FORESTRY COMMISSION OF N.S.W.

DIVISION OF FOREST MANAGEMENT

RESEARCH NOTE No. 10

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INVESTIGATIONS INTO THE NATURAL REGENERATION OF BLACKBUTT — E. PILULARIS

AUTHOR

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CONTENTS

INVESTIGATIONS INTO THE NATURAL REGENERATION OF BLACKBUTT

(*E. pilularis* Sm.)

SUMMARY

An experiment is described which studied the natural regeneration of Blackbutt (*Eucalyptus pilularis* Sm.) and associated species on Pine Creek State Forest in northern New South Wales using the group selection silvicultural system and various methods of seed-bed preparation. Eight openings in all were either burnt or the litter cleared from portion of the area in various months of the year.

Seed trays indicated that over the three years of study, Blackbutt seedfall may occur in any month if conditions are sufficiently dry.

A maximum effective Blackbutt seed throw of 20 feet from the crown edge was measured for trees 120 feet high. Effective natural germination occurred at the beginning and end of the summer wet season.

Seed-bed preparation by clearing in the spring produced the greatest number of established seedlings, whereas burning produced the greatest total number of germinates.

Shade from the nearby canopy oı more open ground cover was found to reduce early losses and promote more rapid height growth.

On the basis of the results of this experiment, a silvicultural treatment for Blackbutt is suggested for trial.

INTRODUCTION

Although Blackbutt (*E. pilularis* Sm). extends from the Victorian border north to Fraser Island in Queensland, it reaches its best development in New South Wales along the coastal strip from Taree to Woolgoolga. Here it occurs as either a pure stand or as the dominant species associated with Red Mahogany (*E. resinifera* Sm.), Tallowwood (*E. microcorys* F. Muell.), Blue Gum (*E. saligna* Sm.), Red Bloodwood (*E. gumnifera* (Gaertn.) Hockr.), White Mahoganies (*E. acmeniodies* Schau, and *E. carnea* Baker) and Turpentine (*Syncarpia glomulifera* Sm.). The Blackbutt forest type occupies the slopes, giving away to rainforest or Flooded Gum (*E. grandis* Hill ex Maiden) in the gullies. The poorer ridges generally carry Grey Ironbark (*E. decepta* Blakely) and Grey Gum (*E. propinqua* Deane and Maiden).

As Blackbutt is the principal species grown on the North Coast of New South Wales, it constitutes the most important natural forest type in the region. The regeneration of Blackbutt is almost entirely accomplished by natural means on the State Forests of the North Coast and although various silvicultural treatments have given excellent results in most cases, there has been little work carried out to understand the basic causes for these successes.

Therefore, in 1956 the North Coast Silvicultural Research Organisation commenced a study of the seeding and regeneration of Blackbutt on Pine Creek State Forest following various regeneration treatments.

THE EXPERIMENT

The silvicultural system used in the uneven aged Blackbutt stands in New South Wales is commonly referred to as the Australian Group Selection System.

The object of this system is to preserve the smaller size classes of the forest by enlarging the openings created during logging of the mature trees through the falling of useless trees around the perimeters of the openings. The size and shape of these openings is therefore governed by the composition of the stand to a great extent. Such openings may vary from 1 to 5 chains in diameter and from round to lenticular in outline. The experiment was designed to study the seed-fall and germination in typical openings which had either been burnt or cleared mechanically in different months to provide a better seed bed. There is a great diversity of opinion amongst foresters as to which type of seed-bed preparation is most successful, and also as to which time or times of the year are most suitable for its implementation.

Accordingly in April, 1956, a series of nine openings of average size and shape were selected on a west-facing slope on Compartment 3 of Pine Creek State Forest No. 537. This area was considered by the local staff as typical of much of the Blackbutt forests of the Macksville to Woolgoolga coastal strip. By an examination of the stumps and standing trees it was determined that before logging the frequency of the Blackbutt stems over 20 in. d.b.h. was 66.7 per cent. The present frequency after logging and treatment is 87.5 per cent. The experimental treatments given are shown in Table 1.

TABLE 1

Details of Treatment given to Experimental Openings

Opening No.	Openings Enlarged	Slash Burnt	Mechanically Cleared
1	July, 1956	2nd October, 1956 ..	....
2	September, 1956 ..	....	2nd October, 1956.
3	November, 1956 ..	31st January, 1957 ..	....
4	July, 1956	....	....
5	January, 1957 ..	....	15th February, 1957.
6	September, 1956 ..	17th December, 1956	....
7	January, 1957 ..	20th March, 1957 ..	....
8	May, 1956	23rd July, 1956 ..	....
9	March, 1957.. ..	....	3rd April, 1957.

In the case of the openings to be burnt, their enlargement was undertaken two months prior to the scheduled time for burning in order that the heads would be dry enough to burn. However, where the openings were to be mechanically cleared, the enlargement was carried out just prior to this operation. A small bulldozer was to be used for all three plots to heap the debris and thus clear the lanes across the openings. Unfortunately, the bulldozer was not available for openings 5 and 9, which were prepared instead by hoeing cleared paths of comparable width. The burning of the slash on the five openings listed was carried out in each case so as to destroy the heads and undergrowth without scorching the fringe of seed trees and advanced growth. No seed-bed preparation was carried out on opening No. 4 which served as a control. Eleven seed trays, each of 1 foot square catchment, were located along three randomly located lines in this opening. The contents were collected periodically from August, 1956, to July, 1959, and germinated on moist blotting paper in the laboratory to determine viability. Milliacre plots were laid out along either two or three transects located at random in each opening. The plots were at 30-link intervals along the transects. One hundred and thirty-five milliacre plots were inspected periodically from the commencement of the experiment to July, 1959, and the number and height of all seedlings and coppice noted.

RESULTS

As this experiment deals with two distinct though related aspects of the regeneration problem, namely seedfall and regeneration, it will be convenient to discuss each section in turn.

1. Seedfall of Blackbutt

A. TIME OF FLOWERING

Blackbutt flowers regularly from September-November each year with occasional sporadic light flowerings reported by some workers in autumn. The variation in spring flowering is found with all native species and is related to the mildness or otherwise of the preceding winter.

B. NUMBER OF SEEDS PER CAPSULE

The Blackbutt capsule usually contains 4 cells, each of which contains from 0 to 2 dark brown fertile seeds at the base with an average of 7 lighter-brown or red-brown sterile seeds above. An analysis of 54 capsules collected from the experimental area in December, 1956, yielded the following data:—

Mean No. of Viable Seeds/Capsule	2.61
Mean No. of Sterile Seeds/Capsule	28.43
Total ..	31.04

C. RATE OF SEED SHED FROM PICKED CAPSULES

The 54 capsules mentioned in the previous section were collected from a well formed co-dominant tree with a d.b.h. of 24 inches which was felled on 4th December, 1956. These capsules were allowed to dry out in the laboratory and were gently shaken after 3, 10, 17, 29 and 40 days. The free seed on each occasion was tested for viability by germination. Table 2 shows the progressive percentages of viable, sterile and total seed shed over the period.

TABLE 2

Progressive Percentages of Blackbutt Seed Shed from Picked Capsules During the Succeeding 40 Days

	No. of Days Since Picking				
	3	10	17	29	40
Percentage of Total No. of viable seeds	27·9	74·0	94·8	100	100
Percentage of Total No. of sterile seeds	33·1	81·5	94·0	98·7	100
Percentage of Total No. of capsule contents	32·6	80·8	94·1	98·8	100

Over the first 3 days there is a considerably greater percentage of sterile seeds shed representing an increase of 5.2 over the viable seed percentage. During the next 7 days the sterile seed percentage continued to exceed the viable seed figure by 2.3. Therefore, over the first 10 days the sterile seed percentage exceeded the fertile seed figure by 7.5, resulting in a seed mixture of low viability. However, during the period from 10 to 17 days there is a far greater release of the basal viable seeds from the capsules totalling 20.8 per cent in comparison with only 12.5 per cent of sterile seeds. Therefore, if the seed released up till 10 days after picking was sown, only 8.4 seeds in every 100 would germinate; but if the seed bed between 10 and 17 days was sown a germination of 14.4 seeds in every 100 would be obtained. Under the conditions of this experiment, seed shed was virtually complete after 17 days.

