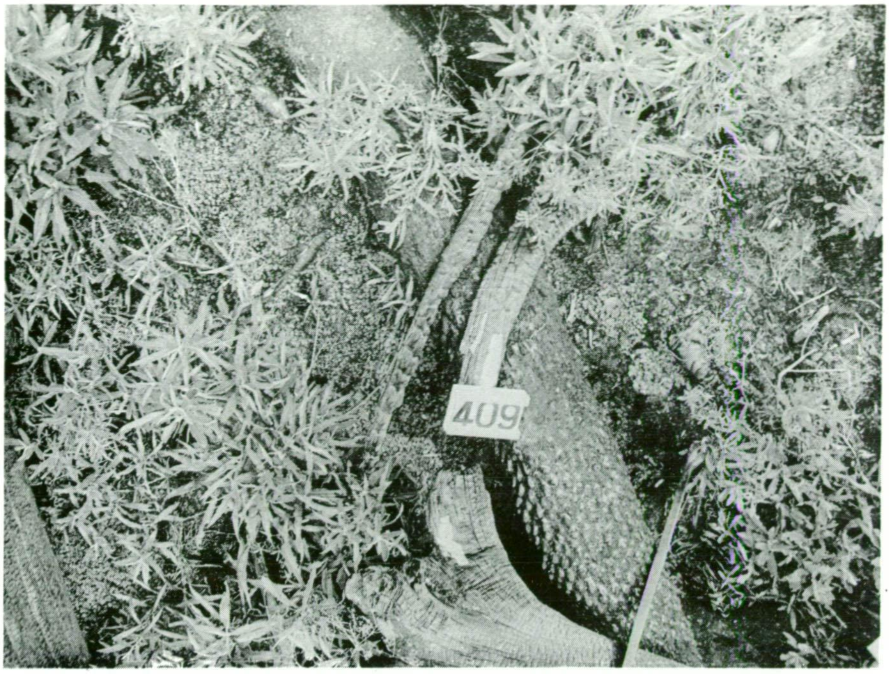


Photo No. 19 : Rainforest site on dolerite burnt in March 1958, photographed on 10.11.59 and 26.4.60. Note dense cover of vigorous *Erechthites* during second spring, and its complete death after the following summer.

Photo No. 20 : Rainforest site on mudstone burnt in March 1959, photographed on 10.11.59 and 26.4.60. Note that *Marchantia* covered more than half of the seed bed by springtime and nearly all of the seed bed by the end of the first year.

Photo No. 21 : Developing thicket of *Pomaderris* three years after a March burn on a **fenced** rainforest site. Note 2-year old *E. regnans* seedlings. Note also dead remains of *Erechthites* after its sudden ebb at age two.

browsing and <u>Carduus</u> may, at times, predominate on shallow limestone soils. Two or more of these species are commonly mixed. <u>Erechthites</u> and <u>Carduus</u> have similar life histories but <u>Senecio</u> appears to have a longer life than <u>Erechthites</u>. Only the life history of <u>Erechthites</u> is described below.

<u>Erechthites</u> usually prefers freshly burnt ground. Its seeds are abundant, easily wind blown, germinate rapidly, and presumably are not stored in the ground. They probably do not survive fires. A ground mat of dense, deep mosses reduces its opportunities to establish (See photo. No.17). <u>Erechthites</u> is very light demanding.

Ripe seed is produced annually from February to May. By April abundant germinations appear on freshly burnt or lightly disturbed ground. Mortality during winter is very high. By spring time (September) the seedlings are 1-2" high, but then grow rapidly and start shedding seed in February. The inflorescences and often the top of the plant die back in winter but the plants usually survive to produce a second crop of seed next year. During the second year each plant usually enlarges greatly by sprouting new shoots from its base.

If these plants plus their one year old offspring achieve a uniformly dense cover almost all the fireweeds die suddenly in March-April of the second year after the burn. Sometimes <u>Erechthites</u> makes a dense cover already in the first summer and sometimes, not until the third summer after

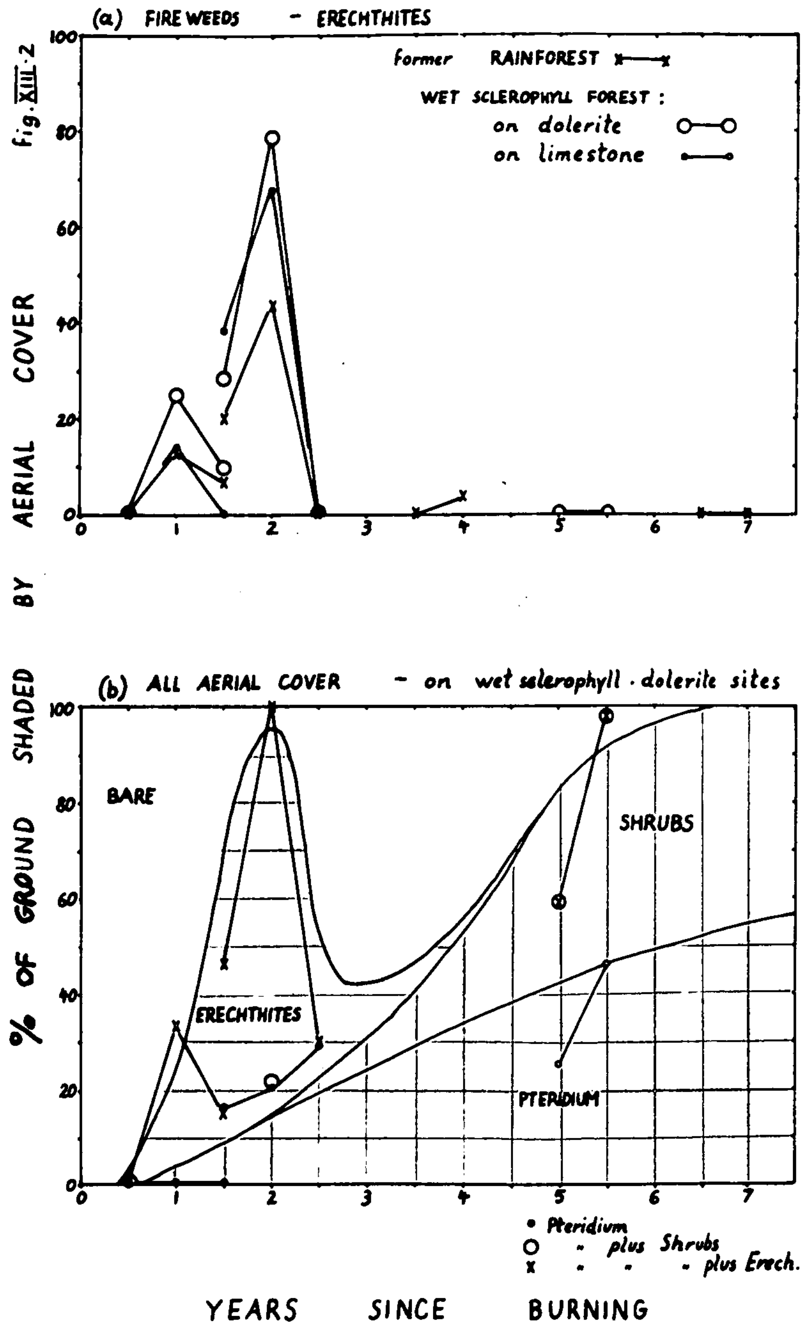


Figure XIII.2 The pattern of aerial cover changes during the early succession on burnt soil. Curved lines indicate estimated trends. Straight lines show changes observed at half-yearly re-inspections of 5 to 10 fixed milacre plots on each site. Note that the cover made by fireweeds and ferns increases during summers and decreases during winters. Age 0 is autumn.

after the fire. In each case, the fireweed ebb occurs in the autumn following the summer during which the dense coverage was achieved. This sudden, wholesale death of fireweeds is as spectacular as it is mysterious (See photo. No.19).

If the fireweed cover does not become dense it does not disappear so suddenly but continues as scattered plants for several years. The sudden ebb of fireweed is not entirely explained by its growth habit. (short life-span, high light requirements, preference of bare ground for germination). It might be due to exhaustion of a certain soil constituent which is especially abundant immediately after a fire.

Browsing can reduce the density and prolong the life of fireweeds. Dense fireweeds can, nevertheless, develop without protection from browsing. The density of fireweeds varies greatly from site to site and from year to year. Availability of seed and the weather conditions may be responsible for this. On the areas studied, fireweeds covered 14 to 25% of the ground in the first summer, 44 to 79% in the second summer and then became insignificant (See figure XIII.2)/

It is thought that the drier summer of 58/59 killed most of the young Marchantia thus permitting the establishment of a dense second generation of Erecthites on the dead Marchantia.

The fourth score of the permanent quadrats is not shown in figure XIII.2. This score showed that the fire weeds had been few (less than 10% coverage) during the summer of 1960/61, not only on the sites burnt in 1958 but also on those burnt in 1959. This means that the 1959 fires produced much less fireweed than the 1958 fires. Comparison with figure XIII.1 will show that the position with Marchantia was the reverse; the 1959 fires produced much more Marchantia than the 1958 fires. The reason for this pattern is not known. Drought is apparently not the explanation. The summer following the 1959 fire was drier than the summer following the 1958 fire. The relative dryness was estimated by Thornthwaite's method which takes account of both rainfall and potential evapotranspiration. Part of the explanation could be that Marchantia and Erechthites might possibly compete for the same special nutrients.

Herbaceous fireweeds similar to Erechthites are typical of freshly burnt ground throughout the world. In Northern America the typical fireweed is Epilobium angustifolium (Weaver, 1938).

2. The Fern Stage.

The fern stage is dominated by ferns and follows the fireweed stage. Its full developments depends upon the absence of an early dense shrub stage.

(a) The soft Ferns.

On former rainforest sites the ferns are "soft" i.e. their leaves are soft and delicate. The only important species of soft ferns are <u>Histiopteris incisa</u> and <u>Hypolepis rugulosa</u>. These two species are of similar importance and usually grow intimately mixed. They appear to spread mostly by vegative means. Their arrival and rate of expansion after a fire therefore depends largely on previously established rhizomes. In spring time (November) it is not hard to find very young fern plants growing from the gametophytic thallus in moist niches.

Both species are present as scattered individuals throughout the virgin rainforest. After felling without burning they expand in dense patches which become continuous about 3 to 5 years after felling. Many, perhaps most of their rhizomes, are confined to the humus layer. A fire which consumes the humus may, therefore, kill most of the rhizomes but a surface fire does not. The amount of live rhizomes present after a fire, therefore, depends on the type of fire and on the interval between felling and burning. A dense stand of wet ferns burnt by a surface fire can become dense again in one year. Rainforest areas which are burnt by a surface fire become densely covered with soft ferns about 4 to 6 years after the fire. This means that there is a low in aerial cover after the fire weeds die off suddenly at about age 2, and before the ferns become dominant. It is not known for how long a humus fire will delay the advent of wet ferns. Most areas of rainforest in the Florentine Valley which have been felled 4 to 10 years ago are now covered by dense wet ferns often to the virtual exclusion of all other plants.

The wet ferns grow 2-3 ft. high and are normally so dense that nothing grows beneath them. Often they transmit only one percent of daylight. Except under shelter all their fronds die off and collapse every winter about June. They re-establish full canopy between September and December.

After about 10 years, the wet ferns are usually being replaced by Pteridium - if the coupe is free from sheltering trees.

Polystichum or Blechnum sometimes persist from the original forest but do not expand after felling. Pteridium is not present in the rain-forest because it is moderately light demanding.

Neither the soft ferns nor Pteridium are browsed. Browsing, therefore, favours the ferns by removing their shrub competitors which are all palatable.

(b) Bracken.

All the fern species mentioned above are present in the wet sclerophyll forest. Pteridium esculentum (bracken) is the most abundant one in open stands. Its rhizomes are not shallow and penetrate below the humus and are, therefore, not killed by any fire. Bracken spreads very rapidly after a fire. Like the wet ferns it can spring up in very isolated patches, especially in the shelter of burnt logs or stumps - thus suggesting that it can be spread by spores.

Pteridium is by far the most important fern on felled areas of wet sclerophyll forest. Its abundance after the fire is very variable but is directly related to its abundance before the fire and consequently depends on the length of time between felling and burning and upon its initial abundance in the virgin forest. A full canopy of *Pteridium* will re-establish itself within one year of a fire, though at a lower height. At first *Pteridium* tends to grow in patches which expand at the rate of several feet in radius annually. A normal fire soon after felling can produce a dense *Pteridium* cover on most of the felled area by age 3 or 4 years on *wet sclerophyll* sites, especially when browsing removes much of the shrub competition.

Repeated burning kills the shrub competitors and establishes pure *Pteridium* over large areas. This is the case with much abandoned high-rainfall farmlands in Tasmania. In the Florentine Valley *Pteridium* often grows over 5 ft. tall and is commonly so dense as to exclude 99% of daylight. Practically all plants below it die. Unlike the wet ferns, and unlike *Pteridium aquilinum* in England the fronds do not all suddenly collapse every winter. Only a proportion collapses unless snow flattens the whole stand.

Once *Pteridium* dominates an area it persists for a long time. It may eventually be shaded out by an advancing forest edge if the tree species can establish at less than 11% daylight (Braid, 1959). There does not seem to be a cyclical succession like that described by Watt (1947) for

Pteridium aquilinum in England. The trunks of standing tree ferns provide elevated well lit seedbeds for invasion by a number of tree and shrub species.

Most areas of wet sclerophyll forest, if burnt only once, will produce enough shrubs and trees to predominate over the bracken within 10 years.

3. *The Shrub Stage and the Effect of Browsing*.

Shrubs and trees will eventually dominate the site. They may be almost absent at age 10, or may already dominate the site at age 4 depending on the availability of seeds and on the browsing history. The shrub stage is more variable than any of the previous stages.

The most important shrub species other than the Eucalypts are *Pomaderris apetala* and *Acacia dealbata* on rain-forest sites - with the addition of *Zieria arborescens* on wet sclerophyll sites. *Olearia argophylla* or *Phebalium squameum* may be also locally important. All these species except the roots of *Olearia* are very sensitive to fire.

The seeds of *Acacia* (Gilbert, 1959) and *Pomaderris* and probably also those of *Zieria* and *Phebalium* are stored in the ground for many years and will germinate after a fire. Large numbers of germinations from *Acacia* and *Pomaderris* may appear on freshly burnt ground which had not carried these species for decades. *Olearia* is easily dispersed by wind. In addition, *Olearia* is the only local shrub species whose roots sprout readily after the top is killed.

The early development of competing woody vegetation presents a serious problem in the regeneration of many forest areas in America. In areas which are burnt more frequently there is a greater proportion of species which can sprout after a fire from underground. In California, the top soil in the forest may store as many as three million seeds of woody species (mainly Céanothus spp, Ericaceae, Leguminosae) which can survive a fire (Buck, 1959).

On areas of former rainforest, intensive browsing by native game will delay or prevent the development of shrub thickets because all the shrub species here are quite palatable and are easily killed or stunted by browsing. On wet sclerophyll sites, however, the shrub regeneration is usually more profuse and includes the relatively unpalatable Zieria. Consequently, wet schlerophyll sites are much more likely to produce a shrub thicket at an early age after burning. Usually Zieria predominates in these areas, even though the germinations of Pomaderris and Acacia after the fire are normally much more numerous than those of Zieria. This means that browsing will change the composition of the shrub thicket in some areas. This view is supported by the fact that the wet sclerophyll scrub which was burnt and gave rise to the Zieria thicket had in all observed cases been dominated by Pomaderris and Acacia, with Zieria apparently absent.

If browsing is prevented before the shrub species are killed, most areas in the Florentine Valley, except a few very old rainforest sites, will produce a shrub thicket ~~at an early age~~ Soon (3 to 5 years) after burning. In many, perhaps most, areas 10,000's and often 100,000's of germinations per acre of shrub species (mostly Pomaderris and Acacia) can be counted in the spring following the fire.

Table XIII.3

The effect of browsing on the development of shrub species.

1,000's of plants per acre (other than Eucalypts) on burnt ground free of logs estimated on transects of 30 to 80 half milacre plots each. (The area had been a rainforest site without Pomaderris or Acacia and was burnt in March, 1958 and 22 acres of it were fenced in May, 1958).

