Fire Management Branch
Department of Conservation & Environment

SOME EFFECTS OF LOW INTENSITY BURNING ON RADIATA PINE

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SUMMARY

The results from two studies into the effects of low intensity burning in *Pinus radiata* plantations are reported.

In the first study, trees subjected to fires with maximum intensities less than 200 kW/m, in stands aged 11 and 16 years, did not show any significant difference in diameter or height increment for the 18 month period after burning. Mortality on burnt plots was not significantly different to mortality on unburnt plots.

Stem damage to burnt trees was minor although more prevalent in the 11 year old stand where the trees had thinner bark.

Eighteen months after burning, the mean fine fuel (< 6 mm diameter) quantities were 96% and 86% of those measured on unburnt plots for the 11 and 16 year old stands respectively. In a 26 year old stand, the fine fuel quantity on burnt plots was 46% of the quantity on unburnt plots, 21 months after burning.

In the second study, the growth of 15 year old trees was monitored after prescribed burning designed to reduce fuel quantities resulting from first thinning of the stand. Maximum fire intensities were less than 200 kW/m.

Twelve months after burning there was no significant difference in diameter increment between burnt and unburnt trees. The fine fuel quantity added to the forest floor over the 12 month period was significantly less on burnt plots than unburnt plots.

INTRODUCTION

There has been little work carried out into the effects of burning on growth and wood quality in *Pinus radiata* plantations. The work reported by Nicholls and Cheney (1974) and Jones (1974) are among the few studies available. Nicholls and Cheney reported that experimental fires ranging in intensity from 100 kW/m to 3400 kW/m, resulted in a loss of only 0.4% of the total possible sawn volume and had no effect on growth rate in a 28 year old stand. Jones reported that a 13 year old stand could withstand a fire intensity of 150 kW/m with minimal loss in diameter growth and little butt damage. However, an intensity of 750 kW/m caused severe crown damage and resulted in a complete loss of increment for 15 months.

This report discusses the results of two separate studies established to examine some effects of low intensity fire on young stands of *P. radiata*. The first study was established following experimental burning in 11, 16 and 26 year old pruned stands in north-east Victoria (Thomson, 1978). The second study was established following experimental burning in a 15 year old pruned stand, that had been first thinned approximately 14 months before burning, in plantations in south-west Victoria (Billing, 1979).

STUDY 1 - NORTH-EAST VICTORIA

During September and October 1976, experimental low intensity burning was conducted in *P. radiata* plantations in the Myrtleford district. Fires were lit on plots of 15 m x 15 m and 30 m x 30 m in stands then 11, 16 and 26 years old.

Following burning, stand growth was monitored in the 11 and 16 year old stands. Data were collected on stem damage caused by fire, and fuel accumulations since burning. Some data on stem damage and fuel accumulations have also been obtained from the 26 year old stand. On each of the burnt plots studied, the maximum recorded fire intensity was less than 200 kW/m.

1 EFFECT ON STAND GROWTH

Method

In the 11 and 16 year old stands, trees on a number of burnt plots were measured to monitor stand growth. Plots were established in adjacent unburnt areas to serve as a control. Each tree was numbered, the position of breast height permanently marked and the diameter (DBHOB) recorded. Stand top height, for each age, was calculated by averaging the heights of the 20 trees of largest diameter measured on the burnt plots, and the 10 trees of largest diameter measured on the unburnt control plots.

Plots were remeasured in May 1978, approximately 18 months after establishment. A tally was made of trees that had died since burning. Volumes were calculated using the formula

$$V = 0.0000271\ D^2H - 0.0001325H^2 + 0.0405$$

Where V = total volume (m^3)
D = tree diameter (cm)
H = stand height (m)

Results and Discussion

The results in Table 1 show no significant difference between the mean height and diameter increment on burnt and unburnt plots at either age. Volume increment on the 16 year old burnt plots was significantly lower than on unburnt plots, although there was no significant difference at the younger age. Analysis of the diameters recorded at the time of plot establishment showed that the burnt trees in the 16 year old stand had a significantly lower diameter then than the unburnt trees (see Table 2). This could be one reason for the difference recorded in volume increment.