The location of the fertile seeds at the base of each cell therefore results in a greater shed of sterile seed in the early stages followed by the higher proportion of fertile seed towards the end of the seed shedding operation. There are several important practical consequences to this anatomical feature, namely:—

(*a*) When collecting seed from felled trees, care should be taken to ensure that the capsules are not discarded until the vital basal seeds are extracted.

(*b*) Under natural conditions of seedfall, a *prolonged* dry period is necessary to cause the shedding of all the overlying sterile seed before the fertile seed is shed. The latter is therefore unlikely to be shed by a short freak dry period which could be followed by adverse conditions for the germinates. Under the category of short dry periods could be included bushfires which cause a very rapid seedfall. There is a much greater probability of the initial shedding of sterile seeds falling on to lethally hot surfaces such as smouldering ash beds and logs than the later release of the fertile seeds. Even a matter of a few hours could be very significant in this case.

D. NUMBER OF SEEDS PER POUND

From seed counts and germination tests carried out on various seed batches the total number of seeds/lb. was found to vary from 370,000 to 490,000. The more practical figure of the number of viable seeds/lb. is less variable.

Seed Source	Year	No. of Viable Seeds/lb.
Coffs Harbour	1953	38,556
Urunga	1955	36,741 + 3,016
Pine Creek, Cpt. 3	1956	37,300
Pine Creek	1957	36,288

The mean number of viable seeds/lb. is therefore approximately 37,000. The ratio of the number of viable to total seeds in the above tests was calculated at .09462. This figure is useful for obtaining a rapid approximate estimate of the number of viable seeds in a mixture.

E. TIME OF NATURAL SEEDFALL

The complete lack of reliable information on the time of the year when Blackbutt seed is normally shed is amazing. Local North Coast bushmen are of the opinion that seedshed occurs in January-February. However, in Figure 1, the seed collection data from the eleven seed trays on the experimental area is shown graphically from September, 1956, to July, 1959. The peaks in seedfall appear most erratic at first sight and vary from year to year. However, the only consistent feature in all years is the very low seedfall in December, January and February, which is in direct contrast to local opinion. As seedshed can only occur when the capsules are drying out thus causing the valves to open, it was logical to compare the rainfall pattern for this period with the seedfall. Obviously no seed will be shed from capsules kept damp by frequent rain. Figure 1 shows the excellent correlation between rainfall and seedfall.

It is now possible to deduce the rainfall pattern from the seedfall and vice versa. At the commencement of the experiment in September, 1956, there were several recently rung Blackbutt trees nearby which accounted for the heavy seedfall recorded in September-November, 1956. The seedfall peak in late November can be correlated with the very dry conditions in that month. As good rain fell throughout December, 1956, and continued through until late March, 1957, the seedfall was very low. However, the build-up of mature unopened capsules on the trees during the wet season resulted in a very heavy seedfall during the dry period in April, 1957, which persisted through to August. The exceptionally dry month of May caused a minor seedfall peak. Over six inches of rain at the end of August brought the seedfall down to the previous wet season level. Dry conditions then prevailed till December, 1957, and caused the seedfall graph to climb steadily. The first seven months of 1958 were very wet except for two weeks of dry weather in early April. The seedfall graph faithfully maintains a low figure with a small increase in early April, 1958. July was dry whilst early August was wet followed by another dry period. As the seed trays were not emptied from June to September, only a uniformly minor peak in seedfall is shown. In actual fact there would probably have been two more pronounced peaks separated by a trough. The end of 1958 was remarkable for the early summer rains which extended right through to July, 1959. The only dry period exceeding one week in duration occurred in early March, 1959. The seedfall pattern was at a constant low figure except for this peak in March.

The time of Blackbutt seedfall is therefore most flexible and could occur in any month of the year provided dry conditions are experienced for at least two weeks in summer and somewhat longer in winter. Time of flowering is of little importance, as Blackbutt seed may remain on the trees for at least twelve months after maturity if the weather conditions so dictate. Similarly, the number of flowerings in a particular year will not have much bearing on the time of seedfall, although it will influence the quantity of seed available. An inspection of felled Blackbutt trees in all months of the year has shown that there is generally some viable seed being carried at all times. Sometimes even two years crops may be present.

As these records were kept for a period of nearly three years, the effect of rainfall had become quite obvious; but had the experiment been terminated after only one year, erroneous conclusions could have been drawn if an attempt had been made to correlate seedfall with flowering time.

F. DIRECTION OF SEED THROW

The eleven seed trays used in this experiment have collected seed from a total of ten Blackbutt seed trees. It is possible to determine the directions of the winds causing each seedfall by relating the quantity of seed collected in each tray to the adjacent trees. These winds fall into two sectors of the compass, namely north-east to south-east in the late spring and summer, and south-south-west to west in the autumn, winter and spring. These winds are the prevailing ones in those seasons. The easterly breezes are not dry; but replace the drier light westerlies later in the day during hot weather. They thus cause the seed to be shaken out of the capsules opened by the drier westerly winds.

G. DISTANCE OF SEED THROW

The seed trays were not located so as to give a direct measure of the distance of seed throw from the seed trees; but it was found that trays located more than the height of a particular seed tree away from its butt on the leeward side contained very few or no seeds. The average annual seedfall as measured by tray 11 situated 1.2 chains from the nearest seed tree to the south-west was only 5 seeds, all of which were sterile. Tray 9 at 0.5 chains from a similar seed tree in the same direction yielded 8 sterile seeds per year. Tray 4 which was placed practically underneath the crown averaged 52 seeds per annum.

RAINFALL AND BLACKBUTT SEED FALL,
COMPARTMENT 3, PINE CREEK S.F.

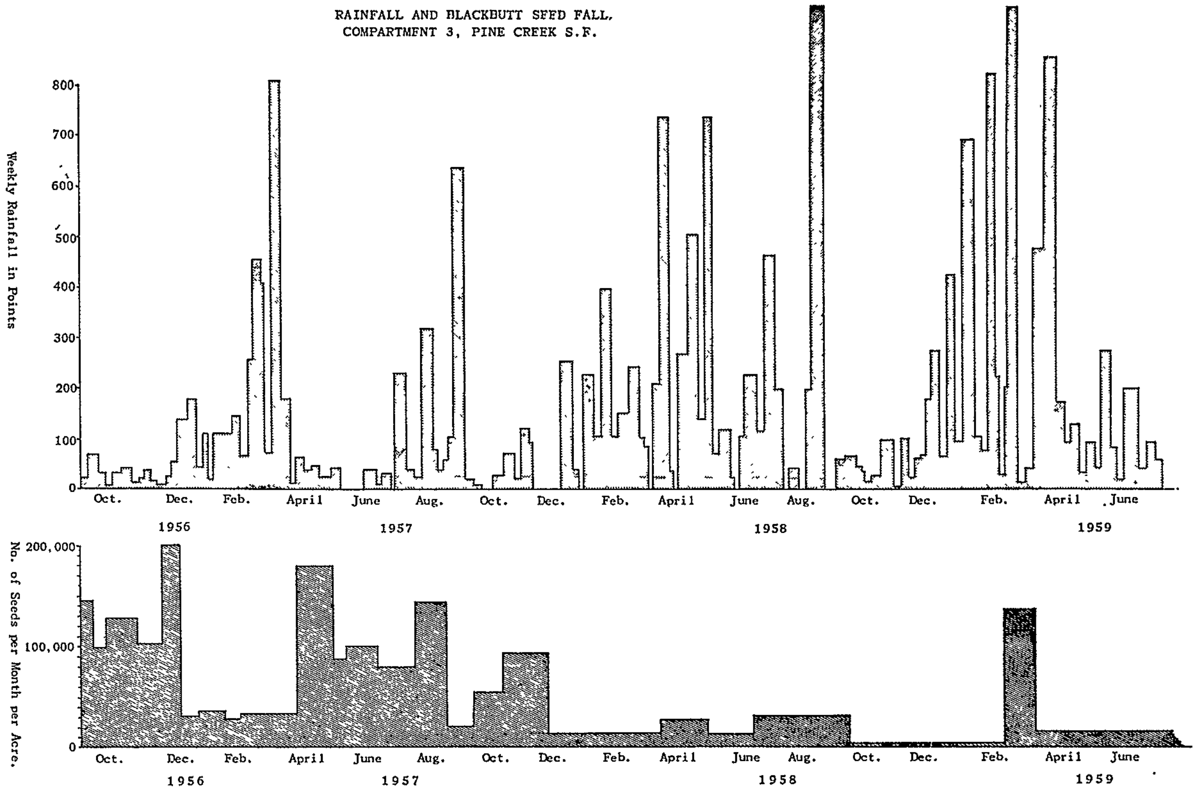


FIGURE 1.