Species	Date of scoring					
	6/59		10/60		8/61	
	fenced	NOT fenced	fenced	NOT fenced	Fenced	NOT fence
Pomaderris			62.3	1.1	58	2
Acacia			2.5	0.2	4	7
Other woody species			3.8	1.1	1	0
Total	35.7	7.0	68.6	2.4	63	9
Erechthites	5.3	2.0	0.4	5.2	0	0

The data in Table XIII.3 ~~III~~ illustrate how very striking the effects of browsing control can be. Inside the fence (at W.56) there is a dense, five feet high thicket on all the burnt ground. Outside the fence, the ground is almost free of shrubby cover. Not only is the number of plants very much lower than inside the fence but also the size of the plants is very much smaller. (See photo. No.21)

Pomaderris showed the strongest response to fencing. This plant is apparently most palatable and extremely sensitive to defoliation. *Acacia* seems much less vulnerable and is more patchy in distribution.

The fencing did not obviously affect the survival of *Acacia*, although height growth inside the fence was much greater. There were relatively few woody plants other than *Pomaderris* and *Acacia*. The fencing also protected *Erechthites* from browsing. As a consequence *Erechthites* reached its peak during the second summer after burning inside the fence and during the third summer outside the fence. There are numerous examples elsewhere to show that lack of browsing control does not necessarily prevent or delay the formation of an early dense cover of *Erechthites*.

It should be remembered that it is not necessary for the formation of a thicket to have extremely large numbers of plants. 5,000 to 10,000 individuals per acre may be quite enough after browsing permits each individual to grow large and vigorous. It could be that *Acacia* will form patches of thicket outside the fence in a few years' time.

The table also suggests that new woody plant individuals may appear during the second year after the fire, but not in later years (at least inside the fence).

The effectiveness of fencing on the stimulation of growth of woody plants depends on whether there are any plants present at the time of fencing. There is no doubt that immediately after fire is the most effective time to fence. When new germinations have ceased and the old plants have been killed by browsing, fencing does not improve the growth of woody plants. This appears to have been the case on the two quadrats on former rainforest sites fenced at age 3½. The four quadrats fenced at age ½ behaved like W.56 above. The three quadrats fenced at age 1½ were intermediate but rather variable. They support the suggestion that Pomaderris thickets may be prevented by 1½ years' browsing and that Acacia and Zieria thickets can still occur after 1½ years' browsing.

If a dense thicket is formed before the ferns can become dense, the fern stage in the succession is bypassed. This is the case inside the W.56 fence but not outside the fence. The Pteridium on wet sclerophyll sites develops relatively rapidly and, therefore, may have a greater chance of dominating some patches of ground before the shrubs become dominant.

Because of their relative scarcity and slow growth rate Nothofagus and Atherosperma do not usually make a significant contribution to the development of an early thicket.

III. SUMMARY OF THE SUCCESSION ON BURNT GROUND

On good forest sites in the Florentine Valley a dense ground mat consisting predominantly of fire mosses and *Marchantia* will colonize about 90% of all burnt ground within one year of a fire in autumn. The ground mat becomes deeper and denser and covers about 99% of the burnt ground after another half year.

Marchantia may cover over 70% of the burnt ground at age $1\frac{1}{2}$ years on wet soils e.g. on mudstone. On dry, shallow limestone soils *Marchantia* may be almost absent. Most of the ground not covered by *Marchantia* is colonized by the fire mosses *Funaria* and *Ceratodon*.

In the third and fourth years after the fire *Polytrichum* replaces most *Marchantia* and nearly all the fire mosses. *Polytrichum* is eventually shaded out by the aerial cover.

Hydrocotyle is the most important herb in the ground layer. The herbs increase in importance with increasing dryness of the site. On former rainforest sites the herbs of the ground mat are relatively unimportant. On former wet sclerophyll sites low herbs are of greater significance and may often occupy 20 to 30% of the ground.

Three stages are recognized in the early succession of the aerial layers; the fireweed stage, the fern stage and the shrub stage.

The fireweed stage is usually dominated by *Erechthites*. During the second summer the fireweeds may reach a peak of over 80% aerial cover. Browsing may reduce fireweed density. After their peak the fireweeds disappear suddenly.

On rainforest sites the ferns Hypolepis and Histiopteris should become dense about age 4 or 5 years. They dominate large areas to the exclusion of nearly all other plants. On wet sclerophyll sites Pteridium takes the place of the above ferns. Pteridium develops a little faster because its rhizomes are not killed by any regeneration burns. The rate of fern development after a burn depends on their abundance before the burn. The wet ferns are set back if the fire burns the humus.

Shrubs and trees eventually dominate a site. Their domination is earliest on wet sclerophyll sites but is greatly accelerated on all sites by the prevention of browsing. If browsing is prevented, thickets are formed so early (age 4 or 5) that the fern stage is by-passed.

The changes of vegetation described above are not a succession in the classical sense because succeeding stages do not appear to depend on the preparation of the site by the previous stages. The succession here appears to be controlled by the speed with which each species can establish itself in quantity and by its relative competitive ability. It is characteristic that the first species which occupy the burnt ground are extremely mobile but weak in competition with the more slowly growing species.

The establishment and growth of the climax rainforest species does not depend on the succession described above.

B. SUCCESSION ON UNBURNT GROUND

I. Succession on Unburnt, Undisturbed Ground.

A detailed study of unburnt soil was not made because the excessive amounts of logging debris make a relatively poor seedbed for Eucalypt regeneration; only general observations were made.

The ground mat develops more slowly than on burnt ground. The fire mosses are rare or absent. Some remnant mosses from the virgin forest survive and expand. In the absence of fire the germinations of *Acacia* and *Pomaderris* may be less abundant. The soft ferns expand more rapidly. On wet sclerophyll sites many of the original shrubs survive and continue growing.

II. Succession on Tractor Tracks.

The tracks made by logging tractors cover about 20% of a coupe's area. Most of such tracks are severely puddled. Few or no seedlings of any species can establish on recently puddled soils.

Recovery from puddling usually takes several years, sometimes more than ten years.

The rate and pattern of succession on puddled soils is quite different from and much more complex than that on burnt ground. Certain species such as *Juncus*, *Carex* and *Gahnia* are favoured. Fire mosses are rare. Eucalypts are among the pioneers. *Carduus* may thrive on lightly disturbed soil. Otherwise, the fireweeds are relatively infrequent and less vigorous.

A detailed study of the succession was not made because Eucalypt regeneration is not limited by weed competition on soils which are beginning to recover from puddling.

C. THE INFLUENCE OF THE VARIOUS STAGES OF THE SUCCESSION ON REGENERATION OF E. REGNANS.

I. Regeneration from seed.

The succession in flora is accompanied by changes in fauna. The seed-robbing *Dieuches* bug appears soon after a burn and builds up to very large populations by the second summer. The influence of insects on Eucalypt germination rates may be greater than the influence of the early stages of vegetation. The effect of vegetation is more precisely assessed by comparing survival rates.

(1) Regeneration from Broadcast Sowing or from Seed shed from Standing Seed Trees.

The final results from the experiment referred to above will not be available before 1963. It should be mentioned, however, that it is already obvious that no significant regeneration will be obtained on plots which were sown 3½ years or later after burning. The plots sown at ½ and 1½ years after burning did produce some regeneration. There are, in addition, a number of earlier experiments with some bearing on this problem - see Gilbert 1958 and chapter XI of this report.

The germination percentages and survival rates from sowings of *E. regnans* on one-year old, burnt seed bed were not poorer than those from sowings on younger seed beds (see cahpter XI). One year after the fire, most burnt ground is thinly covered by moss and <u>Marchantia</u>. Moss does not seem to be detrimental when it is still very shallow. <u>Marchantia</u> was scarce on these particular sowings. Its horizontal growth tends to bury very young seedlings. Where it is dense it may offer the Eucalypt seed insufficient niches for germination - and may present a barrier between the seed and the soil.

The pellet experiment (Chapter XI) has shown that germination percentages of seed sown on the surface of two year old seed beds are often much lower than those on freshly burnt seed bed, even if all ground and aerial vegetation is removed. Two year old, dense, deep fire mosses permitted considerable numbers of germination but allowed only extremely poor survival. Growth was poor. Penetration of rootlets through the moss to the nutrient soil appears to be difficult. Consequently death rates were very high as soon as the moss dried out in summer.

Because of its greater depth <u>Polytrichum</u> is likely to be even more forbidding than old fire mosses.

<u>Shade-bared</u> soil permits germination but no survival.

It is concluded that the chances of regeneration from seed decrease rapidly during the second winter and spring after burning when the mosses become deep and dense.

There are countless examples of cases where an abundant annual seedshed fails to produce additional regeneration apparently mainly because the ground is densely covered with ferns or scrub. For instance, the ground at W.36 is covered by dense soft ferns and has not produced any significant regeneration in recent years even though there has been a measured rate of seedshed of more than one pound per year, per acre.

(2) Regeneration from Spot Sowings.

Spot sowing implies removal of the ground mat and perhaps some reduction in the aerial cover.

Removal of the one year old ground mat in March, 1959 at W.56 was followed by very rapid re-invasion of the cleaned spots by fire mosses, Marchantia, and by very numerous Erechthites germinations. Most spots cleared in autumn were covered again by spring time. The effect of this on the germination and survival of E. regnans spot sowings was not serious (see Chapter XI).

Removal of the ground mat more than one year after the fire (see pellet experiments in Chapter XI) was not followed by rapid recolonization. However, the Eucalypt seed sown on the surface of this cleared ground germinated very poorly. This is ascribed to high temperatures and to seed robbery by insects. If the seed had been raked into the soil and if the sowings had been followed by moist, cool weather, then the sowings should have have succeeded.

If the seed is sown at the right time and is protected from insects, spot sowing with protection from browsing should be successful until the ferns or shrubs become dense. Dense fire weeds decrease survival of very young Eucalypt seedlings. For this reason, spot sowing during a dense fire weed peak should be avoided.

3. <u>Regeneration from Plantings</u>.

It was shown in chapter X that planting amongst undisturbed, well established ferns is not successful. It is assumed that thickets are even less suitable for planting in.

Planting with protection from browsing should be successful wherever shade bared soil is not extensive. Dense fireweeds allow good survival of planted seedlings.

4. <u>Conclusions</u>.

Burnt seed bed probably deteriorates rapidly after one year. Broadcast sowing, therefore, should be done within one year of burning. The effectiveness of seed trees greatly decreases after one year. Provided the seed is protected from insects spot sowing with control of browsing is likely to be successful until ferns or shrubs become dense, i.e. several years after a fire.

With protection from browsing, planting may be successful one or two years after spot sowing has become impossible. Planting is not successful amongst undisturbed well established ferns or shrub thickets when nearly all the ground is bared by shade.

APPENDICES

I	Data on :	Distance of Seedshed, Road 11 experiment.
II	" " :	Distance of Seedshed, W.48 Experiment.
III	" " :	Effect of fire on the shedding of seed and floral parts
IV	" " :	Development of natural regeneration : W.54 experiment
V	" " :	Development of natural regeneration : Experiments at Roads 7A and 8 West.
VI	Statistical Analysis of :	"Puddled Soil Experiment"
VII	" " " :	Autumn 1960 Field test of pelleted seeds
VIII	" " " :	Seed Burial Experiment
IX	Details of methods and results of sowing experiments	
X	Details on planting stock used in Project I.	
XI	Reprint of "Eucalypts in Rain Forest"	
XII	Reprint of "Problems of Eucalypt Regeneration in the Florentine Valley	

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List of specific names and authorities of plants mentioned in the text.

References

APPENDIX I

DISTANCE OF SEED SHED   Rd 11

Data not contained in J.M. Gilbert's Report.

Catch

Date of Catch	No.	F/N + Seeds/2 traps per month T	S	F/NE Ratio: mean/actual T	S	Roving Traps free seed / trap / month: Stratum I D	T	S	D	T	S	Stratum II D	T	S	D	T	S	Stratum III D	T	S	D	T	S	
9.3.58	25																							
2.5.58	~~25~~ 26	291.0		.515		170	11	2 ~~.57~~	10	83	14	390	2	1	330	7	1	725	2	0	735	0	0	a
							3.15	.57		23.8	4.01		.572	.286		2.01	.29		.29			o	0	R
24.6.58	27	71.4		2.09		40	29	0	45	50	1	340	2	1	490	0	0	705	1	0	670	3	0	a
							34.3	0		59.2	1.18		2.36	1.18		0	0		1.B	0		3.55	0	R
12.8.58	28	30.0		4.99		40	7	1	45	← 7	← 1	340	0	0	385	0	0	685	0	0	720	0	0	a
							21.3	3.0		21.3	3.0		0	0		0	0		0	0		0	0	R
30.9.58	29	130.		1.15		45	17	3	60	← 33	2	275	4	0	365	1	0	005	17	4	355	1	0	a
							11.9	2.18		23.2	1.41		2.82	0		1 .705			11.9	2.82		.705	0	R
8.12.58	30	96.6		1.55		140	3	1	170	6	1	210	3	1	300	4	1	335	4	0	390	0	0	a
							.220	.674		.404	.674		.220	.674		.270	.674		.270	0		0	0	R
30.1.59	31	101		1.48		5	53	5	25	39	11	175	5	0	280	2	0	355	4	0	445	0	0	a
							44.4	4.18		32.7	7.62		4.18	0		1.68	0		3.35	0		0	0	R
12.3.59	32	298		.502		65	5	0	60	2	0	270	0	0	320	0	0	-	-	-	-	-	-	a
							1.83	0		.735	0		0	0		0	0							R
3.5.59	33	292		.513		235	5	1	200	6	0	470	0	0	485	0	0	-	-	-	-	-	-	a
							1.48	.296		1.78	0		0	0		0	0							R
19.6.59		45.5		3.29		170	0	0	150	2	0	300	1	0	-	-	-	-	-	-	-	-	-	a
							0	0		5.3	0		2.66	0										R
		X → X X																						

No.26-34: Total free seed shed 2280
Days of catch 457
Monthly catch = 149.5

D = distance (ft)
T = total free seed
S = sound free seed
a = actual No. caught in that period
R = "a" converted to mean monthly rate.

DISTANCE OF SEED THROW

APPENDIX II

~~SOUTHERN AREA ASSESSMENT~~

W 48

Date Collected	Total No. of free seed caught per trap per month at given distance from seeding edge - in ft.						
7.11.57	85	95	160	195	250	350	D
	5.7	4.3	1.4	0	0	0	T
	1.4	1.4	0	0	0	0	S
16.12.57	10	15	175	215	355	360	D
	3.8	16.2	0.8	0	0	0	T
	0.8	0.8	0	0	0	0	S
29.1.58	110	115	165	195	275	315	D
	4.8	2.0	1.4	1.4	1.4	0.7	T
	0	0.7	0	0	1.4	0	S
9.3.58	105	110	175	195	290	340	D
	3.8	6.1	0	0	0.8	1.5	T
	0	0	0	0	0	0.8	S
2.5.58	000	60	150	155	335	325	D
	11.1	5.5	0.5	0.5	0	1.7	T
	2.2	1.1	0	0.5	0	0	S
+ ~~24.6.58~~ 12.8.58	35	35	125	220	340	355	D
	0	0	0	0	0	0 0	T
	0	0	0	0	0	0	S
30.9.58	85	35	130	190	330	360	D
	1.2	3.1	1.2	0	0	0	T
	0	0.6	0	0	0	0	S
8.12.58	120	40	160	135	285	300	D
	1.3	3.0	1.7	1.3	0.4	0.4	T
	0.4	0.4	0	0.4	0	0	S
30.1.59	000	120	175	240	350	310	D
	2.3	2.8	0	0	0	0	T
	0	1.1	0	0	0	0	S
12.3.59	30	35	200	205	255	335	D
	1.5	2.9	0.7	1.5	0	0	T
	0	0	0	0	0	0	S
3.5.59	110	65	140	215	265	335	D
	6.9	5.3	2.3	1.2	0.6	0	T
	0	1.2	0	0.6	0	0	S
10.6.59	10	20	225	200	315	285	D
	0	0	2.1	0	2.1	0	T
	0	0	0	0	0	0	S

D = distance from forest edge in feet
T = total free seed) daught in one trap of 1/4,400 acre during that period
S = sound free seed)

Date of installation 26.9.57.