Table 1 - Increment

Stand Age	Stand Height (m)		Mean Tree Diameter (cm)		Total Volume (m^3)	
	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt
11	1.6	1.9	0.8	0.8	0.019	0.024
16	0.9	1.5	0.7	0.8	0.026*	0.036

*Significant at 95% level

Table 2 - Mean Tree Diameter at Plot Establishment

Stand Age	Mean Diameter (cm)	
	Burnt	Unburnt
11	15.4	15.7
16	18.4*	20.2

*Significant at 95% level

A count of the trees that died over the 18 month period is shown in Table 3. There was no significant difference in mortality between burnt and unburnt plots. Mortality is also shown as a percentage of the total number of trees included on the plots.

Table 3 - Mortality

Stand Age	Burnt	Unburnt
11	11 of 523 (2.1%)	3 of 115 (2.6%)
16	4 of 452 (0.9%)	0 of 90

Each dead tree was inspected for the presence of sirex wood wasp *(Sirex noctilio)*. Evidence of infestation was found only on unburnt plots in the 11 year old stand.

Conclusion

Fires with a maximum intensity less than 200 kW/m have not affected diameter or height increment in 11 and 16 year old stands in the 18 month period since burning. A significant difference in volume increment was recorded for the 16 year old stand. However, there is evidence that this difference may have been caused by factors other than fire.

2 STEM DAMAGE ASSOCIATED WITH BURNING

Method

At establishment of the trial, data were collected on the extent of stem blackening associated with burning. The maximum height of blackening, and the number of faces blackened (of a possible four) were recorded. The variation in fire intensity on each plot was very high and the average intensity of the fire would be of limited value in defining the likely damage to each tree. The height of stem blackening has been used as an indicator of the fire intensity experienced by each tree.

To allow an assessment of stem damage, a total of 31 trees was selected for felling in 16 year old stands. The trees felled showed a range of stem blackening but were generally more severely burnt than the remaining trees. This is emphasised by a comparison of the mean height of stem blackening which was 0.4 m for all trees measured in the 11 and 16 year old stands, and 1.2 m and 0.9 m respectively for the trees felled.

After felling, sections were cut from each tree at 10 cm and 20 cm above ground level, and then at 20 cm intervals to the height of stem blackening. Each section was examined for areas of cambium that had been killed by fire.

To identify cambial damage not readily visible, each section was oven dried at 100°C for 24 hours. This procedure was based on evidence of damage in a stand being clear felled at the time of the study, that had been burnt by wildfire 20 years previously. Damage to trees from this stand was not always apparent until the sawn timber was being dried, when splitting often occurred around the growth ring of the year in which the stand was burnt. Oven drying of sections taken from trees in this stand proved the technique to satisfactorily identify damaged sections.

Following drying the overbark diameter of each section taken 10 cm above ground was measured. Bark thickness was calculated by subtracting the mean of two underbark diameters (taken at right angles to each other) from the overbark diameter. The minimum bark thickness was calculated from the mean depth of bark taken at five points around the section within the bark fissures. The extent of damage within this first section was defined by the arc length of obviously dead cambium or the length of split developed during drying. This length has been expressed as a percentage of the underbark circumference of the section.

The extent of damage along the length of the tree was defined by two measures. The first, maximum damage height, was the greatest height above ground at which any damage was found. Often this was associated with a small isolated section of damaged cambium unlikely to have any significant effect on wood quality. The second measure, damage height, was defined as the height above ground at which cambial damage was found which was continuous over some length of stem. Normally the damage began at the base, but occasionally there were large isolated areas of damage some distance up the stem.

Results and Discussion

The data collected from trees felled in the 11 and 16 year old stands are shown in Table 4.