The mean quantity of seed shed per tray per annum was 12.9 which is equivalent to 560,000 seeds per acre or 1.4 lbs. per acre. However, the mean number of viable seeds per tray per annum was only 0.7 or 30,000 seeds per acre.

Although sterile seeds were shed up to 120 ft. from the seed trees, no fertile seed was collected over the three-year period at a distance greater than 25 feet from the butt. This shorter distance of dispersal of the fertile seed is due to its equal size and shape but greater weight than that of the sterile seed. Fertile seed was found to weigh .00142 gms. whilst the hollow sterile seed weighed only .00097 gms.

In order to determine the maximum distance of effective fertile seed throw as evidenced by the germination of seedlings in the field, the 135 milliacre plots were grouped according to their proximity to the crown edge of the nearest seed tree.

TABLE 3

Distance of Observed Regeneration from the Crown Edge of Blackbutt Seed Trees

	Distance of Plots from the Crown Edge					
	Beneath Crown	0-7 ft.	8-13 ft.	14-20 ft.	21-26 ft.	27 ft.
No. of Stocked Plots ..	18	11	9	3	1	0
No. of Unstocked Plots	12	15	11	4	9	42
Percentage Stocked ..	60	42	45	43	10	0

Table 3 shows that *seed trees are only effective within a 20-ft. radius of their crown when approximately* 120 *ft. high and* 24 *inches d.b.h.* This is a somewhat greater area than that derived from a study of the seed trays, possibly due to natural seed distributing agencies such as transportation by heavy rain. No precise data can be quoted for the washing of Blackbutt seed by rain, although sowing experiments with Flooded Gum on Lower Bucca State Forest on fairly steep slopes and subjected to a cyclonic downpour of over 8 inches of rain in one day caused maximum transportation of this very fine seed of only 10 feet. As the average radius of the crowns of these Blackbutt seed trees was found to be 13 feet, the effective regeneration was found up to 33 feet from their butts (i.e., 20 ft. from the crown edge). Therefore, transportation of the seed on the ground for an additional 8 feet has occurred. This would appear to be in keeping with the figure of 10 feet for Flooded Gum. The distance of dispersal will, however, vary with the slope.

This observed maximum fertile seed throw of 20 feet from the parent tree crown poses the question as to how can these openings of up to 300 feet wide possibly be regenerated successfully by this means? The explanation of this anomaly, as adequate regeneration *is* obtained, will be discussed in the next section.

2. Regeneration of Blackbutt

A. GERMINATION

Although all details were recorded for species other than Blackbutt, their germination follows closely that of this major species and will not be discussed further in this paper. Because most of the remaining seed trees are Blackbutt, this species forms the bulk of the seedling regeneration.

As the time of seedfall has already been discussed the next important stage to be investigated is the time of germination of this seed in the forest.

(1) Time of Germination

Assuming that there is no carry-over of dormant seed in the ground, it is logical to expect seedshed at a particular time to germinate on the first occasion that conditions are favourable. Squash tests at the conclusion of germination counts have shown a negligible number of sound ungerminated seeds, which substantiate the above assumption. Figure 2 shows the dates of germination over the three-year period of the experiment for all species on unprepared seed beds. By comparing these germination dates with the seedfall and rainfall pattern of Figure 1, it is possible to study the weather conditions responsible for germination. The first germination occurred in early December, 1956, immediately after a very heavy seedfall and during the first good rains since the start of the experiment. Another burst of germination occurred in early April, 1957, following a short dry period which produced a heavy seedfall. Showery weather continued through April. Although good seedfalls occurred from April to August, 1957, with good falls of rain in July and August, no germination took place until late August. This delayed germination in winter is possibly due to the inhibiting effect of low temperatures. Three samples of Blackbutt seed were placed in this area on 15th May and did not germinate until 14th August, 1957. As in 1956, germination occurred in mid-November, 1957. after heavy seedfalls followed by good rain earlier in the month. Seedlings again appeared in early April, 1958, where a short dry period of two weeks' duration brought down a small quantity of seed.

A prolonged wet spell was experienced until August and then a wetter than average spring. The summer rains were earlier than usual in 1958, commencing in November and extending right through to the end of the experiment in July, 1959. The only significant seedfall in the last twenty months resulted from a period of two weeks' dry weather in March, 1959, which was responsible for a heavy germination later in the month. There have therefore been six germination periods in the three years under study, viz.:—

March-April	1957	Heavy germination
	1958	Heavy germination
	1959	Heavy germination
August-November	1957	Light germination
November-December	1956	Moderate germination
	1957	Light germination

HEIGHT OF SEEDLINGS IN THE BLACKBUTT FOREST TYPE - PINE CREEK S.F.
NOT BURNT OR MECHANICALLY CLEARED.

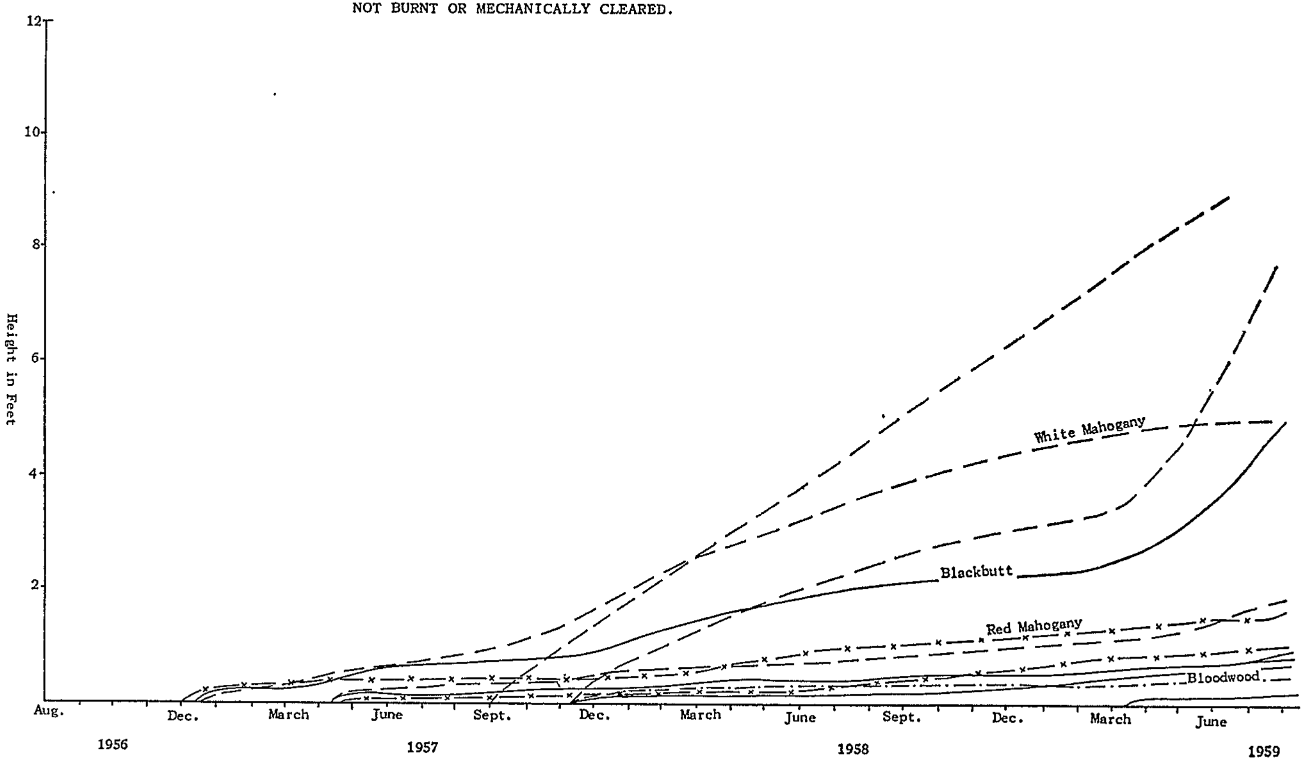


FIGURE 2

The autumn period is obviously the main regeneration time when the wet season is nearing an end. At this time of the year short but hot dry periods of up to two weeks are generally encountered between rainy spells. The accumulation of seed on the trees throughout the wet summer months ensures a heavy and rapid seedfall, whilst the often humid conditions enable the seedlings to make rapid early growth.