+ 24.6.58	60	70	230	130	350	255	D
	1.1	2.9	1.1	0.5	0	0	T
	0	0	0	0	0	0	S

APPENDIX IV. DEVELOPMENT OF NATURAL REGENERATION.

Date of Score	BURNT								NOT BURNT								TOTAL			
	with litter: BL				without litter: B n L				puddled: n B P				not puddled: n B n P				for all seed beds			
	No of plots (½000 Ac)	No. of germ's	No. of deaths	nett	plots	germ's	deaths	nett	plots	germ's	deaths	nett	plots	germ's	deaths	nett	plots	germ's	deaths	nett
Series I at W 54, burnt on 23.2.59																				
23.4.59	16	24	-	24	15	20	-	20	7	5	-	5	12	10	-	10	50	59	-	59
29.5.59	16	46	5	65	15	38	3	55	7	8	1	12	12	12	4	18	50	104	13	150
24.6.59	16	31	9	88	15	23	3	74	7	5	2	15	12	7	3	21	50	66	17	198
21.7.59	16	8	14	81	16	9	6	79	8	3	3	16	10	2	0	19	50	22	23	195
19.8.59	17	12	7	87	15	9	10	78	7	3	3	15	11	2	2	20	50	26	22	200
23.9.59	17	103	25	164	15	124	17	184	7	26	2	40	11	31	6	46	50	284	50	434
23.10.59	17	16	52	127	15	33	42	175	7	11	9	42	11	5	12	40	50	65	115	384
23.11.59	17	18	42	104	15	16	62	129	7	8	6	45	11	8	11	39	50	50	121	317
22.12.59	17	9	15	96	15	14	31	105	7	3	3	45	11	9	3	45	50	35	52	291
22.1.60	17	3	18	85	15	8	17	100	7	11	1	53	11	6	4	46	50	28	40	284
Series II at W 54, burnt on 23.2.59																				
19.8.59	13	-	-	8	18	-	-	32	12	-	-	7	11	-	-	16	54	-	-	63
23.9.59	13	39	2	41	19	168	10	190	12	24	3	29	11	26	3	38	55		18	298
23.10.59	13	4	9	40	19	41	62	167	12	5	3	30	11	15	8	46	55		82	283
23.11.59	13	12	21	31	19	22	62	126	12	4	7	27	11	10	16	39	55		106	223
22.12.59	13	7	6	32	19	6	36	96	12	9	1	36	11	6	8	37	55		51	201

+ "germ's" means number of new seedlings which have appeared since the previous score.

APPENDIX V

DEVELOPMENT OF NATURAL REGENERATION AT RD. 7A + 8W AFTER THE REGENERATION BURN ON 4.3.60.

SERIES III

Date of Score	No. of E.regnans scored on 10 plots each 1/4000 acre		No. of E.obliqua scored on 5 plots each 1/4000 acre	
	Germ's (1)	stocking	Germ's (1)	Stocking
7/7/60	-	881	-	148
8/8/60	146	-	58	-
5/9/60	635	-	99	-
23/9/60	278	1,182	51	190
2/11/60	74	-	13	-
8/12/60	23	-	21	-
4/1/61	12	-	8	-
7/2/61	0	-	1	-
/3/61				
/4/61				
/5/61				

Note: (1) "germ's" means new seedlings which have appeared since previous score.

Appendix VI

PUDDLED SOIL EXPERIMENT

Summary of Statistical Analysis of Seedlings Scored at W.57 in November, 1960.

Analysis of Variance

Source	Degrees of Freedom	Sums of Squares	Variance	F	P
Rows	4	41.84	10.46	0.24	N.S.
Columns	4	114.64	28.66	0.66	N.S.
Treatments	4	1,216.24	304.06	7.029	0.01
Error	12	519.12	43.26		
Total	24	1,891.84			

Appendix VII

Statistical Analysis of the Results from the Autumn 1960 Field Test of Pelleted Seed.

Summary

(1) Germinations on older burns

Analysis of Variance

Source	Degrees of Freedom	Sums of Squares	Mean Squares	F
Blocks	3	1,699.5	566.5	
Treatments	9	9,867.0	1,097.0	6.453 XX
Error	27	4,606.5	170.1	
Total	39	16,173.0		

XX highly significant.

(2) Germinations on recent burns

Analysis of Variance

Source	Degrees of Freedom	Sums of Squares	Mean Squares	F
Blocks	3	52,483	14,131	
Treatments	9	30,964	3,441	1.588X
Error	27	58,520	2,167	
Total	39	141,967		

X not significant

(3) To test whether the latex and the asphalt pellets were more superior over bare seed when sown on older burns than when sown on younger burns. (Analysis by G. A. McIntyre, C.S.I.R.O., Canberra).

Analysis on log (XM) of selected treatments.

Analysis of Variance

Source	Degrees of Freedom	Sums of Squares	Mean Squares	F
Sites	1	1.714676	1.714676	
Blocks with sites	6	0.725921	0.120987	
Treatments	2	2.362383	1.181192	
Treatments x sites	2	0.560576	0.280288	1.78X
Treat'sxblocks with sites	12	1.888997	0.157416	

X not significant

Appendix VIII

SEED BURIAL EXPERIMENT

Summary of some statistical Analyses of the total Number of Germinations obtained from different Sowings.

(a) Comparison of germinations of seed sown on the surface of normal compared with puddled soil.

Analysis of Variance

Source	D.F.	S.S.	M.S.	F.
Treatments	1	465.1	465.1	4.15 X
Error	6	671.8	111.9	
Total	7	1,136.9		

X not significant

(b) Comparison of germinations of seed sown at the surface as against ¼" below the surface of normal soil.

Analysis of Variance

Source	D.F.	S.S.	M.S.	F.
Treatments	1	5,941	5,941	28.7 XX
Error	6	1,239	207	
Total	7	7,180		

X P.001 ; is highly significant

(c) Comparison of germinations of seed sown ¼" as against ½" below the surface of normal soil.

Analysis of Variance

Source	D.F.	S.S.	M.S.	F.
Treatments	1	5,151	5,151	24.1 XX
Error	6	1,282	214	
Total	7	6,433		

XX P = .001 ; is highly significant.

Appendix IX

Details of Methods and Results of Sowing Experiments

PROJECT I.

All sowings described below, except that at Road 11, are part of Project I.

Aim: This project has been referred to in the chapter on planting, where its general aims and layout have been described. Its particular aim in relation to the sowings was to demonstrate the likely level of success obtainable on a field scale if up to date findings were applied, namely: the dusting of seed with D.D.T. , sowing at a reasonable time on freshly burnt seedbed and protecting the seedlings from browsing.

Methods: All seed was dusted with a little more D.D.T. than would adhere to the seed coats. Estimation of viable seeds shown is based on laboratory germination tests. Two seed lots were used, one for the autumn '58 sowings and another but similar one for the later sowings. All weights of seed and numbers of seeds per pound are based on sieved seed that went through holes 0.0553" in diameter but did not pass through 0.0166" holes.

Broadcast Sowing:- This sowing was done by throwing the seed which was dusted with D.D.T. and mixed with dry myrtle sawdust on all but impossible seedbeds such as ground covered with logs, excessive unburnt litter and badly puddled tractor tracks. Seedlots were weighed out separately for each stratum of one square chain (1/10 acre) to ensure reasonably uniform seed distribution. To follow the course of germinations, deaths and growth, systematically located, permanent, circular sample plots each one quarter milacre in size and identified by a map of the positions of their two feet high centre pegs were used. The Autumn '58 sowing was sampled by 25 plots per stratum, the other sowings by 16 plots per stratum. It was necessary to restrict sampling to these 200 to 300 plots per sowing because of the laborious nature of early inspections. It was advisable to use permanent plots so that trends of change in the factors studied could be observed precisely. At each score each new germination was pegged with a coloured nail so that it could be found again easily and so that its death could be recognised once the seedling had disappeared.

In the case of the Autumn '58 broadcast sowing where significant quantities of seed were contributed by standing eucalypt trees in one portion of the fenced area, the number of "wildings" was estimated from counts on unsown sample plots along either side of the sown area.

Spot Sowing:- Spot sowing implies special preparation of the seed bed in small but well distributed patches. In these experiments spot preparation involved the scraping away of charcoal or litter and rough cultivation two or three inches deep. The D.D.T. dusted seed was sown on the surface of the ground from a ladle of known capacity. In the case of the Autumn '58 and stratum III of the Autumn '59 sowings, a thimble full of blood and bone manure was mixed with the soil before sowing. Each stratum of 1/10 acre received fourty spots each identified by an aluminium number tag nailed on a two foot peg standing beside each spot. Some intermediate scores were done on permanent samples: 25% random sample of Autumn '58 sowing; 25% systematic sample of other sowings. Germinations and deaths were identified by pegging individual seedlings with coloured nails.

A proportion of the Autumn '58 spots were sown with seed which had been previously stratified.

The seed bed on a logged coupe consists of exposed soil mechanically disturbed by tractors and skidded logs and of undisturbed areas which are deeply covered by slash before burning. The disturbed soils cover about 20% of the coupe and are puddled to various degrees. They normally do not carry any slash. "Unburnt" seedbed is usually synonymous with "disturbed" seedbed.

A. BROADCAST SOWINGS

I. Summary of Results from the Autumn 1958 Broadcast Sowing.

See Table App. IX-1

Germinations: The first score was at a time when near maximum stocking may be expected. The relatively low seedling percent observed at this time could be accounted for by a high death rate in the preceding winter, especially due to heavy frost lift.

The seedbed outside the fence was apparently not favourable to germinations. The thick humus left by the fire appeared rather dry in September 1958. Similar seedbed on the adjacent quarter acre broadcast sown in Spring 1958 gave rise to excellent germinations.

Inside the Fence:

Survival -

Mortality was high at first but dropped to 2 or 3% per month after the first summer. Between 2,000 and 3,000 seedlings would be expected to become established. This is a tree percent of 2%.

Height growth -

Height of Tallest Seedling per Stocked Sample plot

Date of Score	9.9.58	23.2.59	19.11.59	8.3.60
Average on burnt seed bed	1"	3.3"	7.0"	18.9"
" " unburnt " "	1"	2.4"	4.6"	14.7"
Maximum	1"	9"	20"	58"
% above 5"	0%	v.few	14%	75%

Outside the Fence -

Survival -

On the sample plots, the 3,200 seedlings per acre observed on 9.9.58 had dwindled to 710 seedlings per acre 26 months later. The fraction of germinated seedlings which survived outside the fence was not much smaller than that inside the fence.

TABLE APP. IX.1 Summary of Autumn '58 Broadcast Sowing

(sown on 23.4.58 with 25 ounces of E.regnans seed per acre).

	Time of Score / Date of score	Spring 9.9.58	Late summer 23.2.59	Spring 19.11.59	Late Summer 8.3.60	Spring 23.11.60
	Months since sowing	4½	10	19	22½	31
FENCED	number per acre	13,100	5,300	3,950	about 3,600	Burnt out in early March '60
	% of stocked sample plots with seedlings equal to or over ~~6"~~ 6"	cotyledons only	Very few	14%	75%	
	% of stocked sample plots with seedlings equal to or over 24"		0	0	20%	
	monthly death rate %	-	8.7%	2.8%	2%	
	seedling percent	8.35%	3.4%	2.5%	2.3%	
NOT FENCED	number per acre	3,200	2,050	1,030	905	710
	% of stocked sample plots with seedlings equal to or over ~~6"~~ 6"	cotyledons only	Very few	-	25%	73%
	% of stocked sample plots with seedlings equal to or over 24"		0	0	0	9%
	monthly death rate %	-	8.1%	3.2%	3.8%	2.4%
	seedling percent	2.04%	1.3%	0.66%	0.58%	0.33%

Note: These figures are adjusted to exclude wildlings.

Height growth -

The only dramatic effect of browsing on eucalypt seedlings was evident in spring 1959. Whereas 14% of all stocked plots inside the fence carried seedlings six inches or taller, there was no seedling greater than two inches on the sample plots outside the fence. Browsing during winter had reduced the average height of the seedlings greatly and had caused high death numbers. After the second winter browsing was never so severe again.

II. SUMMARY OF RESULTS FROM SPRING 1958 BROADCAST SOWING

See Table App. IX.2.

Germinations -

After 2½ months 14.8% of the viable seed sown was observed to have germinated. In addition to this, there was a further burst of germinations in autumn. The total observed germinations amounted to about 20% of the viable seeds sown. This is twice as good as the previous autumn's sowings.

Inside the fence:

Survival -

A very high percentage of germinated seedlings became established. At a tree percent of 5.0% at the age of 17 months, with the great majority of seedlings taller than six inches, the sowing must be considered a very successful one.

Height Growth -

Height growth was rapid and without a delay after the sowing time. By the first winter, 32% of the stocked sample plots had at least one seedling over 5" tall. By the second winter this figure rose to over 90%. At the same time over 23% of the sample plots carried seedlings 24" or taller. This means that the six months younger sowing overtook the autumn sowing within one growing season.

TABLE IX.2

Spring '58 Broadcast Sowing (Sown 5-8 Oct.'58)

	Rate sown per acre	Scoring time	Late spring	Autumn	Spring	Late Summer	Spring
		Scoring date	17.12.58	15.5.59	29.10.59	9.3.60	20.10.60
		Age in Months	2½	7	12½	17	24½
FENCED		% of stocked sample plots with seedlings equal to or over 6"	Cotyledon and two leaf stages only	32%	59%	89%	BURNT OUT
		12"		0	?	73%	
		24"		0	0	23%	
		Monthly death rate %	-	-	1.9%	-	
	3lb.	No./acre	66,700	17,200^x	15,100^x	19,000	
		Seedling %	17.6%	4.6%	4.0%	5.0%	
	1.5lb	No./acre	18,500	9,900	9,200		
		Seedling %	9.8%	5.3%	4.9%		
		% of plots stocked	79%	77%	79%		
NOT FENCED		% of stocked sample plots with seedlings equal to or over 6"	0	0	0	40%	few, not scored
		12"	0	0	0	4	none, not scored
		24"	0	0	0	4	none not scrd.
		Monthly death %	-	12.5%	18.8%		
	3lb.	No./acre	36,000	24,000^x	3,800^x	11,000	5,000
		Seedling %	9.6%		1.0%	2.9%	1.32%
	1.5lb	No./acre	77,000	12,800	3,500	6,000	1,500
		Seedling %	40.7%		1.9%	3.2%	0.80%
		% of plots stocked	87%	70%	35%	50%	

Note: x on these occasions there was a considerable proportion of cotyledon stage seedlings but they were not included in the scoring.

Average Height of the Tallest Seedling per Stocked Sample Plot NOT on Puddled Soil.

Date of Score	17.12.58	15.5.59	29.10.59	9.3.60
Fenced:				
Burnt seedbed	1"	4.8"	7.6"	20.0"
Not burnt seedbed	1"	3.7"	6.0"	14.8"
Not Fenced:				
Burnt seedbed	1"	2.4"	1.3"	6.4"
Not burnt seedbed	1"	1.9"	1.3"	5.1"

Outside the Fence:

Survival:-

The stocking 2 years after sowing was still reasonable. However, almost none of the seedlings scored could be considered established. Only very few seedlings were 6 to 12" tall. Hence heavy mortality is going to continue if browsing is not controlled. Mortality has been very heavy during both the first and second winters after sowing. This mortality was mostly due to severe browsing. During the first winter the monthly death rate was 18.8%, compared with 1.9% inside the fence.

Height growth -

Browsing kept all seedlings below 6" for over one year. Relative freedom from browsing during the summer of 59/60 permitted considerable height growth. However, this was almost nullified again during the second winter, so that only very few plants were over 5" tall after two years. At the same time probably over 90% of the plants inside the fence were 6" or taller.

Both survival and height growth reflect dramatically the effect of browsing.

The big increase during the 2nd summer in stocking by seedlings above the cotyledon stage shows that germinations during autumn after a sowing in spring may add significantly to the final crop of seedlings which become established.