Table 4

Stand Age (yrs)	Tree No	DBHOB (cm)	Blackening Height (m)	Blackening No of faces	Damage Height (cm)	Max. Damage Height (cm)	Circum. Damaged (%)	Minimum Bark Thickness (mm)	Bark Thickness (mm)
11	1	12.5	0.4	4	30	30	20	1.0	2
	2	17.2	0.4	2	-	-	-	3.0	17
	3	21.6	1.4	4	-	-	-	2.0	18
	4	16.2	1.8	3	30	120	3	2.0	13
	5	18.8	1.7	4	-	-	-	3.0	28
	6	14.0	1.8	4	15	15	4	2.5	7
	7	15.3	1.0	2	-	-	-	3.0	12
	8	14.3	1.2	4	-	-	-	NA	12
	9	8.0	0.8	3	70	70	6	2.0	9
	10	14.4	1.6	4	15	60	18	2.0	18
	11	18.9	1.2	4	-	-	-	2.5	14
	12	16.6	0.7	3	30	30	5	1.5	17
	13	9.1	0.6	4	110	110	8	1.0	7
	14	15.4	1.3	3	70	40	40	2.0	12
	15	20.6	2.2	4	30	205	25	2.0	15
Mean		15.5	1.2		27	47		2.1	13.4
16	16	25.9	0.4	4	-	-	-	3.5	26
	17	9.5	0.1	1	-	-	-	2.0	16
	18	17.0	1.0	4	30	30	18	2.0	15
	19	16.3	1.2	2	-	60	-	2.0	21
	20	23.5	0.6	2	-	-	-	3.0	22
	21	21.0	1.0	3	-	60	-	2.0	20
	22	14.8	0.5	2	-	-	-	NA	17
	23	19.6	0.3	4	-	-	-	NA	19
	24	22.9	0.5	2	-	-	-	2.5	16
	25	17.2	1.0	2	-	-	-	2.0	21
	26	22.2	1.2	2	-	-	-	3.0	15
	27	24.7	0.7	2	-	-	-	2.5	16
	28	12.4	0.5	2	70	70	9	1.5	12
	29	20.6	3.0	3	-	275	-	2.0	20
	30	18.7	1.8	4	-	-	-	NA	17
	31	16.7	1.0	2	-	-	-	2.5	17
Mean		18.9	0.9		6	31		2.35	18.1

Bark thickness plays an important role in determining the level of protection of living plant tissue from otherwise lethal temperatures (McArthur 1968). The relationship between minimum bark thickness and tree diameter (from data in Table 4) is shown in Figure 1. Older stands will generally have thicker bark and this is reflected by a comparison of damage found in the felled trees. The younger trees were found to be much more extensively damaged than those from the 16 year old stand.

On average, the felled trees were more severely burnt than the remaining trees. This is shown by comparing the mean blackening height of trees in Table 4 with the means for all trees of 0.48 m in the 11 year old stand and 0.22 m in the 16 year old stand. Therefore the damage to the remaining burnt trees is likely to be less extensive than the damage recorded in Table 4. However using data from Table 4 it is possible to obtain an estimate of volume loss due to fire damage. The following procedure was used to estimate volume loss in the 11 year old stand.

1 The mean tree was assumed to have a diameter of 15.5 cm, a mean damage height of 27 cm, and a total height of 19.0 m (equivalent to stand height 18 months after burning).

2 Assuming the tree to taper uniformly an estimate was made of

(i) tree diameter at 5 cm (stump height) and 27 cm (damage height) above ground.

(ii) height to an overbark diameter of 10 cm (merchantable limit).

3 The volumes (excluding stump) to the merchantable height and damage height were calculated. Assuming the volume to damage height was a complete loss, the loss to merchantable volume is approximately 4.5%.