Next in importance is the early summer germinations coinciding with the onset of the wet season. The regular showers required to sustain the young seedlings are not as reliable in December as in April and therefore heavier losses can often be expected. The early spring germinates will almost certainly be decimated by the hot, dry months to follow, and will, therefore, contribute very few trees to the future stand. *Effective Blackbutt germination occurs at the beginning and end of the summer wet season.*

(2) Effect of Types of Seed-bed Preparation upon Germination

On 15th May, 1957, three approximately equal batches of Blackbutt seed were sown in opening No. 7 which was burnt two months previously. One batch was sown in a charcoal heap, another in an ash bed resulting from a very intense burn and the third upon bare unburnt ground. As already mentioned, germination did not commence until three months later, on 14th August, 1957. The progressive stocking from that date is given in Table 4.

Table 4

Stocking of Blackbutt Seedlings upon Various Seed Beds

Date	Seed Bed Type		
	Charcoal	Ash	Unburnt
14th August, 1957	13	7	27
17th September, 1957	17	1	46
15th October, 1957	14	1	25
22nd November, 1957	8	1	12
15th December, 1957	7	1	8
24th December, 1957	7	1	8
14th March, 1958	3	1	5
12th June, 1958	3	1	3
28th July, 1959	1	1	2

Early losses were heaviest on the ash bed, which dried out very quickly and remained loose and powdery for at least twelve months. However, the one seedling which survived the first month grew rapidly in the enriched soil and survived the crucial dry spring. A higher germination was obtained on the charcoal bed with proportionally less losses than on the ash. The sowing on the unburnt ground produced the greatest stocking of all seed beds, but a contributing factor could have been the light raking given the top soil after sowing. Losses on the unburnt ground were very heavy throughout the spring and summer, due to the poor growth. Therefore, although charcoal and unburnt ground give high germination figures the survival is better on the charcoal. (Six per cent. survival for charcoal and 4 per cent. for unburnt ground two years after sowing.)

A comparison of these seed-bed types can be made on a larger scale using the germination data from the burnt and mechanically cleared openings. From Table 5 it is clear that burning is preferable to clearing in practically all months, in so far as net stocking is concerned. For the months of October, February and April, where it is possible to compare the treatments, the means from Table 5 show that there were 702 germinates/acre after burning over the duration of the experiment. Clearing only produced 409 germinates/acre, of which 27.1 per cent. had died by July, 1959. On the burnt openings, the percentage mortality was 38.5 per cent. The net stockings for the burnt and cleared openings were therefore 432 and 298 seedlings/acre, respectively.

TABLE 5

Number of Blackbutt Seedlings/Acre for Various Seed-bed Treatments as at July, 1959

Seed-bed Treatment	Total No. Germinated	Total Deaths	Total Stocking	Net Established Stocking
Burnt—				
July, 1956	1640	1047	593	259
October, 1956	1750	750	1000	125
December, 1956 ..	666	415	251	83
January-Febuary, 1957	120	..	120	60
March, 1957	236	59	177	59
Cleared—				
October, 1956	999	333	666	222
February, 1957 ..	249	..	249	166
April, 1957	62	..	62	..
Untreated	120	60	60	..

At first sight, therefore, it appears that burning is superior to mechanical clearing. However, the measure of comparison should be based upon only those seedlings which two and a half years after treatment can be regarded as "established". This state is reached when the seedlings are free of domination by the undergrowth and generally corresponds to a height of approximately 2 feet. Table 5 shows these figures, which reverse the net stockings trend in favour of burning to an established stocking preference with clearing. The established stockings per acre for the three comparable periods give a mean of 81 for the burnt openings and 129 for the cleared plots. The *result* of burning is to provide a seed bed most suitable for initial germination; but also most favourable to subsequent losses. The untreated opening produced no established seedlings after three years. A study of the *cause* of the behaviour of the seedlings on burnt ground is most necessary, as there are many possible explanations of this phenomenon. Fire is known to make many growth elements available to the germinating seedlings; but also more liable to be leached out of the top soil. The loose friable seed bed created by burning also favours germination, but the rapidity with which this loose surface layer dries out could kill many seedlings. Under the effect of heavy rain, cleared ground is quickly compacted on the surface, whereas burnt ground remains loose for many months. The relative importance of these various possible causes is not known. But its effect is clear: *mechanical clearing is superior to burning, which in turn is superior to no treatment in producing established seedlings.*

(3) Optimum Time of Seed-bed Preparation

By reference to Appendices 1 and 2, the most favourabe months of seed-bed preparation by burning or clearing for effective regeneration are July to October. Treatments in December to April produced few established seedlings (Table 5). The graph for the opening burnt in October shows a heavy germination in the autumn of 1958, which is only seen in one other treatment, namely, cleared in October. It is difficult to see why an apparent correlation in time of seed-bed preparation should only become noticeable when eighteen months had elapsed since the time of treatment. However, the proximity of seed trees and their shading effect on the seedlings provides a probable solution. When the percentage of sampled milliacre plots located within 20 feet of the crowns of seed trees (i.e., within the zone of effective seedfall) are compared for each opening, the following figures are obtained:—

Regeneration Treatment	Plots Within Effective Seed Throw and Shade Cast
	Per cent.
July Burn	54
October Burn	80
December Burn	50
February Burn	59
March-April Burn	29
Control	50
October Cleared	100
February Cleared	67
March-April Cleared	50

As the October burning and clearing treatments have the highest percentage of milliacre plots within effective seed throw and shade cast, their better germination is not surprising.

It might be argued, however, that as both treatments in October have been sampled by very favourably located plots (located at random), this would unfairly favour the October time of treatment in comparison with other months. While this is probably so, all treatments show the main germination periods to be at the beginning and end of the wet season; and that young seedlings have a higher survival rate with the early summer germination. Hence seed-bed preparation is recommended in the spring.

Table 5 indicates that burning in March is better than clearing in April, both as regards the total number of seedlings produced and also the number of effective seedlings. As the clearing in April was carried out with hand tools due to the lack of a tractor, some indication of the relative effectiveness of these two clearing methods can be obtained by a comparison of the germination obtained in 1958 and 1959, when the time of treatment would be of little importance. Appendix 2 shows that the autumn germinations in 1958 and 1959 were approximately 200 seedlings/acre for each year on the tractor cleared area, but only 50 seedlings/acre in each year for the manually treated openings. Therefore, hand clearing may not have been as effective as tractor clearing in April, which could, perhaps, have been as good as burning. However, the established stocking of 59 seedlings/acre due to burning cannot be regarded as adequate.

Therefore, seed-bed preparation should be carried out in the spring.

B. SUBSEQUENT GROWTH OF SEEDLINGS

As the germination and establishment of the seedlings was discussed in the previous section, it now remains to study their growth rates under various field conditions.

(1) Effect of Seed-bed Preparation on Growth

Figures 3 and 4 show the height growth of the Blackbutt seedlings after seed-bed treatment in various months. All curves show a slow increase in height up to about 2 feet, corresponding to the height of establishment with a subsequent more rapid growth. Table 6 gives the number of months required for seedlings to reach mean heights of 2 and 4 feet when burnt or cleared at various times. There is a lapse of up to nine months between the dates of treating and germination. The time taken by these germinates to attain a height of 2 feet varies from nineteen months with a summer germination to twenty-three months with a winter germination. However, winter germination is not common; and the rate of nineteen months can be regarded as normal. It is interesting to note that the control plot took twenty months, indicating that burning or clearing does not cause an appreciable acceleration of early growth.

Table 6

Number of Months Required for Blackbutt Seedlings to Reach 2 *or* 4 *Feet in Height*

Treatment	Time From Treatment to 2 ft. Ht.	Time From Germination to 2 ft. Ht.	Time From Germination to 4 ft. Ht.
July Burn	23	23	32
October Burn	21	19	24
December Burn	23	19	29
February Burn	20	18	27
March Burn	32*	23*	..
Control	25	20	31
October Cleared	22	20	31
February Cleared	26	17	26*
April Cleared	No Germn.	No Germn.	No. Germn.

* Denotes extrapolation from the graph.