III. SUMMARY OF RESULTS FROM AUTUMN 1959 BROADCAST SOWING

See Table App. IX.3

Germination -

The germinations observed at 3½ and 7½ months amounted to an average of 16.2% of all viable seeds sown inside and outside the fence. Of the observed germinations 14.9% occurred in spring and 85.1% in the preceding autumn. This is a very satisfactory rate of germination, and occurred from a sowing made when nearly all the burnt ground was occupied by a thin layer of mosses. At this age (1 year after the burn) the mosses are sparse and very shallow. A year later they become very dense and about one inch deep.

Inside the Fence:

Survival -

Survival to the age of 30 months was excellent (16,000 per acre) in spite of severe competition by a dense cover of Erechthites and Pomaderris from the 59/60 summer onwards. The death rate during the second winter was surprisingly low in view of the etiolated condition of most seedlings. This can perhaps be ascribed to the wholesale die-back of Erechthites in early March 1960. Competition became very severe again from the summer of 1960/61 onwards because of the very rapid development of Pomaderris. The very good stocking of 16,000 eucalypt seedlings per acre is made up of a large proportion of more or less etiolated seedlings. Even if mortality due to suppression is continuing at a high rate, it is likely that a satisfactory number of seedlings will become established.

Height Growth -

Height growth by the end of the first growing season had been better than from the autumn 1958 sowing, but poorer than the spring '58 sowing. Only 43% of stocked sample plots carried seedlings over 5" tall, 20 months after sowing. Weed competition may have reduced height growth; it certainly produced symptoms of etiolation in most of the seedlings on burnt ground.

Outside the Fence:

Survival -

Survival outside the fence was quite good. There was no weed competition from tall herbs or shrubs. The

TABLE APP.IX.3

Autumn '59 Broadcast Sowing (sown 11.3.59)

	Rate of sowing per acre	Time of score	Early Winter	Spring	Late Summer	Spring
		Date of score	30.6.59	30.10.59	7.3.60	2.11.60
		Age in Months	3½	7½	12	20
FENCED		% of stocked S.plots with seedlings equal to or above 2"	cot's only	mostly cotyledons	64%	86%
		6"			11%	43%
		24"			0%	0%
		Monthly death %	4%frost lift	7.3%	12.5%	1.6%
	3 lb.	Seedling %	13.1%	12.6%	6.0%	5.6%
		No./acre	50,500	48,600	23,000	21,800
	2 lb.	Seedling %	11.5%	9.0%	6.3%	5.0%
		No./acre	28,000	21,800	15,200	12,200
		% of S.plots stocked	77%	72%	57%	51%
NOT FENCED		% of stocked S.plots with seedlings equal to or above 2"	cot's only	mostly cot's	82%	67%
		6"			9%	5%
		24"			0%	0%
	3 lb.	Seedling %	19.6%	15.8%	8.4%	4.3%
		No./acre	75,400	60,600	32,400	16,600
	2 lb.	Seedling %	15.2%	11.9%	5.1%	1.4%
		No./acre	37,000	29,000	12,300	3,500
		Monthly death %	3%frost lift	10.5%	12.0%	7.5%
		% of s.plots stocked	82%	73%	58%	49%

effect of browsing was most evident after the second winter. After good growth and relative freedom from browsing during the first summer, the eucalypt seedlings outside the fence were taller and sturdier than those inside the fence, where weed competition was intense. Browsing during the second winter was very severe, contributing to a death rate of 7.5% per month, compared with 1.6% inside the fence. By spring time the survivors outside the fence were much reduced in number and height. All seedlings were subject to further mortality if browsing continued. At the age of 30 months the stocking was still good at 15,000 seedlings per acre, many of which were now established.

Height growth :-

While browsing happened to be more or less absent, height growth outside the fence in the absence of taller weeds was better than growth inside the fence. This improvement in growth was even more evident from the visual impression in much more bulky seedlings with larger, darker leaves. However, browsing during the second winter reversed the situation, so that only 5% of stocked plots carried seedlings over 5" tall outside the fence, as against 43% inside the fence in the following spring. (2/11/60).

IV. SUMMARY OF ROAD 11 SOWINGS

Methods -

This sowing of E.regnans was made by Gilbert on 20/11/1957 to study the effect of summer conditions on very young seedlings. The author carried on observations on germinations, survival, and growth after March 1958 to obtain further data on broadcast sowing.

Sowing was at a rate of 2 lb/acre on each of ten milacre plots on disturbed mineral soil; at 4 lb/acre on six burnt milacre plots; and at 6 lb/acre on ten milacre plots on unburnt slash. The plots each have a surround and are well scattered over coupe W43 which was logged in 1956/57, and partly burnt in September 1957. The limestone soil formerly carried a dense forest of E.regnans with a rainforest understorey, both 150 years old.

Results -

The total observed germinations amounted to 28% of the viable seed sown on mineral soil, 22% on burnt seedbed, and 10% on unburnt slash. This is good. The poorer rate amongst the slash may be largely explained by difficulty of observation, and by failure of germinated seedlings to grow up to an observable size. Slash is likely to dry out before the seedlings' roots can penetrate to the soil.

This late spring sowing was followed by a cool, moist summer. Hence germinations were not delayed but were rapid even in summer and did not exhibit a marked peak in autumn. See figure XI.2. Such a pattern of germination differs markedly from that observed during years with relatively dry summers where germinations practically cease during summer. In this sowing about half of all germinations appeared within 49 days of sowing. The germinations on mineral soil were similar to those on other seedbeds at first, but continued at a higher rate for a longer time. Germinations were complete by the second winter. Had the summer been hot and dry most germinations would have been delayed till autumn or the following spring. This would have exposed the seed to more seed robbery and probably would have reduced the percentage of seeds which germinate.

The survival of observed germinations was poorest on mineral soil and best on unburnt slash, i.e. the reverse of germination percents! The mineral soil, even though puddled, allowed excellent germinations. However, growth and survival were very poor on the puddled soils. Seedlings on puddled soils usually turned reddish or purple and remained at or near the cotyledon stage for a long time, often for more than one year, and eventually died mostly during winter. In any case, mortality due to browsing was highest on tractor tracks because these are the most easily accessible to the animals. While the low survival on disturbed soil here was a real effect of puddled soil and high browsing pressure, more lightly disturbed soils (especially when protected from browsing) are usually good for the survival as well as the germination of eucalypts.

The seedling percent at 36 months was 0.9 to 1.3% In the case of mineral soil plots the tree percent may be expected to fall well below this, because half the seedlings are still less than 6" tall. On the other seedbeds 80-85% of seedlings were over 5". Their tree percent can be expected to be about 1%. Results are summarised in Table App. IX.4

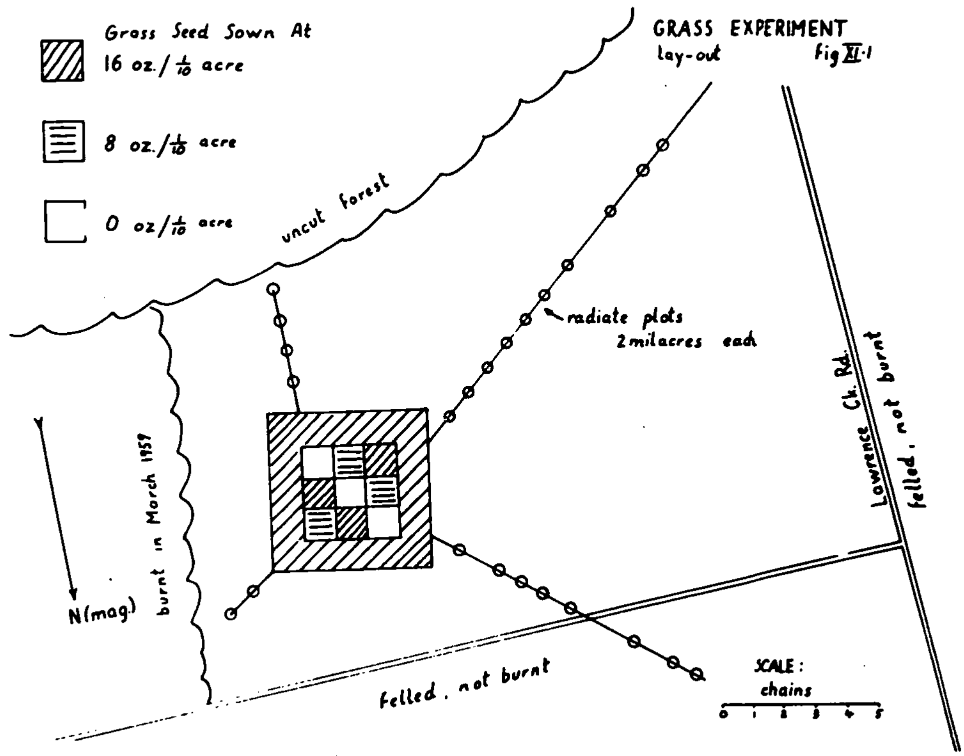

Figure X1. 1 Lay-out of grass experiment.

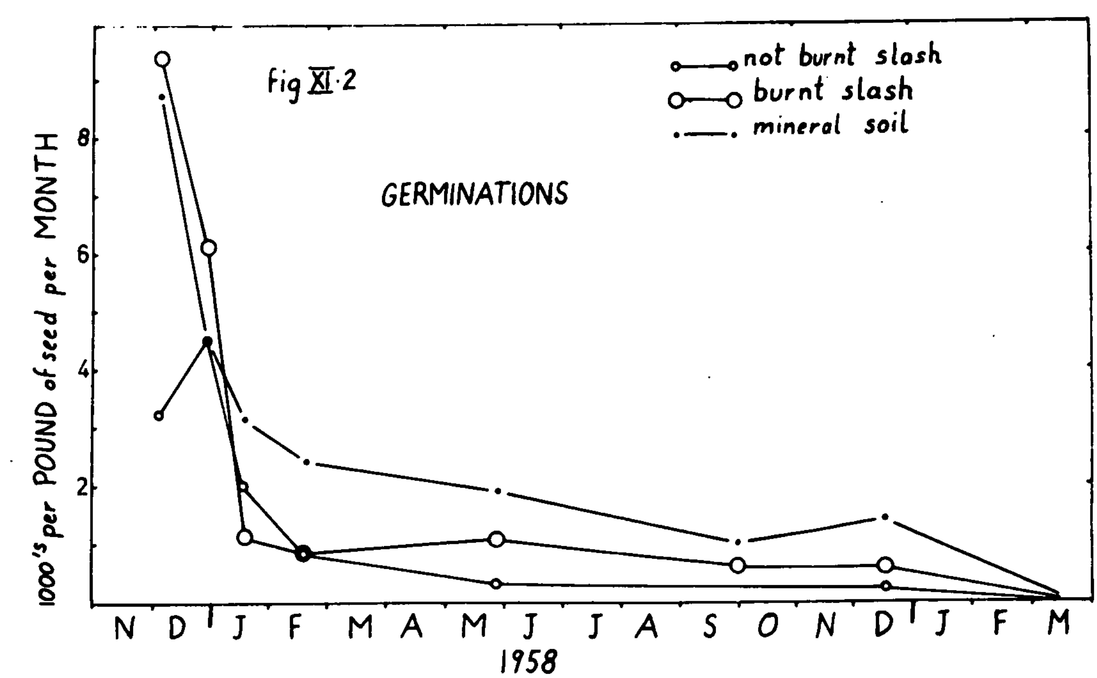

Figure X1. 2 Pattern of germinations from broadcast sowing on 20. 11. 57 on 6 milacres of burnt seedbed, and 10 milacres each on mineral soil and unburnt slash.

TABLE APP.IX.4 SUMMARY OF ROAD 11 SOWINGS (SOWN 20.11.57)

There were 116,300 viable seeds per pound.

Date of score	Months since sowing	MINERAL SOIL germ's per lb per 30 days	% deaths per 30 days	Nett. per lb.	UNBURNT SLASH Germ's/ lb/30 days	% deaths per 30 days	Nett. per lb.	BURNT SLASH Germ's/ lb/30 days	% deaths per 30 days	Nett./ per lb.
20.12.57	1	8,720	-	8,700	3,180	-	3,300	9,400	-	9,700
8.1.58	1½	4,580	17.5	10,900	4,520	16.8	5,800	6,120	28.4	11,800
30.1.58	2½	3,070	6.3	12,700	2,000	9.9	6,800	1,250	37.0	9,600
10.3.58	4	2,390	3.6	15,100	800	4.1	7,600	780	26.6	7,200
15.8.58	9	1,900	9.0	18,100	330	8.1	6,100	1,280	7.8	11,000
17.11.58	12	990	16.0	11,200	210	15.8	3,600	600	11.4	8,900
16.1.59	14	1,370	19.3	10,000	250	13.7	3,000	580	18.8	6,700
29.5.59	18	± Nil	10.4	5,500	± Nil	7.5	2,000	± Nil	9.4	3,600
23.2.60	27	Nil	7.2	2,000	Nil	4.2	1,300	Nil	4.6	2,100
8.12.60	37	Nil	4.4	1,200	Nil	1.8	1,100	Nil	3.1	1,500

On 8.12.1960

	Mineral soil	Unburnt slash	Burnt slash
Total germination %	27.5	9.7	21.7
Seedling %	0.99	0.94	1.3
% survival of germ's	3.6	9.7	6.0
% of survivors above 5"	48	85	80
% of survivors above 23½"	0	30	70
Probably tree %	.2 to .5	0.8	1.0

B. SPOT SOWINGS

I. SUMMARY OF RESULTS FROM AUTUMN 1958 SPOT SOWING

See Table App. IX.5

Germination -

Germination was almost complete after 7 months, i.e. by the end of the first spring. Observed germinations amounted to about 15% of the viable seeds sown. A little less than half of the germinations occurred After the winter. Stratification made germinations only slightly more rapid and complete. The seedlot used germinated rapidly and completely in the laboratory without stratification.

Inside the Fence:

Survival -

Mortality was very high during the first winter and spring. The lowe seedling percent of 1.1% at 18 months is likely to be further reduced considerably because only few plants could be regarded as established at this stage. The expected tree percent is of the order of 0.5%. Browsing by possum and poor height growth are both partly responsible for this. 40 to 50% of the spots may become established.

Height Growth -

Many of the seedlings were nearly stagnant till the beginning of the second growing season. Scoring of the occasional survivors from the fire in March 1960 showed that height growth had sharply accelerated during the second summer.

Average Height of the Tallest Seedling per Stocked Spot NOT on Puddled Soil.

Date of score:	9.12.58	12.5.59	26.10.59	8.3.60
Height:	2"	4.0"	5.2"	17.0"

Outside the Fence:

Survival -

Mortality outside the fence was similar to that inside the fence until the end of the first summer. By then seedlings had become browsable and suffered 9.4%

TABLE IX.5 SUMMARY OF AUTUMN 1958 SPOT SOWINGS - SOWN 22-30 APRIL '58

Scoring Time	Winter	Late Winter	Spring	Late Spring	Autumn	Spring	Late Summer	Spring
Scoring Date	24.7.58	2.5.58	3.11.58	9.12.58	2.5.59	26.10.59	8.3.60	23.11.60
Months since sowing	3	4	6	7	12½	18	22½	31
% of spots scored	25%	25%	25%	25%	100%	100%	100%	100%
FENCED -								
% of stocked spots with seedlings equal or above 2"	0	0	-	40%	65%	-	burnt out	
6"	0	0	0	0	14%	27%		
24"	0	0	0	0	0	2%		
Monthly death rate %	-	45%	19.4%	18.1%	4.2%	4.4%		
% of spots stocked	97%	94%	85%	80%	74%	61%		
No. of seedlings/stocked spot	8.70	5.19	5.55	4.5	3.2	2.9		
Seedlings %	7.2	4.5	4.1	3.1	2.1	1.1		
New seedlings/spot	8.2	4.8	2.8	0.2	Nil	Nil		
NOT FENCED -								
% of stocked spots with seedlings equal to or above 2"	0	0	0	-	56%	-	-	-
6"	0	0	0	0	38%	38%	68%	81%
24"	0	0	0	0	0	4%	24%	47%
Monthly death rate %	-	35%	15.6%	21%	5.4%	9.37%	3.00%	3.15%
% of spots stocked	85%	69%	92%	96%	76%	48%	44%	34%
No. of seedlings/stocked spot	21.8	19.3	16.9	6.7	3.9	3.0	2.8	2.7 22
Seedlings %	11.8%	8.5%	10.0%	4.1%	1.9%	0.93%	0.80%	0.59%
New seedlings/spot	18.5	3.8	6.0	0.1	Nil	Nil	Nil	Nil

Note on rate of sowing: Fenced 200 spots at 72 viable seeds each (stratified)
200 spots at 157viable seeds each (not stratified)
Not Fenced 200 spots at 157viable seeds each (not stratified).

mortality outside the fence (as against 4.4% inside) during the following (2nd) winter. The seedling percent of 0.6% at 31 months is composed of a majority of established plants. 20 to 30% of spots may become established.