FIGURE 1 Minimum Bark Thickness vs DBHOB

$Y = 0{\cdot}88 + 0{\cdot}08x \qquad R^2 = 0{\cdot}35$

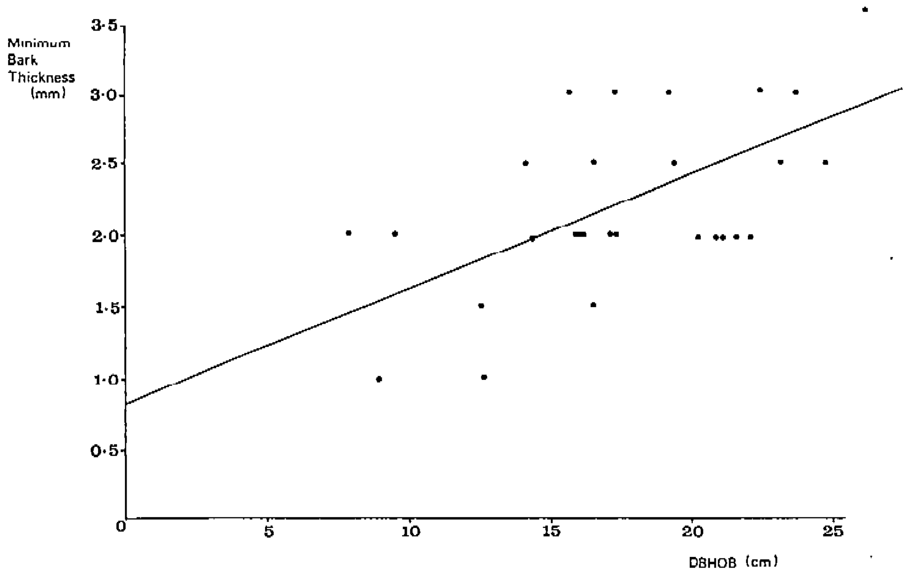


FIGURE 2 Damage Height vs Minimum Bark Thickness

$Y = 0{\cdot}67 - 1{\cdot}48 \, \mathrm{Log}\, x \qquad R^2 = 0{\cdot}45$

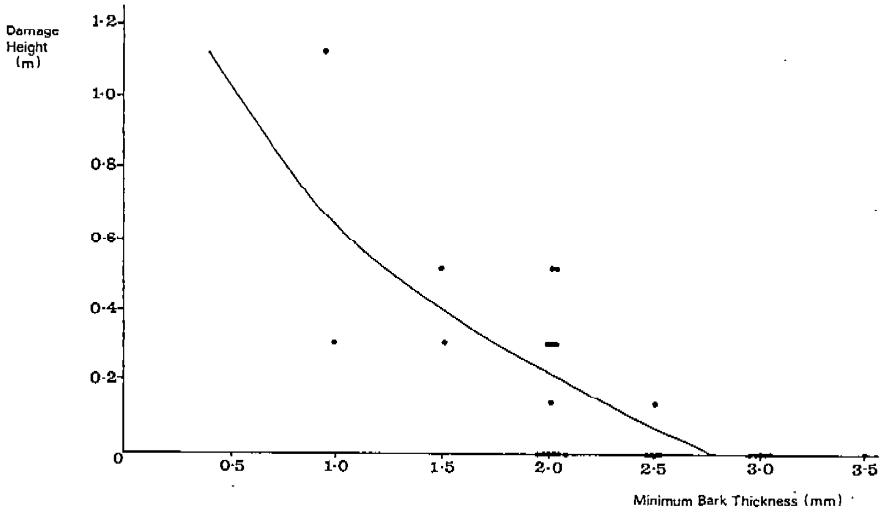
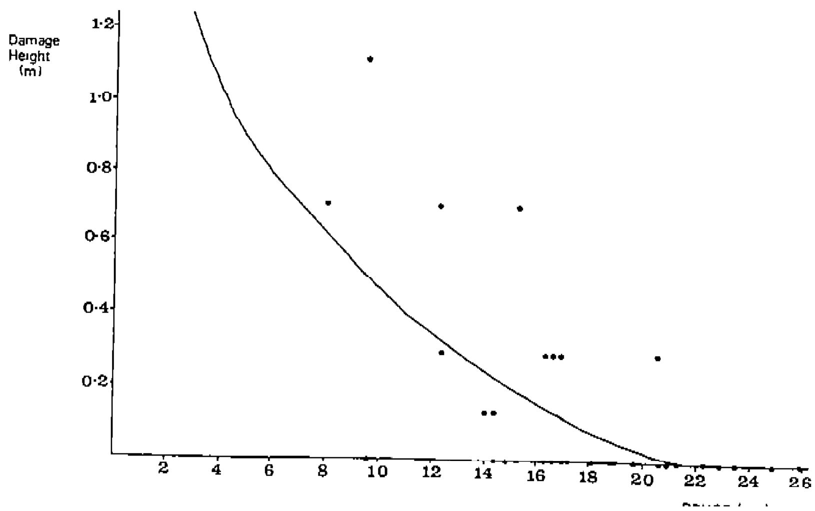