EFFECT OF MECHANICALLY CLEARING AT VARIOUS MONTHS UPON THE HEIGHT GROWTH OF THE RESULTANT BLACKBUTT REGENERATION - PINE CREEK S.F.

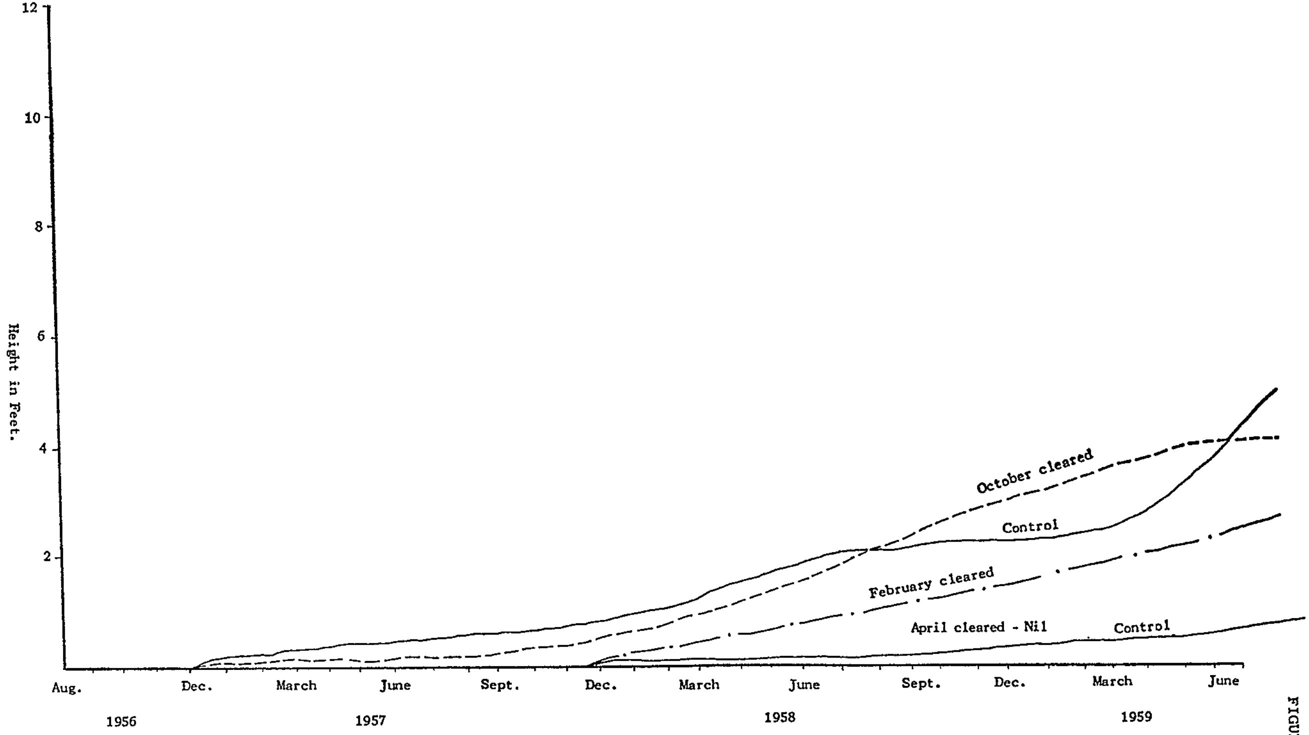
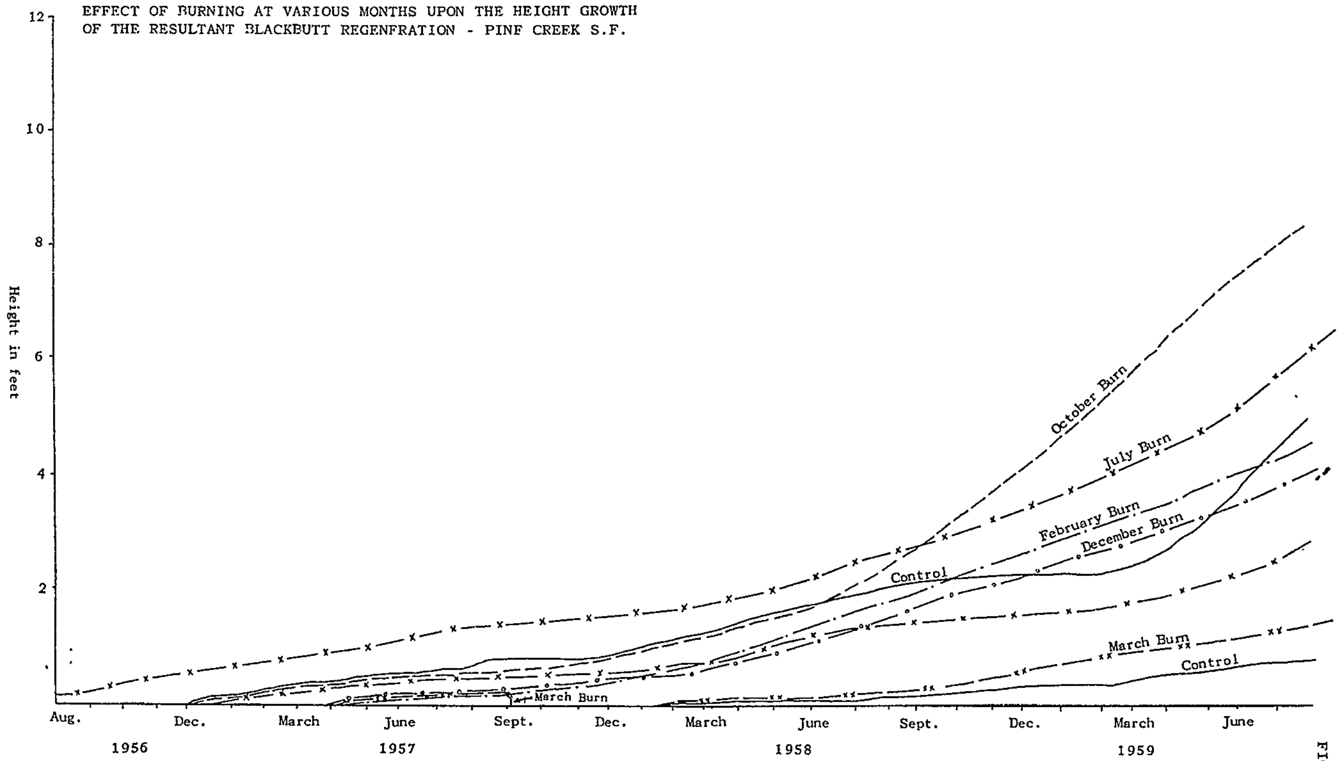


FIGURE 3.



EFFECT OF BURNING AT VARIOUS MONTHS UPON THE HEIGHT GROWTH
OF THE RESULTANT BLACKBUTT REGENERATION - PINE CREEK S.F.
Height in feet
12
10
8
6
4
2
Aug.
Dec.
March
June
Sept.
Dec.
March
June
Sept.
Dec.
March
June
1956
1957
1958
1959
October Burn
July Burn
February Burn
December Burn
Control
March Burn
Control
March Burn

FIGURE 4

The second height increment of 2 feet was produced in from nine to eleven months on all plots except the October burn. On the latter, the single seedling present took only five months. *Therefore, for all the successful spring and summer burnings or clearings there is a negligible difference in height growth up to 4 feet,* which requires an average of twenty-nine months from germination.

The above conclusions are based on many observations over areas sufficiently large to yield many degrees of burning or clearing. The results are, therefore, what can be expected from large-scale routine treatments; and should not be interpreted as indicating that a particular seedling on a fiercely-burnt spot will not grow faster than one on an unburnt grass-covered site. Reference to Fig 5 shows the growth response recorded by three groups of seedlings on unburnt and two types of burnt ground. In this specific case the seedlings reached the establishment height of 2 feet in only twelve months after germination on both the ash bed and the charcoal bed. This early rapid growth is maintained on the burnt sites with a height C.A.I. of 5 feet on the ash bed and 3 feet on the charcoal bed for the twelve months following the time of establishment. By contrast, the unburnt seed bed produced seedlings only 1 foot high after two years. These sites were carefully picked extremes and serve to delimit the range of sites and growth rates possible. However, as already stated, a mean time of nineteen months to reach 2 feet in height applies over the experimental area generally.