Height Growth:

After slow growth during the first growing season height growth became much more rapid, but was partly set back by fairly severe browsing during the second and third autumns.

II. SUMMARY OF RESULTS FROM SPRING 1958 SPOT SOWING

See Table IX.6.

Germination:

72.5% of all germinations occurred within two months of sowing. Germinations practically ceased during the summer, but had a significant burst in autumn amounting to 22.5% of all observed germinations. The final burst (5%) of germinations occurred during the second spring. Thereafter further germinations were insignificant . The observed germinations amounted to about 16% of the viable seed sown.

Inside the Fence -

Survival:

At the age of 24 months, 91% of the spots were stocked with an average of 5.0 seedlings each. 93% of the stocked spots bore seedlings over 5" tall. Hence about 90% of all sown spots can be expected to become established. This is excellent, and represents a tree percent of about 3%.

Height Growth:

There was no delay in growth due to a winter following immediately after the sowing. After two growing seasons more than half of the stocked spots carried seedlings over two feet tall.

TABLE IX.6 SUMMARY OF SPRING 1958 SPOT SOWING (SOWN 27-28 OCTOBER 1958)

Scoring Time Scoring date Months since sowing	Late Spring 4.12.58 2	Autumn 15.5.59 7	Spring 29.10.59 12	Late Summer 9.3.60 17	Spring 20.10.60 24	Viable seeds sown per spot
FENCED -						
% of stocked spots with seedlings equal to or above 6"	0	17%	17%	86%	93%	
24"	0	0	0	29%	67%	
Monthly death rate % approx.	-	10%	10%	2%	5%	
% of spots stocked	97%	99%	97%	94%	91%)	
No. seedlings/stocked spot	18.4	14.1	7.9	7.3	5.0)	133
Seedling percent	13.4	10.7	5.6	5.0	3.3)	
New seedlings/spot	18.4	4.7	1.0	+_Nil	Nil)	
% of spots stocked	100%	100%	99%	98%	-)	
No. seedlings/stocked spot	28.1	32.6	-	burnt	)	266
Seedling percent	10.5	12.2%	-	out	)	
New seedlings/spot	28.1	12.2	-		)	
NOT FENCED -						
% of stocked spots with seedlings equal to or above 6"	0	3%	1%	27%	-)	
24"	0	0	0	0	-	
Monthly death rate % approx.	-	12%	15%	4%	7%	
% of spots stocked	100%	98%	74%	68%	43%)	
No.seedling/stocked spot	16.0	11.2	3.97	3.5	2.8)	133
Seedling percent	12.0	8.2	2.2	1.8	0.89)	
New seedlings/spot	16.0	4.4	1.0	+Nil	Nil)	
% of spots stocked	100%	100%	95%	90%	75%)	
No.seedlings/stocked spot	19.8	23.3	6.7	4.9	2.8)	266
Seedling percent	7.45%	8.8%	2.4%	1.7%	0.81)	
New seedlings/spot	19.8	11.5	2.0	+-Nil	Nil)	

Average Height of the Tallest Seedling per Spot on Soil Which was NOT Puddled.

Date of Score	14.12.58	22.1.59	15.5.59	9.3.60
burnt seedbed	1"	3.6"	4.8"	22.8"
disturbed seedbed	1"	4.0"	5.9"	23.8"

III. SUMMARY OF RESULTS FROM AUTUMN 1959 SPOT SOWING

See Table IX.7.

Germination:

Germination began within 3 weeks and was practically complete within four months of the late summer sowing. Very few germinations occurred after the first winter. The seedlings observed four months after sowing amounted to 16.8% of the viable seed sown. The actual germination percent was therefore a little higher than this figure.

Inside The Fence -

Survival:

As usual, mortality during the first winter was quite high, but thereafter was in this case very low. As a result nearly half of the observed germinations survived to the age of 20 months. At this age 80% of the stocked spots carried at least one seedling over 5"tall. Hence between 70 and 80% of all sown spots can be expected to become established. The expected tree percent is of the order of 4%, i.e. very high.

Height Growth:

Growth was quite rapid and was delayed only by the winter. The commonly severe competition amongst the seedlings of each spot, and against the fireweeds and *Pomaderris* caused growth to be mainly in height, rather than in bulk of the plants. On 14/10/59 the average dominant height per spot was 1", on 10/3/60 it was 8.8".

Table IX.7

Summary of Autumn 1959 Spot Sowing -(Sown 8th March 1959)

Scoring Time	Winter	Spring	Late Summer	Spring	
Scoring Date	9.7.59 4	14.10.59 7	10.3.60 12	20.10.60 20	viable seeds sown per spot
FENCED					
% of spots with seedlings equal to or above. 6"	0	2%	43%	80%	
24"	0	0	0	27%	
Monthly death percent approx.	-	13%	1%	2%	
(%of spots stocked	97%	90%	85%	80%)	
(No. seedlings per stocked spot	23.7	13.6	13.3	12.4) 130	130
(Seedlings percent	17.7	10.1	9.5	8.3)	
(new seedlings per spot	23.0	v.few	Nil	Nil)	
(%of spots stocked	96	90	78)		
(No. seedlings/stocked spot	36.9	23.7	Burnt)		
(			out)	260	260
(Seedling percent	13.1	7.6			
(new seedlings per spot	34.1	v.few	Nil)		
NOT FENCED					
%of stocked spots with seedlings equal to or above 6"	0	0	0	6%	
24"	0	0	0	0	
Monthly Death rate % approx.	-	18%	6%	6%	
%of spots stocked *	100	92	86	39)	
No. seedlings per stocked spot	22.6	10.1	6.8	3.3)	130
SEEDling percent	12.4	7.4	4.5	2.1)	
(New seedlings per spot	22.6	v.few	Nil	Nil)	

Outside the Fence -

Survival:

During the first winter mortality was similar to that inside the fenced area, but thereafter it continued at a comparatively high rate due to the incidence of severe browsing especially during the second winter. At the age of 20 months, i.e. after the second winter, only 39% of the sown spots were still stocked. Of these only 6% carried seedlings over 5" tall. Hence the tree percent can be expected to be less than half of the present seedling percent (2.1% at 20 months) and the proportion of established spots will probably be less than 30% of those sown.

APPENDIX X.

DETAILS OF PLANTING STOCK USED IN PROJECT I.

A. AUTUMN 1958 PLANTING

Tag No. B1 to B40 were planted inside the fence on 29/5/58. The other 460 plants were nearly all completely defoliated by possum before being planted on 9/6/58. Only 4% of these survived the first winter. The defoliation experiment (Chapter XII) showed subsequently that this drastic deathrate is due to defoliation.

All plants were tubed and healthy before planting.

B. SPRING 1958 PLANTING

Tubed stock: healthy, actively growing, about 6" tall.

Rootballed stock: plants dug up from the nursery bed 1 to 3 days previous to planting with a 2" x 2" x 2" cube of soil adhering to the roots. The plants were 2" - 9" tall.

Tag. No.	Date of planting	Type of stock	
W1 - W46	16.9.58	rootball	fenced
81 - 160	10.10.58	"	fenced
501 - 540	"	"	fenced
1 - 80	"	tubed	fenced
61 - 200	"	"	fenced
541 - 640	17.10.58	"	not fenced

C. AUTUMN 1959 PLANTING

All plants were tubed.

Types: 1. Tall, mostly between 10 and 14", pale green, stagnating.

2. Short, mostly between 2 and 6", reddish, stagnating.

3. Pruned, tall stock was pruned down to two pairs of leaves in February, leaving a stump 3 to 6" high. These plants had sprouted one or more 1 - 2" long vigorous axillary shoots by the time of planting.

Tag No.	Planting Date	Condition of stock	Soil when planting
G1 - 40	4.3.59	short	dry
G41 - 80	"	pruned	"
G81 - 160	"	tall	"
G161 - 200) G341 - 390)	13.3.59	short	moist
G201 - 220) G261 - 284)	"	pruned	"
G221 - 260) G285 - 340) G391 - 400)	"	tall	"
G401 - 450	18.5.59	short	"
G451 - X30	15.7.59	"	"
G541 - 599	2.10.59	"	"

No. G201 - G300 were outside the fence.

LIST OF SPECIFIC NAMES AND AUTHORITIES OF PLANTS MENTIONED IN THE TEXT.

Acacia dealbata Link	Silver wattle.
Acaena Anserinifolia (J.R. & G.Forst) Druce	Buzzy.
Agrostis tenuis	New Zealand Brown top grass.
Atherosperma moschata Labill.	Sassafras.
Betula (Tourn) L.	Birch.
Blechnum procerum	Leech fern.
Bryum chrysoneuron C. Muell.	Moss
Campylopus introflexus (Hedw.)Brid.	Moss.
Carduus syn.Cirsium vulgare (Savi) Ten.	Spear Thistle.
Carex paniculata Linn	Cutting grass.
Ceratodon purpureus (Hedw.)Brid.	Fire moss (red).
Coprosma billardieri Hook.	Native currant.
Dicksonia antarctica Lab.	Man-fern.
Erechthites prenanthoides D.C.	Fireweed.
Eucalyptus diversicolor F.V.M.	Karri.
E.delegatensis RT.Baker syn.gigantea Hook. f.	Gum top.
E.globulus Labill	Tasmanian Blue Gum.
E.marginata Sm.	Jarrah.
E.obliqua L'Herit.	Stringy Bark.
E.radiata Sieb.	Grey Peppermint.
E.regnans F.v.M.	Swamp Gum.
E.simmondsi(i) Maiden	Peppermint.
E.viminalis Labill	White Gum.
Eucryphia lucida (Labill)Baill.	Leatherwood.
Festuca rubra	Chewings Fescue grass.
Gahnia psittacorum Labill.	Cutting grass.
Histiopteris incisa.	Wet fern or soft bracken.
Hydrocotyle hirta R.Br.	
Hypolepis rugosula	Wet fern.
Juncus pallidus R.Br. and J. pauciflorus R.Br.	Rushes.
Lolium perenne	Perennial Rye grass.
Nothofagus cunninghamii Cerst	Myrtle(=beech)
Marchantia polymorpha	Marchantia
Olearia argophylla F.v.M.	Musk.
Phebalium squameum (Labill.)Druce	Lancewood.
Pinus radiata Don.	Monterey pine.
Pittosporum bicolor Hook.	Cheesewood.
Polystichum proliferum	Cat-head fern.
Polytrichum juniperinum Hedw.	Moss.

Pomaderris apetala Labill.	Native pear or hazel.
Pteridium aquilinum Kuhn	Bracken.
Pteridium esculentum.	Bracken.
Robinia pseudo-acacia L.	Locust tree.
Salix (Tourn) L.	Willow Tree.
Senecio velleyoides D.C.	Fireweed.
Tetrarrhena juncea R.Br.	Wire grass.
Zieria arborescens Sims.	Stinkwood.

Nomenclature of ferns is according to Wakefield, N.A. (1955) Ferns of Victoria and Tasmania. Publ. Field Naturalists Club of Victoria.

REFERENCES

Addicot, F.T.; Lynch, R.S. (1955) -

"Physiology of abscission". Ann. Rev. Plant Physio. 6:211-238.

Ashton, D.H. (1957) -

Studies on the autecology of Eucalyptus regnans. Ph.D. thesis, Uni. Melbourne.

Baur, G.N. (1959) -

Raising and planting Flooded Gum. F.C. of N.S.W. Div. of Forest Management. Research Note No.4.

Boden, R.W. (1958) -

Differential frost resistance within one Eucalyptus species. Aust.Jour.Sci.21,3:84-86.

Bowling, P.J. (1960) -

Pers. Comm.; Forestry and Timber Bureau, Dover Tasmania.

Braid, K.W. (1959) -

"Bracken: A review of the Literature". Publ. No.3/59, C/w Bureau of Pastures and Field Crops. U.K.

Buck, J.M. (1959) -

Site preparation for forest regeneration in California. Pamphlet of U.S.D.A. Forest service. 26 pages.

Burgeff, H. (1943) -

Genetische Studien an Marchantia. Publ. Gustav Fischer, Jena.

Cain, S.A. and Castro G.M. de Oliveira (1959) -

Manual of Vegetation Analysis. Harper & Bros., New York. 325 pages.

Campbell, K.G. (1960) - Paper on phasmids. Proc. Linn. Soc. N.S.W. 81, 1:121-141 (1961) = Pers. Comm.

Cremer, K.W. (1958 - 1961) -

Reports to A.N.M. Forestry Research Fellowship Supervisory Committee.
(1960) - Problems of eucalypt regeneration in the Florentine Valley.APPITA 14, 2:71-78.
(1960) - Eucalypts in rain forest. Australian Forestry, 25, 2:120-126. (Appendix XI) (Three other papers by Cremer are included in the text of this thesis).

Cunningham, T.M. (1957) -

Seed production and seed fall of E.regnans (F.Muell.) Australian Forestry 21 :30-39.
(1960) - The natural regeneration of Eucalyptus regnans. Bull.No.1, School of Forestry, University of Melbourne.
(1961) - Pers. comm. c/- Forestry Commission of Tasmania.

Cunningham, T.M. and Cremer, K.W. (1962) -

The competitive understorey in wet eucalypt forests - can we control it? Paper presented to Third Conference of Institute of Foresters of Australia, Melbourne, May 1962.

Drangsholt, K. (1956) -

Mountain Ash. seed throw. Vic.For.Newsletter No.7.

Edwards, C. (1956) -

A convenient method of raising eucalypts from seed. Aust. For. 20, 2.

Eldridge, K.G. (1961) - The effect of hive bees on seed

production of Eucalyptus regnans. Final report LT4 to Forestry & Timber Bureau, Canberra, 4 pages.

Fielding, J.M. (1960) -

Branching and flowering characteristics of Monterey Pine. F. & T. B. Aust.Bull. 37.59 pages.

Geiger, R. (1950) -

The climate near the ground. Harvard Uni. Press.

Gilbert, J.M. (1958) -

Eucalypt rainforest relationships and the regeneration of the eucalypts. Ph.D. thesis, Uni.Tas.
(1959) - Forest Succession in the Florentine Valley, Tasmania. Pap. Proc. Roy. Soc. Tas. 93: 129-151.
(1961) - The effect of browsing by native animals on the establishment of seedlings of _Eucalyptus regnans_ in the Florentine Valley, Tasmania. Aust. For. _25_,2:116-121.

Grose, R.J. (1957) -

A study of some factors associated with the natural regeneration of Alpine Ash. (E.delegatensis) For. Comm. Vic. Bull. 4.
(1961) - Some silvical characteristics and notes on the silviculture of Alpine Ash, _E.delegatensis_, R.T.B. Paper presented to Second World Eucalyptus Conference, Brazil.

Haagen, H. (1961) -

"Wald, Wild und Mensch heute." Bayerland _63_. pp. 179 - 184.

Hall, M.J. (1960) -

The effect of stocking density on seed productivity in some eucalypts. APPITA _14_, 1:48-56.

Hall, M.J. and Richmond, K.P. (1961) -

Recent trends in eucalypt reforestation in Gippsland, Victoria. APPITA _15_, 1:35-45.

Hansen, A.G. (1961) -

Position of the wood of the _Eucalyptus_ in the Australian timber trade 1956 - 1961. Paper presented to Second World Eucalyptus Conference, Brazil.

Isaak, L.A. (1943) -

Reproductive habits of Douglas Fir. Charles Lanthrop Pack Forestry Foundation, Washington, D.C.

Jacobs, M.R. (1955) -

Growth habits of the eucalypts. F. & T.B., Dept. Interior.

Levitt, J. (1958) -

The hardiness of plants. Academic Press. Inc., New York.

Loneragan, O.W. (1958) -

Aust. Forestry Inst. Newsletter 2, 1.

McGeorge, W.T.; Breazeale, J.F. -

Studies on soil structure: Effect of puddled soils on plant growth. Uni. of Arizona, Agric. Expt. Stn. Tech. Bull. No. 72 pages 413-447.

Mollison, B.C. (1960) -

Progress report on the ecology and control of marsupials in the Florentine Valley. APPITA 14, 2: XX1-VII. (1959-61).Pers. comm.

Mount, A.B. (1961) -

"The First Seven Years". Report on Maydena Research Station. For. Comm. of Tas. (M.S.).

Needham, R.H. (1960) -

Problems associated with regeneration of *Eucalyptus gigantea* in the Surrey Hills area. APPITA 13, 4: 136-140.

Newman, R.L. (1958-59) -

Pers. comm. c/- A.N.M. Maydena.

Powles, R. (1940) -

Artificial regeneration of mountain ash (*E.regnans*) Aust. For. 5,:28-32.

Pracy, L.T. and Kean, R.I. (1949) -

The Possum in New Zealand. Wildlife Branch Bulletin 1, N. Zld. Dept. Int. Affairs.

Pryor, L.D. (1960) - The "ash-bed" effect in *Eucalyptus*

ecology, Inst. For. Aust. Newsletter 2,9:23-26
(1956) - Proc. Linn. Soc. N.S.W.81, 3:299.
(1957) - Selecting and breeding for cold resistance in *Eucalyptus*.

Raeder-Roitsch, E.J. (1958a) -

Experiments on transplanting open-rooted eucalypt seedlings. Aust. For. 22, 1: 24-29.
(1958b) - Spot sowing of eucalypts under asphalt. Inst.For.Austr.Newsletter 2,1:3-5.

Redmond, J. (1953) -

The development of planting techniques for mountain ash. Paper presented to Victorian Division, Institute of Foresters of Australia.

Richards, P.W. (1958) -

The Liverwort Marchantia, New Biol. 27, pp 87-108.

Rolland, R.; Heisler, J. (1959) - Pers. comm. c/- Forestry Commission, Victoria.

Rowe, R.K. (1955) -

A preliminary investigation of the effects of fire on the viability of seeds of E.obliqua before they are shed from the capsule. M/S School of Forestry Uni. Melbourne.

Station de Recherche Forestiere de Rabat (1957) -

"Premiers traveaux d'amelioration genetique des Eucalyptus". Rapport annuel 4, 1:65-85.

Steinbrenner, E.C.; Gessel, S.P. -

Effect of tractor logging on physical properties of some forest soils in S.W. Washington, Journal of American Forestry.

Teller, L. (1957) -

An investigation into the effect of tree age of Eucalyptus regnans on quantity and quality of seed produced. M/S, School of Forestry, Uni. Melbourne.

Thomas, D. (1960) -

Pers. comm. c/- University, Tasmania.

Thornthwaite, C.W. (1948) -

An approach towards a rational classification of climate. Geogr. Review 38, 1:55-95.

Watson, E.V. (1955) -

British Mosses and Liverworts. Cambridge Univ. Press. (419 pages).

Watt, A.S. (1947) -

Pattern and process in the plant community. Jour. Ecol. 35, 1:1-22.

Wallace, W.R.; Hatch, A.B. (1952) -

Aust. For. 28, 1:37-38.

Weaver, J.E. and Clements, F.E. (1938) -

Plant Ecology. McGraw-Hill Book Co. New York, 601 pages.

Wilm, H.G. (1946) -

The design and analysis of methods for sampling microclimatic factors, Journ. Amer. Stat. Assn. 41:221-32.

Woodbury, E.N. (1943) -

Repellency of organic compounds to the Mexican bean beetle. Publ. of the Americal Assn. for the Advancement of Science No. 20 pages 174-176.

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EUCALYPTS IN RAIN FOREST

By K. W. Cremer

SUMMARY

This paper is a discussion of published views on the ecological significance of eucalypts in rain forest.

A definition of rain forest is given so that temperate rain forest is readily included. It is shown that the low light intensity obtained under an undisturbed rain forest canopy is incompatible with eucalypt regeneration. Hence "mixed forest", i.e. eucalypts over rain forest, is normally a late stage in a fire sere of the succession towards a pure rain forest climax. Eucalypts have invaded rain forest areas in geological times; rain forest has advanced into eucalypt forest in historical times; but the immediate reason for the existence of eucalypts over present rain forest is the fire which made the eucalypts' regeneration possible.

THE RAIN FOREST HABITAT

Except for the self-contradictory "dry rain forest" or monsoon forest, rain forest is the sort of vegetation which occupies the more continuously moist land habitats if they remain undisturbed for long enough and are not subject ot extremes of cold, wind, or poor soil. High edaphic soil moisture supply is always required. The factors determining soil moisture (climate, physiography, soil) may individually have very large ranges if the others are compensating.

Though the rain forest formation has considerable ecological latitude, both structure and floristics of the rain forest vary greatly in response to individual ecological factors. Passing from tropical to temperate climates, vascular epiphytes are replaced by bryophytic epiphytes, and more striking still: extreme floristic and structural complexity gives way to great simplicity. The cooler the climate, and the richer the soil, the simpler will be the rain forest.

Definitions of rain forest have so far neglected the simple, temperate end of the rain forest spectrum. More comprehensively rain forest may be defined as a climax plant community of water-loving, shade-tolerant, very dense vegetation dominated by trees which characteristically bear an abundance of vascular or non-vascular epiphytes, or both.

Of interest here is the dense and moist nature of this vegetation. As a consequence it is penetrated by merely ½ to 2% of daylight and only very rarely by severe fires.

GROWTH REQUIREMENTS OF THE EUCALYPT

The almost ubiquitous dominance of eucalypts in Australia's wide range of habits is proof of the great adaptability of this genus. Apparently all its species require a relatively large amount of light. Under rain forest or dense wet sclerophyll canopy low light intensities (½ to 2%) certainly do not permit eucalypt seedlings to grow up.

Ashton (1955) showed that light requirements of *E. regnans* are higher than those of its competitors in the wet sclerophyll and rain forest, and that its light requirements increased with age and temperature. It is therefore impossible to give a minimum light intensity applicable to all conditions; 2-3% of daylight being insufficient for continued growth of

E. regnans. From planting amongst fern it appears that even 5 to 10% does not permit long-term survival and growth.

The eucalypts recorded under rain forest or dense wet sclerophyll conditions include such important species as *E. regnans,* F.v.M.; *E. gigantea* Hook.; *E. obliqua* L'Her.; *E. microcorys* F.v.M.; *E. pilularis* Sm., *E. fastigala* D. and M.; *E. viminalis* Labill.; *E. datrympleana* Maiden; *E. saligna* Sm.; *E. grandis* Maiden; *E. maculata* Hook.; *E. diversicolor,* F.v.M.; *Tristania* and *Syncarpia,* and even *Agathis* spp. and *Araucaria* spp., though perhaps not quite so light-demanding, may have a status in rain forest analogous to that of *Eucalyptus* spp.

Any rain forest area should be capable of growing eucalypts if these are given an equal start wth their competitors.

Indeed it would be hard to name several really high-quality (height, volume per acre) eucalypt stands in Australia which are not in rain forest or wet sclerophyll areas. It is only in the denser wet sclerophyll and rain forest areas that the very best of eucalypt stands are grown (*E. regnans* in Victoria and Tasmania, *E. diversicolor* in Western Australia).

Sometimes, however, perhaps when the rain forest component becomes excessively dense the emergent eucalypts suffer premature crown deterioration or even death, e.g. Styx Valley (Needham 1959; Cromer and Pryor 1942).

If then eucalypts are incapable of regenerating, how do they come to be there, and what is their status in that community?

THE MIXED FOREST

Definition of Mixed Forest

''The mixed forest consists of eucalypts with an understorey of rain forest species. In old stands the understorey is not essentially different in structure and floristics from that of pure rain forest'' (Gilbert 1959).

This definition was given for some Tasmanian areas, but probably applies well to all rain forests with eucalypts. There are large areas of mixed forest in Queensland, New South Wales, and Tasmania. The latter alone has between one and two hundred thousand acres.

Mixed forest could be regarded as either a stable climax or a stage in a succession. As a stage in succession it could be a phase of eucalypt forest advance into rain forest, or vice versa, or a stage in a fire sere leading up to the pure rain forest climax. These possibilities are discussed below:

(a) *Mixed Forest as a Stable Climax Community*

(1) Petrie, at least at one time, did call mixed forest a climax community, but later described it as a stage in a fire sere.

(2) Having demonstrated that mixed forest, if undisturbed, ends up as rain forest, Gilbert (1959) then gave a hypothetical exception and said that, in the absence of fire, very poor soils under high rainfall would have a mixed forest climax.

It may be possible that on extremely poor soils the climax will be ''Mixed Forest'' under high rainfall in the absence of fire. But the ''rain forest'' understorey would have to be so open that it could hardly merit the name of rain forest.

(3) Martin believed that under certain conditions of exposure to (desiccating) winds, the shelter of eucalypts is necessary for the good development of *Nothofagus.* When emergent eucalypts die the *Nothofagus* community opens up because of exposure and thus allows eucalypts to regenerate. The community is then in a stable dynamic equilibrium. He quotes the "Tyenna Gap" as a possible example. This view is not applicable there, because of the absence of the regenerating phase. The rain forest would have to open up before the sheltering eucalypt tree is entirely dead. Otherwise there would be no seed for regeneration because of the very short dissemination and ground storage life of eucalypt seed.

(b) *Invasion of Rain Forest by Eucalypts*

Normally it is impossible for eucalypts to invade rain forest, for ecological reasons already discussed. But Phillips (1947) is quoted by Baur to have reported that the Robertson (N.S.W.) rain forest is being invaded by eucalypts. This is probably due to the initial opening of the forest by logging and its subsequent further deterioration on exposure.

A further example is reported by Brough, McLuckie, and Petrie (1924) for the Mt Wilson area (N.S.W.), where eucalypts are supposed to have invaded a healthy rain forest.

Indeed the interacting effects of fire and soil quality provide a much more elegant explanation for the three main associations described than the hypothesis that the outmoded species of the rain forest are being invaded by a superior life form, viz. eucalypts. The undisturbed rain forest is characterized by the presence of *Ceratopetalum, Doryphora,* and *Alsophila,* and the absence of eucalypts. This association has escaped the fires because the better soil maintained it in a wetter and therefore less inflammable condition.

On its periphery the soil is less ideal and fires do occasionally penetrate. This has eliminated the fire-sensitive non-mobile rain forest species *Ceratopetalum* but has permitted the regeneration of the mobile *Doryphora* as well as *Eucalyptus.* On still more marginal sites fires are so frequent that the slow-growing *Doryphora* is eliminated also, but *Eucalyptus* thrives. The fire-resistant *Alsophila* has survived in all three associations. Exactly analogous cases are found with *Nothofagus, Atherosperma, Dicksonia,* and *Eucalyptus* in Tasmania.

Petrie, Jarrett and Patton (1929) described another case of eucalypt invasion into rain forest on the Black's Spur in Victoria. Once again an explanation in terms of fire is more reasonable than the "superiority" of *Eucalyptus.*

The hypothesis that eastern Australia was formerly covered with much more extensive rain forest which has now retreated to its rather isolated present outposts since the climate became drier in the Tertiary is widely accepted but only on a geological time scale. This does not preclude an increase in rainfall during historical times, as discussed above. And it certainly does not provide an explanation for the existence of mixed forest in terms of eucalypt advance at the present time.

(c) *Has Rain Forest Advanced Into the Eucalypt Forest?*

This view is most widespread (Burgess and Johnston, Cromer and Pryor, Curtis and Somerville, Frazer and Vickery, Herbert, Jackson, Needham, Martin). It depends largely on the premise that the Australian climate is becoming more humid. The evidence in favour is considerable, though mostly indirect.

The cases cited by several of the above observers can be better explained in terms of fire. However, both fire and rain forest advance are required to explain all the observed facts. The former is a short-term and the latter a long-term necessity, i.e. fire is immediately responsible for the existence of the eucalypts, while rain forest advance accounts for the distribution of the mixed forests.

Rain forest advance into eucalypt areas is reported to have been actually observed over the past century in an area of NW. Tasmania which experienced an increase of average annual rainfall of 10 in. over the past 75 years (Needham 1959).

Other evidence for rain forest advance comes from Tasmania's West Coast, where there are isolated mature stands of eucalypts surrounded by large tracts of rain forest. Some areas show a gradation of age-classes. The older mixed forests are furthest away from the source of fire. Such patterns would indicate progressively less penetrating fires due to rise in rainfall (Jackson). The advent of the white man is too recent to account for these patterns.

Also in S. Central Tasmania eucalypts sometimes exist in rain forest, old and isolated; and some savannah had changed to dense wet sclerophyll forest (Gilbert).

Further ''convincing evidence of this advance (of rain forest in S. Queensland) is provided from the presence of dead eucalypts in the ecotone region, and the fact that *all age-classes* have died shows that they have succumbed to the aggressive advance of the rain forest formation'' (Cromer and Pryor 1942).

These observations could hardly all be due to man's decreasing fire-making efforts alone. In some areas rain forest therefore has advanced, probably as a response to an increase in rainfall. Decrease in fire frequency may often be explained by the disappearance of the aborigines.

(d) *Mixed Forest as a Stage in a Fire Sere*

There are eucalypt forests in the drier country where eucalypt regeneration is essentially only limited by competition with its own kind and by the vagaries of the climate. Here regeneration is continuous. Where rainfall is sufficient to allow considerable development of understorey, eucalypt regeneration may largely depend on fires, eucalypts rarely occupy a site to the exclusion of undergrowth because their crowns allow so much light to pass. Where the undergrowth is xerophytic fires occur so frequently that eucalypts have become adapted to survive them, and regeneration is continuous. But as the undergrowth becomes denser and wetter, fires become rarer but more intense when they do occur, and eucalypts often are more fire-sensitive. Hence there is a tendency towards even-aged, discontinuous regeneration. As far as the eucalypts are concerned a rain forest understorey is the ultimate in lush weed growth, causes the rarest but most intense fires, and the most discontinuous regeneration.

The importance of fire in the regeneration of eucalypts in the wetter areas has ben realized at least as early as 1924 (Swain) or -1926 (Rodway), and since then many have stressed its significance (Casson 1952;

Jackson 1958; Martin 1950). The most detailed recent evidence for Tasmanian mixed forests comes from Gilbert (1959).

The eucalypts in a mixed forest occur in extensive even-aged stands. This has been determined by ring counts and inspection of the diameter class distribution. An extensive even-aged stand implies that conditions suitable for eucalypt regeneration are only a rare occurrence, of short duration, and obtained over considerable areas at the same time. In rain forest areas climate is suitable for regeneration continuously. Windthrow is unlikely to have operated over such large areas and produced suitable eucalypt seed beds. Fire is the only cause which could account for mixed forests as described above. The evidence in favour of fire is therefore very strong. Evidence for regeneration without fire is practically absent for well-developed mixed forests. Fire destroys the forest, prepares a good seed bed, and causes rapid seed shed. Soon after the fire dense weed growth prevents further regeneration. Hence the extensive areas of even-aged eucalypts. If some of the old eucalypts survive the fire, the stand will be two-aged. Charcoal can be found even in old mixed forest. Where several ages of eucalypts exist the older ones show fire scars.

Old mixed forest and some rain forests have eucalypt downers on their forest floor, but no regeneration; i.e. the eucalypt component of the mixed forest fades away without replacement and the climax of pure rain forest is achieved (Gilbert 1959).

CONCLUSION

Owing to the interdependent factors of fire frequency and climate rain forest has been retreating from and advancing into eucalypt forest at different times. Over the past 500 years or so and over the past century since the disappearance of aborigines, the main trend has been one of rain forest advance. However, the existence of any individual stand of mixed forest must be explained by fire. Eucalypts do not invade or regenerate in an unburnt rain forest except as a result of disturbance by the axe or perhaps under conditions of extreme exposure.