(2) Effect of Ground Cover on Growth

The ground cover present over the nine experimental openings at the conclusion of the experiment could be grouped into five categories according to the frequency and height dominance of the component species. The 135 milliacre plots were classified into these categories. Table 7 lists the percentages of milliacre plots in each ground cover type for each treatment according to the light received.

The ground cover types were:—

(1) Bladey Grass (*Imperata cylindrica*).

(2) Kangaroo Grass (*Themeda australis*).

(3) Bracken Fern (*Pteridium aquilinum*).

(4) Soft Ferns (*Culcita dubia* and *Dennstaedtia davallioides*).

(5) Litter.

The light types were found to fall naturally into three groups according to the readings of a Weston Exposure meter:—

(1) Full sun: Reading of 200+ at midday.

(2) Part shade: Reading of 20-200 at midday.

(3) Full shade: reading of 20— at midday.

The distribution of ground cover is for the grasses to prefer the more sunny situations and the ferns the shadier sites. Of the two species of grasses, Kangaroo Grass is more tolerant of shade than Bladey Grass; and dominates cleared ground more readily than the latter, which is spread more rapidly by fire. Fire generally favours fern growth, also; but clearing, as the farmer well knows, will control it. The ground cover is therefore greatly influenced by the method of seed-bed preparation. Burning will stimulate the coarser Bladey Grass and dense shade-casting ferns, while clearing will favour the finer-leaved Kangaroo Grass. Therefore, the Blackbutt seedlings will suffer less competition from the ground cover resulting from clearing than from that due to burning. The nature of the ground cover may therefore be the deciding factor accounting for the greater established stockings of seedlings on the cleared rather than the burnt openings.

FIGURE 5

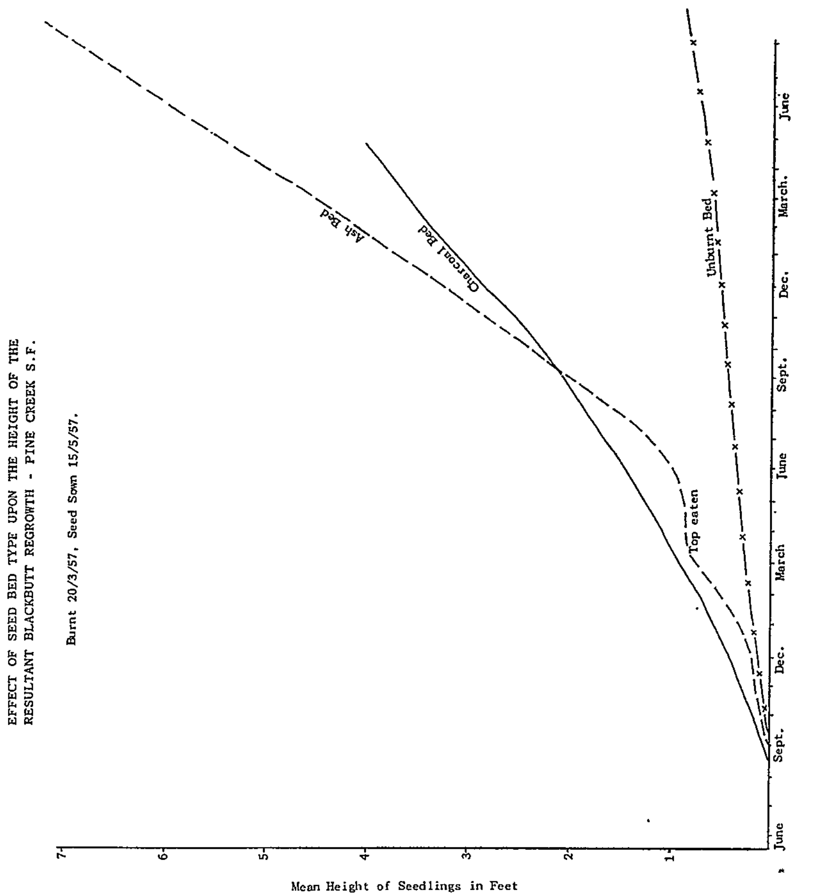


Table 8 correlates light intensity, seed-bed preparation and ground cover with the observed percentage milliacre plots stocked and mean height. Each milliacre plot was regarded as stocked if it contained at least one seedling. The consistent superiority of the Kangaroo Grass ground cover over all other types is evident for all light intensities and types of seed-bed preparation. Not only are the Kangaroo Grass sites better stocked (45 per cent. as against 30 per cent. for all Bladey Grass milliacre plots), but the mean height is also greater (5.38 feet as against 3.94 feet). The ferny sites have produced the greatest height growth with 7.08 feet for Bracken Fern and 10.0 feet for the Soft Ferns. However, they are seriously understocked due to the severe fern competition. The sites still devoid of ground cover show the best stocking distribution with 60 per cent. of all plots stocked. However, this stocking consists of recent seedlings with a mean height of .08 feet, which will probably die in the next dry period. There are, therefore, only two suitable types of ground cover for Blackbutt, of which Kangaroo Grass is preferable to Bladey Grass.

TABLE 7

Percentage of Distribution of Ground Cover under Different Light Conditions after Various Seed-bed Treatments

Light Intensity	Seed Bed Treatment	Type of Ground Cover				
		Bladey Grass	Kangaroo Grass	Bracken Fern	Soft Ferns	Litter
Full Sun	Burnt ..	31	46	16	5	2
	Cleared ..	29	71	..	..	..
	Control ..	40	47	13	..	..
	Mean ..	33	49	13	3	2
Part Shade	Burnt ..	50	20	30	..	..
	Cleared ..	50	12	..	..	38
	Control ..	24	24	4	40	4
	Mean ..	36	21	10	23	10
Full Shade	Burnt ..	28	36	14	22	..
	Cleared ..	..	100	..	..	..
	Control ..	20	40	20	20	..
	Mean ..	24	40	16	20	..

(3) EFFECT OF SHADE ON GROWTH

Table 8 shows that a milliacre stocking of 35 per cent. with a mean height of 3.93 feet was obtained for all plots in full sun; but that under full shade this increased to 40 per cent. and 8.00 feet mean height. Those sites carrying a Bladey Grass ground cover showed the greatest increase in stocking and height with reduced light, mainly due to the unfavourable growing conditions for this grass at low light intensity. This fact is important in practice, as where a Blackbutt forest with a dense Bladey Grass cover is to be regenerated best results will be obtained by retaining as much crown cover as possible until the seedlings are established. This could be achieved by delaying the removal of unwanted trees for two to three years after logging and seed-bed preparation. Where burning was carried out the percentage of stocked plots on Bladey Grass sites increased from 25 per cent. in full sun to 40 per cent. in partial shade and 50 per cent. in full shade. Where mechanical clearing was tried, it is not possible to trace the effect of lower light values on stocking as there is only a single plot in full shade. However, the untreated areas also show the same trend as the burnt openings.

(4) Relative Growth Rates of all Associated Species

The growth rates of all species of seedlings are shown in Figure 2. Because of the preference for Blackbutt seed trees, the other species are not very common. Only those plots where the seed bed was not prepared were examined as they represent the largest number of any treatment. The growth from each germination period is shown by a separate curve. White Mahogany (*E. carnea*) is the fastest-growing species in the early stages at least, followed by Blackbutt. Tallowwood is a little slower, whilst Red Mahogany and the Red Bloodwood are particularly slow. The mean height of these species at twelve months after germination in December was:—

	feet
White Mahogany	1.7
Blackbutt	1.0
Tallowwood	0.9
Red Mahogany	0.5
Red Bloodwood	0.4

Over the duration of this experiment only the White Mahogany and Blackbutt seedlings became established and showed a more rapid growth rate during the second wet summer and autumn. The White Mahogany was capable of sustaining growth through the second winter and spring, whereas the Blackbutt growth was greatly reduced. The position at the termination of the experiment when these first seedlings were thirty-one months old was that although the White Mahogany showed a mean height of 9.1 feet in comparison with 4.1 feet by Blackbutt, the latter was steadily overtaking the White Mahogany. It therefore appears that the only rival species to Blackbutt as seedlings is White Mahogany.

C. ADVANCED GROWTH

As discussed under the section on the effect of seed-bed preparation on growth, it was found that twenty-nine months after germination the mean height of Blackbutt seedlings was 4 feet on all types of seed-bed treatment. However, the experimental area at that time was quite impressive, with many Blackbutt saplings over 10 feet high. Advanced growth could account for this apparent anomaly. Table 9 lists the stockings per acre of each treatment for Blackbutt and all species, both as seedlings and advanced growth.

The term "advanced growth" refers to all trees less than 10 feet in height at the commencement of the experiment which have not resulted from seedlings germinating during the experimental period. It therefore includes coppice from damaged saplings, lignotuberous shoots and seedlings produced by treatment prior to the experiment. It can be seen that over 25 per cent. of all Blackbutt stems present are advanced growth and that there is an average of 122 such stems per acre on all openings, regardless of treatment. The mean height of this Blackbutt advanced growth at July, 1959, on the cleared openings was 13.5 feet and on the burnt areas 16.6 feet. On the untreated opening it was 15 feet. As the mean height of the seedlings at this time is only 4 feet, it is clear that they pass unnoticed beside the taller advanced growth.

TABLE 8

Effect of Light, Seed-bed Preparation and Ground Cover upon the Percentage of milliacre Plots Stocked and Mean Height of Blackbutt Seedlings—July, 1959

Seed-bed Treatment	Full Sun					Part Shade					Full Shade					All Light Intensities					Mean
	BG	KG	BF	SF	L	BG	KG	BF	SF	L	BG	KG	BF	SF	L	BG	KG	BF	SF	L	
Burnt—																					
Per cent. Stocked ..	25	33	0	50	0	40	50	33	..	..	50	60	50	0	..	33	40	18	20	0	32
Mean Ht.	2.3	3·5	..	8·0	..	0·2	8·0	0·5	..	..	5·7	3·2	20·0	..	..	1·63	3·57	10·35	8·0	..	3·39
Cleared—																					
Per cent. Stocked ..	50	60	..	..	..	25	100	..	..	67	..	100	..	..	..	33	71	..	..	67	56
Mean Ht.	1·2	2·2	..	..	..	9·0	1·5	..	..	0·1	..	0·7	..	..	..	5·12	1·65	..	..	0·1	1·8
Control—																					
Per cent. Stocked ..	33	71	0	..	..	0	0	100	0	100	50	25	0	50	..	23	37	20	9	100	26
Mean Ht.	5·1	6·5	..	..	..	..	..	0·7	..	0·1	10·3	16·0	..	12·0	..	8·23	10·48	0·75	12·0	0·08	9·06
Mean of Treatments—																					
Per cent. Stocked ..	30	48	0	50	0	21	25	50	0	75	50	50	25	20	..	30	45	19	12	60	33
Mean Ht.	3·1	4.3	..	8.0	..	1·4	3·7	0·6	..	0·1	8·5	9·8	20·0	12·0	..	3·94	5·38	7·08	10·0	0·08	4·43
Mean for Light Intensity—																					
Per cent. Stocked ..	..	..	35	..	..	..	..	26	..	..	..	..	40	..	..	..	..	33	..	..	..
Mean Ht.	..	..	3·93	..	..	..	..	1·33	..	..	..	..	8·0	..	..	..	..	4·43	..	..	..

BG—Beadey Grass BF—Bracken Fern L—Litter KG—Kangaroo Grass SF—Soft Fern

TABLE 9

Stocking Per Acre of Blackbutt and all Species as at July, 1959

Seed-bed Treatment	Blackbutt		All Species		
	Seedlings	Advanced Growth	Seedlings	Advanced Growth	Total
Burnt—					
July, 1956	593	222	593	741	1334
October 1956 ..	1000	..	1250	500	1750
December 1956 ..	250	..	250	583	833
Jan.-Feb., 1957 ..	120	177	472	1236	1708
March, 1957.. ..	177	177	706	883	1589
Cleared—					
October, 1956 ..	666	111	1444	444	1888
February, 1957 ..	249	167	500	1000	1500
April, 1957	62	62	682	682	1364
Control	60	177	1294	1294	2588
Mean	353	122	799	818	1617

Reference to the "total" column of Table 9 shows that all areas are fully stocked with from 833 to 2,588 stems/acre. However, of a mean total stocking of 1,617 stems/acre there are 1,142 stems of species other than Blackbutt. Blackbutt seedlings represent only 22 per cent. of the stand as a whole, but this has been raised to 57 per cent. by burning in October, or 35 per cent. by clearing in that month.

No importance should be attached to the absence of Blackbutt advanced growth in the openings burnt in October and December, 1956, as immediately after the December burn there were 160 such stems/acre. These were reburnt and killed by the adjoining March burn.

Many foresters are not concerned at the high percentage of other species present in these regeneration areas, as they claim that the faster growth of the Blackbutt will ensure its survival. The growth rates of all species present as advanced growth is shown in Figure 6. The relative growth rates are similar to those found for the respective seedlings in that Blackbutt and White Mahogany are faster than Bloodwood, Tallowwood, Blue Gum, Brush Box, and Turpentine. These latter species are certainly no threat to the Blackbutt. Red Mahogany shows slow growth when under 2 feet in height; but a sudden increase when over 7 feet which may or may not be typical. White Mahogany remains as a serious rival to Blackbutt, even at 12 feet in height. The proportion of White Mahogany in the regeneration is therefore important, particularly if present as advanced growth.

CONCLUSIONS

For the experimental area on Pine Creek State Forest the following conclusions have been drawn:—

(1) Blackbutt normally flowers each year in September-November.

(2) Seedfall may occur in any month following at least two dry weeks in summer or a somewhat longer period in Winter.

(3) The mean number of viable seeds per capsule is 2.61 and are located at the base of the cells. As a result, the first seed shed is mostly infertile. Seed released from capsules within ten days of picking contains 41.7 per cent. less viable seeds than that released between ten and seventeen days. This protects the viable seed against rapid release under extereme conditions of dryness, such as fire.

(4) There are from 370,000 to 490,000 Blackbutt seeds per pound, containing approximately 37,000 viable seeds.

(5) The winds generally causing natural seedfall are N.E.-S.E. in the late spring and summer; and S.S.W.-W. in the autumn, winter and spring.

(6) Maximum effective Blackbutt seed throw is 20 feet to leeward of the crown from trees 120 feet high.

(7) Effective Blackbutt germination occurs naturally at the beginning and end of the summer wet season.

(8) Seed-bed preparation by burning produces more germinates than either mechanical clearing or no treatment; but mechanical clearing results in more established seedlings than the other two methods.

(9) The spring is the optimum time for seed-bed preparation.

(10) There is no significant difference in height growth resulting from successful spring or summer burning or mechanical clearing. A mean height of 4 feet is reached at age twenty-nine months.

(11) Blackbutt seedlings prefer a ground cover of Kangaroo Grass to that of Bladey Grass, which in turn is superior to ferns. Kangaroo Grass is favoured by absence of fire and the use of mechanical clearing.

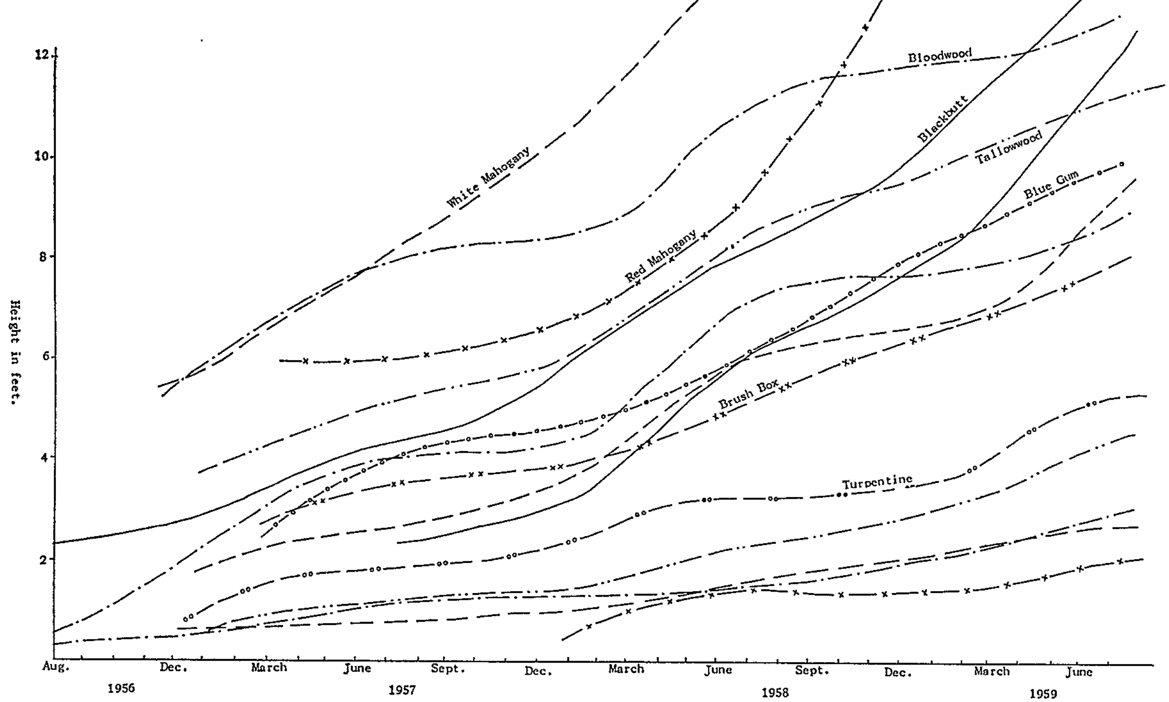
(12) Shade is desirable in that it inhibits the growth of Bladey Grass and promotes rapid height growth of Blackbutt seedlings with a minimum of losses.