Like the majority of the world's most important timber species, *Eucalyptus* spp. of the mixed forests are relatively light-demanding and therefore absent from the climax vegetation. From the point of view of the rain forest the eucalypts are but a transient fire weed. The mixed forest is then a fire sere in the succession towards the rain forest climax. Eucalypts cannot regenerate in an undisturbed mixed forest, but the rain forest component can arise, develop, and perpetuate itself irrespective of the presence of eucalypts. In old temperate mixed forest the understorey is practically identical with rain forest. Eucalypts, though much taller, cannot be regarded as dominant in this community because their influence on the habitat is negligible by comparison with that exerted by the rain forest understorey.

A mixed forest cannot therefore be regarded as a climax of any sort because it is no more permanent then the eucalypt's life span. Eucalypts are only incidental to a rain forest.

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REFERENCES

Ashton, D. H. (1955) — Studies on the autecology of **Eucalyptus regnans,** Ph.D. Thesis, Univ. Melb.

Baur, G. N. (1957) — Nature and distribution of Rainforests in New South Wales. **Aust. J. Bot.** 5 (2).

Beadle, N. C. W., and Costin, A. B. (1952) — Ecological classification and nomenclature. **Proc. Linn. Soc. N.S.W. 77**:61-82.

7th Brit. Commonwealth Forestry Conference (1957) — Tas. tour notes.

Brough, P., McLuckie, J., and Petrie, A. H. K. (1924) — An ecological study of the flora of Mt Wilson . Part I. The vegetation of the basalt. **Proc. Linn. Soc. N.S.W. 49**:475-98.

Burges, A., and Johnston, R. D. (1953) — The structure of a N.S.W. subtropical rain forest. **J. Ecol. 41**:72-83.

Casson, P. B. (1952) — The forests of western Tasmania. **Aust. For. 16** (2):71-86.

Clifford, H. T. (1952) — On the distribution of the species of **Eucalyptus** in the region of the Dandenong Range, Victoria. **Proc. Roy. Soc. Vict. 65** (1).

Cromer, D. A. N., and Pryor, L. D. (1942) — Contribution to rain forest ecology. **Proc. Linn. Soc. N.S.W.** 67:249-68.

Curtis, W. M., and Somerville, J. (1949) — "The vegetation". A.N.Z.A.A.S. Handbook for Tasmania 1949.

Fitting, H., Schumacher, W., Harder, R., and Firbas, F. (1954) — Lehrbuch der Botanik.

Francis, W. D. (1951) — "Australian Rain Forest Trees". 2nd Ed. (Angus and Robertson: Sydney.)

Frazer, L., and Vickery, J. W. (1938) — The ecology of the Upper Williams River and Barrington Tops district. II. Rain forest formations. **Proc. Linn. Soc. N.S.W. 63**:138-84.

Frazer, L., and Vickery, J. W. (1939) — III. Eucalypt forest and general discussion. **Proc. Linn. Soc. N.S.W. 64**:1-33.

Gilbert, J. M. (1958) — Eucalypt — rainforest relationships and the regeneration of the eucalypts. Ph.D. Thesis, Univ. Tasm.

Gilbert, J. M. (1959) — Forest succession in the Florentine Valley, Tasmania. **Pap. Proc. Roy. Soc. Tasm. 93**:129-51.

Herbert, D. A. (1935) — The climatic sifting of Australian Vegetation. A.N.Z.A.A.S. Report 22:349-70.

Holloway, J. T. (1954) — Forests and climate in the south island of New Zealand. **Trans. Roy. Soc. N.Z. 82**:329-410.

Jackson, W. D. (1958) — Rain forest — eucalypt and fire. The vegetation of the lower Pieman River region, Tasmania. Unpublished M.S.

Jacobs, M. R. (1955) — "Growth Habits of the Eucalypts". (Forestry and Timber Bureau, Govt. Printer: Canberra.)

Jarrett, P. H., and Petrie, A. H. K. (1929) — The Vegetation of the Black's Spur region. II. Pyric succession. **J. Ecol. 17**:249-81.

Kensington, W. C. (1909) — Forestry in New Zealand. (Govt. Printer.)

Martin, D. (1939) — The vegetation of Mt Wellington and a census of the plants. **Pap. Proc. Roy. Soc. Tasm. 97**:124.

Martin, D. (1950) — Tasmanian plant ecology. Notes on Lectures 5, 6, 13; unpublished M.S. at Univ. Tasm. Library.

McLuckie, J., and Petrie, A. H. K. (1927) — An ecological study of the flora of Mt Wilson. Part IV. Habitat factors and plant response. **Proc. Linn. Soc. N.S.W.**

Needham, R. H. (1959) — Problems associated with regeneration of **Eucalyptus gigantea** in the Surrey Hills area. Paper read at A.P.P.I.T.A., Melbourne.

Patton, R. T. (1933) — Ecological studies in Victoria. II. The fern gully. **Proc. Roy. Soc. Vict. 46**:117-29.

Petrie, A. H. K., Jarrett, P. H., and Patton, R. T. (1929) — The vegetation of the Black's Spur region. I. Mature plant communities. **J. Ecol. 17**:223-48.

Phillips, Marie E. (1957) — Vegetation of the Wianamatta shale and associated soil types. M.Sc. thesis, Univ. Sydney.

Richards, P. W. (1952) — "The Tropical Rainforest". (Cambridge Univ. Press.)

Rodway, L. (1924) — Some ecological features in Tasmania. Report A.A.A. Sc. **17**:730-738.

Swain, E. H. F. (1924) — Notes on the silviculture of the eucalypts. Qld. For. Service, For. Bull. No. 5.

Swain, E. H. F. (1928) — "The Forest Conditions of Queensland". (Qld Govt. Printer: Brisbane.)

Webb, L. J. (1956) — Environmental studies in Australian rain forests. Ph.D. Thesis, Univ. Qld.

Webb, L. J. (1959) — A physiognomic classification of Australian rain forests. **J. Ecol 47**:551-70.

PROBLEMS OF EUCALYPT REGENERATION IN THE FLORENTINE VALLEY

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PROBLEMS OF EUCALYPT REGENERATION IN THE FLORENTINE VALLEY[1]

K. W. CREMER*

SUMMARY

The problems of natural eucalypt regeneration in the Florentine Valley, central Southern Tasmania, are discussed. This paper deals only with *Eucalyptus regnans* but the findings may also apply to other related species. The special regeneration problem arises mainly from the presence of a dense understorey of temperate rainforest or wet sclerophyll scrub, and from the high light requirements of the eucalypts.

In the Florentine Valley, central Southern Tasmania, the most important eucalypts are the closely related species of *Eucalyptus regnans, E. delegatensis* and *E. obliqua.* This paper deals only with *E. regnans,* but the findings may also apply to other related species. The eucalypts overtop a dense understory of temperate rainforest or wet sclerophyll scrub. The problems of the natural regeneration of eucalypts in the Florentine Valley area are discussed in this paper.

NATURAL REGENERATION

The silvicultural system employed to obtain such regeneration in the Florentine forests has been explained earlier in Frankcombe's paper to this meeting (14th APPITA Conference). The "natural" feature of this system is sowing of the seed, *viz.* by seedshed from standing trees. Provision of suitable seedbed and light conditions involves considerable and carefully planned efforts aimed at destroying and burning the understorey. The term "natural regeneration" does not necessarily imply cheaper regeneration than by artificial means.

Removal of the rainforest remnant understorey (after utilization) is a mechanical operation of felling and eventual burning. Amongst a variety of tree poisoning methods tried, the only promising one was using arsenic pentoxide (As_2O_5) solution in continuous frill girdles. However, mechanical slash falling is favoured because of its easier administration and safer resultant fires.

Three main variables influence the provision of an adequate seed supply:

(i) timing of the regeneration burn
(ii) timing or removal of the eucalypt seed trees
(iii) supplementary action, such as protection from browzing, to make limited seed supplies more effective.

Timing of the regeneration burn

This must be based on an assessment of the present or potential seed crops in the next three or four years. It is necessary because of the great variability of the seed crop from year to year, from coupe to coupe, and even from tree to tree and because of the necessity to obtain an adequate seed fall before the rapidly deteriorating seedbed makes further seedshed ineffective.

In the Florentine, seedbed deteriorates very fast after felling and/or burning. The actual rate of deterioration in terms of decreasing tree per cents (per cent of viable seed sown actually producing a

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tree) with increasing age of the coupe is being studied at the moment. It is doubtful if seed sown three or more years after a fire can be significant in regeneration.

It seems obvious that seed sown within the first year is the most effective, because seedlings from it meet with the longest period of relative freedom from weed competition. Moreover, it would be favourable to fell the seed trees after adequate seedshed has been obtained, but before the seedbed has become unreceptive. If this is done, felled tree crowns become an asset rather than a liability, because they will give rise to further regeneration rather than destroying existing regeneration. For these reasons enough seed fall should be planned to occur very soon after the fire.

The basis of the assessment. E. regnans seedshed from any one crop is spread over two years. It begins in December, eight to nine months after flowering. The flowers (March to June) come from flower buds which have been developing on the tree for fifteen to sixteen months previously, and which in turn arise from nine to ten months old primordia (1) Gilbert. Hence an assessment of mature capsules, immature capsules or flowers or old flower buds; flower buds; and primordia will indicate the relative amounts of seed mature at present and in the future first, second, or third years respectively.

Assessment in a semi - quantitative manner can be made either by inspection of the felled proportion of eucalypts or by inspection of standing trees through a telescope. The former can be used in spar stands but the latter must be used in eucalypt rainforest stands where none of the eucalypts are felled prior to the regeneration burn.

Significance of the assessment. It is likely that at some times seed supply will be deficient. Hence optimum conditions must be aimed at. Whether the optimum in any one instance is good enough is another question. The answer will be based largely on a knowledge of what the seed crop assessment means in terms of pounds of seedshed per acre per year. Inference from inspection of the felled subdominant and suppressed portion of a spar stand is likely to lead to an underestimate of the seed crop, unless account is taken of the fact that the dominants carry most of the stand's seed. An answer can also be given subsequently, based on assessment of the regeneration that actually has come up. This is discussed later.

It is improbable that an efficient fire can be achieved in slash more than four years old. Forecasting cannot cover more than three or four years of the future. Hence felling of the potential seed trees at the time of regeneration felling is advisable if an early assessment cannot predict a reasonable seedcrop within the next four years. Artificial regeneration must then be used. Sometimes slash falling can be postponed beyond the regeneration felling so that the timing of the slash burn can be according to flowering more than four years hence. This would involve more than one assessment of the floral crop.

If an adequate mature seedcrop is available the regeneration burn should occur at the earliest opportunity. If, however, the flowering of any future year is much heavier the burn should take place soon after the first January following that flowering.

Timing of removal of seed trees

After the seedbed has become unsuitable for further regeneration, *i.e.* within a few years of the burn, the seed trees will not only be ineffective, but give competition to their offspring. Hence they should be removed and utilized as early as possible, *i.e.* after having shed enough seed, but before the seedbed has become unreceptive.

To help decide the timing of seed tree removal we require:

knowledge of the state of the seedcrop, from the original assessment,

knowledge of seedshed patterns, particularly in relation to burns,

knowledge of the course of germinations and deaths following the burn, so that a regeneration survey can be timed efficiently and given its proper significance, if it is felt that confirmation of the treatment's success is needed in any one instance, and

knowledge of the rate of seedbed deterioration.

Supplementary action to make limited seed supplies more effective

It is possible to increase the efficiency of a particular seed supply by two to four times by poisoning browzing wallabies and possums. Regeneration can also be improved by sowing, if the seedbed is still receptive, or by planting.

FINDINGS RELATING TO THE ABOVE DISCUSSIONS

Effect of fire on seed trees and their seed crops

If the seed tree does not survive the regeneration burn only those seeds mature at the time of the fire are effective.

Effect on the crown

E. regnans is a fire sensitive eucalypt. All degrees of fire kill may be experienced depending on the tree's fire resistance (age, height) and the intensity of the fire (depending on fuel and weather). The important part of a seed tree is its crown. Apart from crown fires, which do not occur in controlled burns, two types of fire damage may be distinguished, though not always separated. In neither case is living tissue consumed by the fire.

Crown scorch. In this type some or all leaves and twigs may be partially or entirely killed by heat scorch. If a leaf is excessively scorched while its sustaining twig remains alive, the leaf is usually abscissed quickly, even though part of it still looks healthy. This is the lightest form of fire damage. It results in rapid leaf shed and soon becomes invisible except for the suggestion of a thinned crown. More intense heat will kill leaves and twigs as well. In this case the injured portions cannot be abscissed and remain on the tree for a long time till rot and weather tear them off. After five months such crowns still retain most of their leaves, but at the end of eleven months they are almost bare.

Both leaf abscission and twig kill may occur on the same tree. The lowermost portion of the crown suffers most. Degree of crown scorch varies with the height of the crown and the intensity of the fire.

At coupe W54 where there is a mixture of three main age groups, the shortest trees (100 yr. old, suppressed) suffered 55 per cent scorch to their total crown volume while spar aged trees (150 yr.) had only 17 per cent and mature trees (250+ yr.) 12 per cent of their total crown volumes scorched. At coupe TS3, with a much hotter fire, mature trees suffered 65 per cent crown scorch.

Recovery is usually good. Eleven out of fourteen trees with apparently their entire crowns scorched brown had recovered to some extent by the next growing season.

Cambium kill at the tree base, i.e. fire girdling. This can be quite independent of crown scorch. If the girdling is complete the damage is fatal in *E. regnans.* The entire crown will show signs of pale wilt within two weeks.

The bark at the butt begins to split off within a year. Leaf shed is as in twig scorch above.

Bark scorch varies with thickness of the insulating woolly portion of the tree bark (*i.e.* with tree age) and with proximity and intensity of the fire at the tree base. For this reason slash should not be heaped at the tree. *E. regnans* less than thirty years old rarely survives any fire.

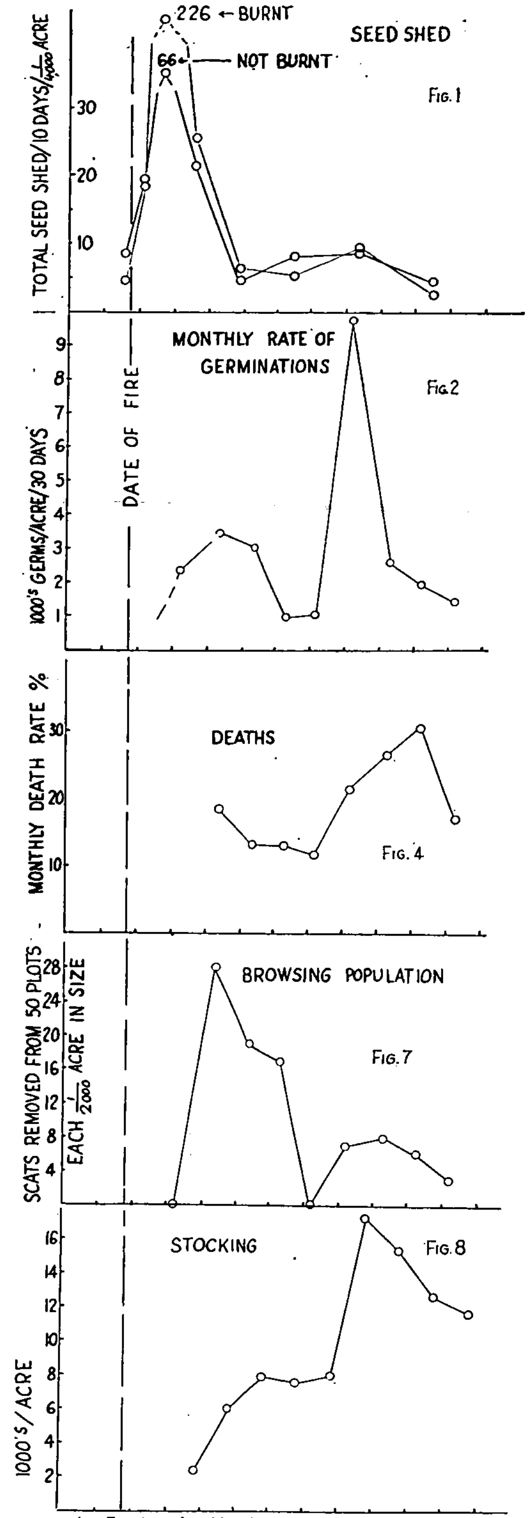
Autumn burns effect on present and future seed crops.

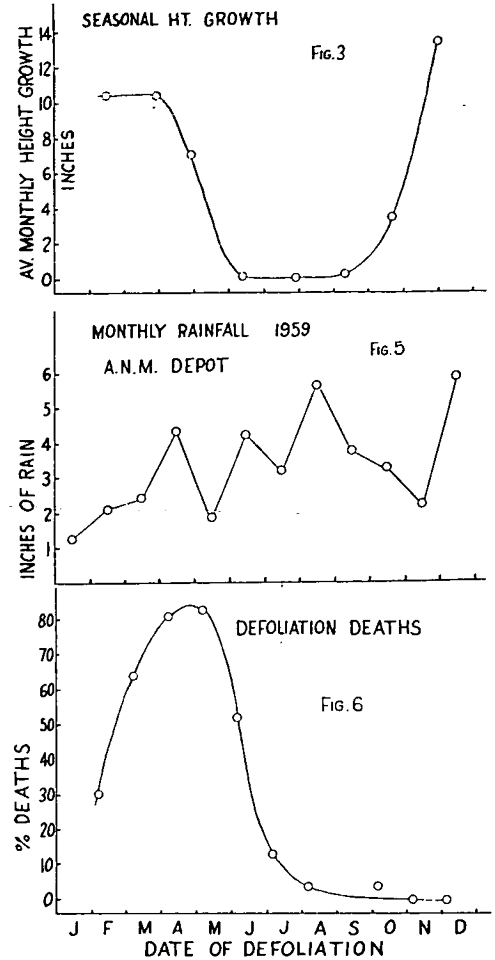
Immature fruits and floral parts cannot develop further when the twig dies. Persistent brown foliage indicates dead twigs, and therefore dead floral parts. However, floral parts do survive on green portions of partially scorched crowns, and some even survive nearby leaf abscission due to heat scorch.

Primordia. Primordia do not arise till March, and therefore may not have to survive a fire. They do arise from the axils of heat abscissed leaves. It is not known how their numbers are affected by a fire prior or subsequent to their birth.

Young flower buds. Young flower buds are relatively fire resistant. Healthy flower buds can be seen on twigs almost bare of leaves due to heat scorch abscission,

Old flower buds. Flower buds just before flowering appear to be the most sensitive to fire. An isolated case of dead buds with nearby uninjured leaves has been observed. Fire scorched crowns with heavy crops do shed (absciss) such buds in umbels by large numbers. This is also the case with some unburnt trees. From trappings of floral parts (4 x $\frac{1}{4}$ milacre traps under both burnt and unburnt trees) no harmful effect of fire could be demonstrated. On the contrary 13.8 per cent of the flower buds existing in February





Figs. 1, 2, 4, 7 and 8 are based on studies carried out at coupe W54 in the central Florentine Valley. W54 had been rain-forest with a relatively dense Eucalypt overstorey. It was slashfelled and then burnt in February, 1959. The studies consisted of —

regular monthly inspection of 50 (later 100) half milacre plots subjectively located on an area of about five acres; and

trapping of seeds and floral parts from eight groups of trees: half of them burnt, the other half control; each half is again subdivided into mature and spar age.

All dates are in 1959.

Fig. 1.—Total free seedshed over variable periods plotted at the middle of the collection period.

Fig. 2.—Monthly observed germination rates, plotted at midperiods.

Fig. 3.—Average monthly height growth of the ten best tubed seedlings of 40 planted at coupe W56 in May, 1958.

Fig. 4.—Death rate as a percentage of the number of live seedlings at the previous score, at midperiods.

Fig. 5.—Rainfall received at about 15 miles S.E. of W54. For a 12 month period.

Fig. 6.—Showing result of a defoliation experiment. Each point represents the percentage of deaths amongst plants completely defoliated at the time shown.

Fig. 7.—Number of scats (from wallaby, kangaroo, and possum) removed monthly from 50 plots at W54, plotted at midperiods.

Fig. 8.—Number of live seedlings per acre recorded on 50 plots at W54, and plotted on the date of inspection.

survived the February fire to develop into mature capsules in December, while the figure for the controls was only 9.6 per cent. The difference is due either to experimental error or variable survival rate of widely different flowing intensities. One of the controls shed over 1,400 opercula (one operculum per flower) into its trap, while the four burnt trees totalled only 560 opercula.

It is certain that flowering does take place after a fire, and it appears likely that flowering in unscorched portions of trees is not seriously reduced.

Flowers and immature capsules. Flowers and immature capsules are unlikely to meet fire.

Seed survival. In mature capsules on the crown, seed survives even wild fires.

Seed shed acceleration. Seed shed after a fire is accelerated to a degree depending on the intensity of the fire. The fire helps to kill and dry out the capsule and its sustaining twig. Average results from four traps under burnt trees are compared with their unburnt counterparts in Fig. 1. It is notable that the controls showed a distinct March peak. This follows the first unusually hot Tasmanian summer of the past three years. It is for the first time during this period that these trees showed a uniform response to the weather, comparable to the autumn peak seed fall reported from Victoria. The burnt trees did not differ from the controls 17 days after the fire, but during the next 17 days the controls shed only 66 as compared with 226 seeds from burnt trees. This 17 days' seedshed amounted to 57 per cent of the burnt and 34 per cent of the unburnt trees' seedshed over the ten months following the fire. The most distinct acceleration came from both spar aged groups which shed 70 per cent of their ten months' supply compared with 25 per cent from unburnt spars. The contributing crowns suffered less than 10 per cent scorch to their crown volume.

It can therefore be concluded that some acceleration of seedshed does occur after even a fairly cool fire.

However, all mature seed is not shed even from 100 per cent scorched crowns within a month or two after a fire.

The course of germinations

Fig. 2 illustrates the course of germinations as determined by monthly inspection of fifty half-milacre plots scattered over an area of about five acres after a regeneration burn in February, 1959. Time of germinations was largely independent of seedshed or rainfall (compare with Fig. 1 and 5). Early germinations might have been higher if the seedbed had been moister. The notable features are the winter low and the spring peak (compare with Fig. 3). A similar pattern was not obtained in April, 1956, from nearby sowings (1).

Death rate

The death rates recorded were rather irregular from month to month and from seedbed to seedbed. However, the average results (Fig. 4) may reflect a real trend. From August onwards the death rate curve is a mirror image of the rainfall (Fig. 5). This "drought" sensitivity results largely from the presence of very young seedlings following peak germinations in early September (Fig. 2). The falling death rate in December is the result of ample rain and hardier plants.

In the past death rates could be largely accounted for by fungus, desiccation, and "micro-browzing". There is an animal, presumably very small, which eats the whole or part of the cotyledon stage plants. By November/December many plants had reached a browzable stage. Hence, future death rates will be greatly influenced by marsupial activity.

The evidence so far has not shown that survival under the seed tree system is particularly poor.

Seasonal variability of browzing effects

In a separate experiment, about twenty plants (ten in each of two different localities) were defoliated at monthly intervals without injury to developing buds. The plants were healthy, and 4 to 12 in. high. Both localities showed very marked and similar trends of death rates following defoliation in the different months. Fig. 6 shows the average results. The trend is significant, but because of the small number of plants tested not necessarily quantitatively reliable. The marsupials often defoliate the plant entirely. In addition they may destroy buds or even uproot the seedling. A plant which retains several healthy leaves is not endangered, in spite of severe injury.

Palatability and/or animal activity in any one area varies with time. This has been observed elsewhere, and is to some extent confirmed by the scat count shown in Fig. 7. If number of scats is a measure of animal visits by *Thylogale billardieri* (pademelon), *Protemnodon rufogrisea* (wallaby) and *Trichosurus vulpecula* (brush possum), then reference to Fig. 7 shows that invasion was heavy but did not occur till the third month after the fire. Some animals were present at all times of the year. This is surprising because there is practically no browze for a few months after the fire. Fig. 6 shows the relative importance of browzing damage at different times of the year.

It may be concluded that protection by poisoning is most important during February to June. Since seedlings from autumn sowings (or regeneration burns) do not become browzable till December it follows that the most critical period for protection in the autumn burnt seed tree system is during the first half of the new calendar year following the regeneration burn.

The explanation of defoliation deaths is not known. Comparison of Fig. 6 and Fig. 3 suggests starvation as a cause of death if the following assumptions are correct:

(i) towards the end of the season of rapid height growth the eucalypt seedling is devoid of food reserves, which are not replenished till the "dormant" season, and

(ii) very immature leaves are incapable of photosynthesis and can develop only if there is food supply from elsewhere.

Stocking

The number of seedlings per acre will vary from place to place and from year to year according to factors such as seed supply, seedbed and climate. A knowledge of the relative numbers of seedlings at different times after the regeneration burn is useful for efficient timing and evaluation of a regeneration assessment survey, should one be required. Assessment should be made while the seedbed is still suitable for further treatment should sowing of blank areas be necessary. Fig. 8 suggests that the October following the burn is a suitable time for assessment.

ACKNOWLEDGMENT

Grateful acknowledgment is made to Australian Newsprint Mills Ltd. for the provision of the Fellowship under which this work was carried out.

REFERENCE

(1) Gilbert, J. M.—Eucalypt-Rainforest relationships and the regeneration of the Eucalypts. Ph.D. Thesis, Uni. Tasmania (1958).

ADDENDUM

This paper represents preliminary results of current research. Between its writing and publication the following facts necessary for the amplification of some points have emerged:

1. Sometimes, perhaps when the fire was only just hot enough to kill the cambium, the effects of fire-girdling do not become evident on the unscorched crown for five or more months. Though the bark at the butt may begin to split, the sap is still under tension in the dead discoloured wood and continues through the winter to keep the crown looking healthy except for the slightly leathery immature leaves. Even epicormics appear.

2. Much more so than the light crops of older capsules described in this paper, heavy crops of mature but still green capsules on both *E. regnans* and *E. obliqua* have proved amazingly responsive to heat. A fire barely hot enough to scorch only the very lowest foliage is still sufficient to

cause nearly all young capsules to become abscissed. This results in such rapid free seedshed that over 90 per cent of the young crop comes down in a little over one month, a process which would have taken two years in the absence of fire. The capsules themselves also shed rapidly; only during the first two weeks is their seed content greater than normal, thereafter the shed as well as the still suspended capsules contain less seed than normally shed capsules would. The capsules on the tree are amongst unscorched leaves on live twigs but have died back and turned brown after four months. Abscission layers occur at the base of each capsule as well as at the base of the umbel stalk. Normally, without a fire, even the oldest capsule is alive if its sustaining twig is alive.

When the crown is killed by heat scorch capsules cannot absciss. Nevertheless seedshed is still greatly accelerated. Seed collectors agree that young green capsules are easier to extract than older, grey ones.

3. The very marked spring peak in germinations may be due to the necessity of winter stratification to remove dormancy in the seed induced by heat from the fire.

4. Excised, very immature leaves of *E. regnans* have proved capable of photosyntheses by their uptake of labelled carbon dioxide (D. Thomas, Tas. Uni., pers. comm. 1960). However, starvation of defoliated plants is still possible if the rate of photosynthesis in very young leaves is inadequate for the maintenance of the plant and its own growth.

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DISCUSSION

R. A. Elder: I would like to know what control measures are taken over burns since these may take place in times of acute fire danger.

K. W. Cremer: Bearing in mind the optimum timing in relation to the seed crop we time the fire on the basis of the weather preceding the fire. Other than this we have very little means of control.

M. J. Hall: You mentioned defoliation by small animals and I wonder if that includes insect attack. Secondly, is the logging management flexible enough to take advantage of good seed producing areas, and does logging proceed according to a plan regardless of seed? Also, what success have you had with direct sowing of seed?

K. W. Cremer: It is known that insects can entirely defoliate eucalypt seedlings. However, our problem is due almost entirely to browzing mammals, namely, the wallaby, kangaroo and opossum. It is difficult to time the first stage logging according to an assessment of the seed crop because the very dense undergrowth prevents us looking up into the over-storey. Moreover, some stands are chronically short of flowers. If we had to time our logging according to seed crop it might mean a succession of seed crop assessments and still no assurance of sufficient seed crop density to ensure regeneration. As far as direct sowing of seed is concerned we have had success if the sowing is timed correctly, if the seedbed is prepared correctly, that is burnt or lightly disturbed, and if the young seedlings are adequately protected from browzing.

M. J. Hall: Is the success from spot sowing limited to one trial or has it been tried over a number of years?

K. W. Cremer: We have had quite a number of successful sowings over the past five years; I realize that our problem in getting regeneration from a single sowing is less than yours because we haven't got such critical survival trials as you have in the Victorian summer.

W. D. Muir: Would not the burning of relatively small acreages minimize fire damage to crowns of seed trees? It would seem to me that you could, in that way, control the intensity of your burn and possibly minimize the subsequent build-up of the animal population which must undoubtedly occur on large areas of burnt country.

K. W. Cremer: The first thing to realize is that the patches that are being burnt are as small as thirty acres and probably can't be reduced below this. Very conceivably the fire intensity could be controlled by the extent of the burn. The most obvious control of fire intensity is fuel moisture content. We have to fit in as much fire as possible in the time available because our relatively safe fire season is short. It is more likely that small coupes are more dangerous to the seedlings from the point of view of browzing animals because small coupes are more rapidly invaded than large coupes. For instance the opossum, which may contribute up to 50 per cent of the browzing damage, has only a limited range and fairly slow penetration.

W. G. Meadows: At what time of the year do you get appropriate weather conditions for burning?

K. W. Cremer: Both spring and autumn come into consideration, spring when the fuel is drying out and autumn when the fuel is about to be doused by the winter rains. We are not in favour, at the moment, of burning in the spring because smouldering logs are likely to carry over for a long period into the dangerous conditions which may obtain about January. However, there is some evidence from rainfall records that the rainfall in September and November is reliably high, and that fact may be used in carrying out regeneration operations in the spring. However, this would not be the right thing to do in relation to floral development because the capsules from the flowering earlier in the same year are not capable of opening before about January. This argues in favour of autumn burning, and, in addition, within one month of autumn burning there is no probability of further fires.

W. G. Meadows: What time in the autumn do you burn?

K. W. Cremer: The policy is to wait until after the first good rains following the hot part of summer.

D. T. Kitchener: Usually we wait until the second week in March. If we wait any longer we miss the burn. We are now coming very strongly to the conclusion that we should do our burning from the beginning of February onwards, to make certain of getting the burn that we require. I think perhaps that Mr. Cremer could give some short statement on the necessity for getting a hot burn for regeneration purposes rather than a cold mild burn. In many seasons it is difficult to get that unless you start very early in the season.

K. W. Cremer: Very young regeneration in the drier areas of the concession is likely to suffer heavily from drought during the summer because the thick litter layers not consumed by a hot fire do dry out very readily. This argues against having cool fires.

A. H. Crane: Do you get accelerated seed fall after a fire by a fall of capsules, or do the capsules burst before falling? Incidentally, we have been trying to control these fire intensities and reduce costs by doing strip felling in the rain-forest under-storey, by partial felling, and so on, and I do not think the outlook is very bright at the moment.

K. W. Cremer: I recently walked into an area which had been flowering heavily in 1959 so that the predominant crop of capsules was a very young crop and there was an unusually large number of green unburnt capsules on the seedbed. My first impression was that these capsules had suffered abscission, but further examination showed that at least half the capsules were empty and had shed their seed so that there was an actual seed shed acceleration and not just an acceleration in drop of capsules.

M. R. Jacobs: Would you agree that the damaged crowns resulted from heat radiation rather than from conduction?

K. W. Cremer: There is considerable evidence to show that the damage is done by radiation. Seedlings for instance which have suffered fire scorch have a very clear pattern of damage. There are green portions which have been shielded from direct radiation while other portions which have been exposed are completely dead. At the same time the whole plant was presumably subject to the same drying and smoke conditions. Early patterns of fire and frost damage are very similar. This further suggests that radiation is the cause of death, resulting perhaps in protein denaturation due to high temperature in the former and to desiccation in the latter case.