(13) Only White Mahogany seedlings have a faster growth rate than Blackbutt. Height growth of advanced growth of these two species is similar.

(14) On this experimental area, advanced Blackbutt growth represents 25 per cent. of all Blackbutt stems present when no seed-bed preparation is carried out. Their average height at age 29 months is 15 feet, in comparison with 4 feet for the seedlings. Seedling growth is therefore not obvious for at least three years. Blackbutt seedlings normally represent only 22 per cent. of the stand, but can be increased to 57 per cent. or 35 per cent. by burning or clearing in October, respectively.

FIGURE 6

HEIGHT OF ADVANCED GROWTH IN THE BLACKBUTT FOREST TYPE - PINE CREEK S.F.



APPLICATION OF FINDINGS

As Blackbutt seedlings require seed trees with crowns not more than 40 feet apart for adequate seedfall, mechanical clearing in spring for maximum established stocking and adequate shade for low mortality and rapid height growth, the following silvicultural treatment is worthy of trial:—

(1) Area to be tree-marked to produce gaps not exceeding 1.5 chains between the butts of the remaining Blackbutt seed trees.

(2) Logging to be carried out in any month.

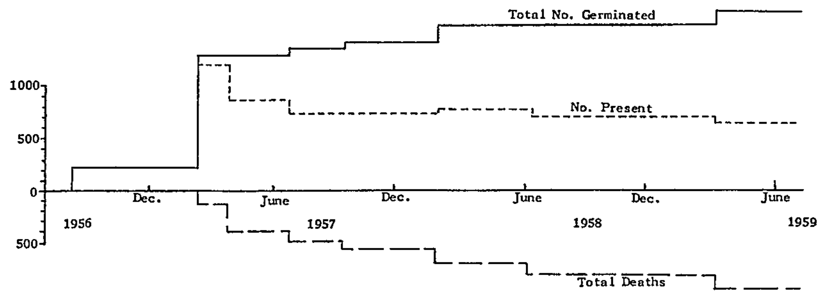
(3) Seed bed to be prepared in September-November, preferably by mechanical clearing or else by brushing and burning.

(4) T.S.I. approximately two years later when all useless trees should be felled.

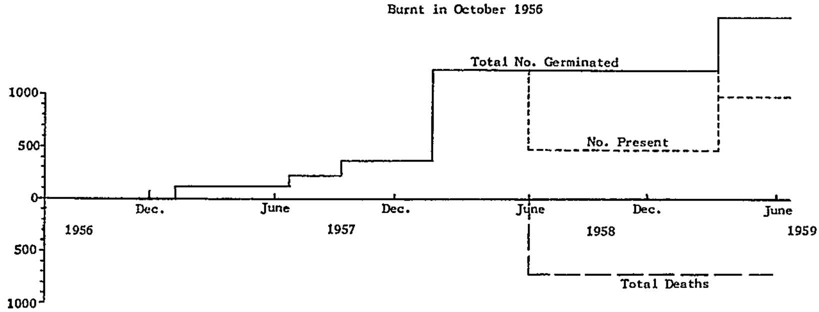
However, although this treatment could apply to Blackbutt forests from Macksville to Woolgoolga, it may not be applicable to the Blackbutt forests on the somewhat dryer areas further south, where the summer cyclonic rains are less marked.

No. OF BLACKBUTT STEMS/ACRE FOR VARIOUS TIMES OF BURNING.

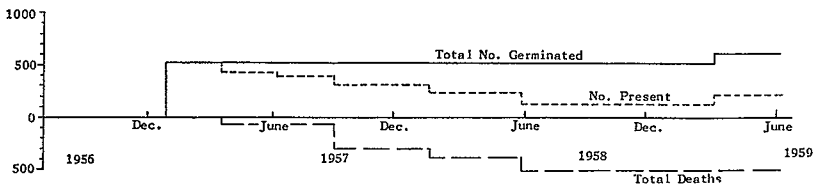
Burnt in July 1956



Burnt in October 1956



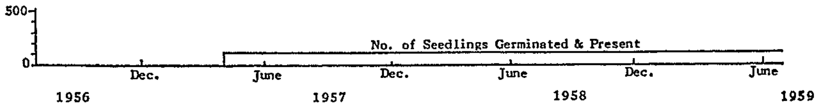
Burnt in December 1956



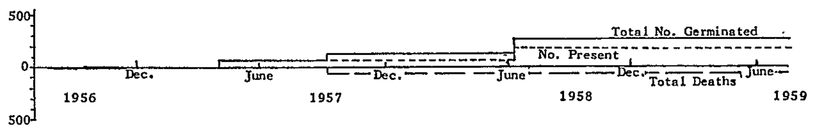
APPENDIX I

No. OF BLACKBUTT STEMS/ACRE FOR VARIOUS TREATMENTS.

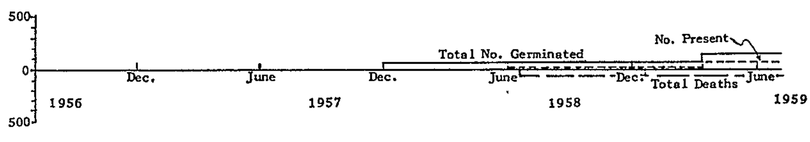
Burnt in January - February 1957



Burnt in March 1957

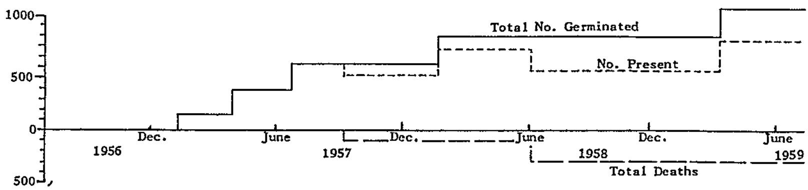


Control - Untreated

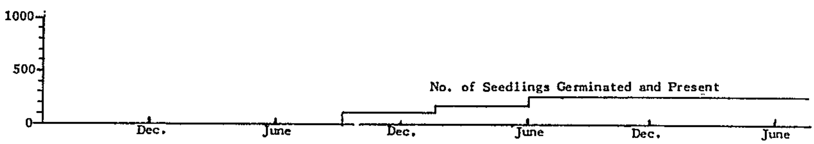


No. OF BLACKBUTT SEEDLINGS PER ACRE FOR VAROIUS TIMES OF MECHANICALLY CLEARING.

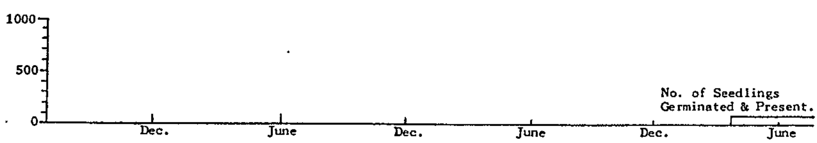
Mechanically Cleared in October 1956



Mechanically Cleared in February 1957



Mechanically Cleared in April 1957



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