FIGURE 3 Damage Height vs DBHOB

$Y = 1{\cdot}92 - 1{\cdot}44 \, \mathrm{Log}\, x \qquad R^2 = 0{\cdot}40$



The actual loss of merchantable volume on 11 year old burnt plots is probably less than 4.5% for the reason outlined above. It is also likely that sections too severely damaged to be suitable for sawlogs would still be suitable for pulpwood. This would further reduce the loss of merchantable volume.

The extent of damage in the 16 year old trees was minor in comparison with the damage found in the younger trees. Apart from increased bark thickness providing more protection, these trees were not as severely burnt. This is most likely to be an indication of the different arrangements of fuel existing in each area. At the time of burning, fuels in the 11 year old stand were more elevated due to recent pruning in the stand, and greater flame heights were encountered.

The importance of bark thickness is emphasised by the data plotted in Figure 2. In trees with a minimum bark thickness greater than 2.5 mm, no damage was found. Slight damage was found in one tree (number 6) with a minimum bark thickness greater than 2.0 mm.

Figure 3 shows the relationship between damage height and DBHOB. Above a diameter of 17 cm, damage was found in only one tree (number 15) which had been severely burnt. Figure 1 indicates that at a diameter of 17 cm, minimum bark thickness is approaching 2.5 mm. The data therefore indicates that trees greater than 17 cm diameter are more likely to remain undamaged by the peaks of fire intensity associated with burning of the type described by Thomson (1978).

Fielding (1967) showed bark thickness in *P radiata* to be related to site quality. The stands studied were SQII and stands on poorer sites may not have the same level of resistance to fire exhibited by the trees in this study.

Conclusion

Damage to the trees selected for felling was not severe and it is likely that damage to the remaining trees in both stands would be less severe.

The concept of fuel reduction burning in plantations involves burning on relatively narrow strips rather than attempting to cover broad areas. Any damage caused by low intensity burning should be considered in relation to the increased potential for loss in a wildfire that is associated with a lack of such protective burning.

3 LOGGING SCARS

The stand which was 26 years old when burnt had also been thinned twice, which had caused some butt scarring. Thomson (1977) noted that, "if there is an occlusion of new wood associated with the scar the heat generated by the burning sheath of resin is sufficient to kill the cambium associated with the occlusion and so extend the logging damage."

To assess this extension of damage nine trees were examined. The bark around the scar was removed so that the dead cambium was visible. The area of the scar and of the killed occlusion were measured.

Results and Discussion

Extension of the scars by the fires was variable although scars on the uphill side of the tree were more likely to have to occluded tissue killed than those which faced across the slope. Beyond this there was no discernible pattern to the increase in scar area.

TABLE 5: Effect of Fire on Logging Scars

Diameter	Scar Area (cm^2)	Area Increase (cm^2)	(%)	Height to top of scar	Direction of scar
28.6	400	100	25	50	Up slope
33.8	2177	0	0	87	Across slope
33.8	1143	0	0	62	" "
35.1	490	289	59	41	Up slope
35.1	136	128	94	102	" "
35.2	105	217	207	33	Across slope
30.5	162	60	37	60	Up slope
36.7	123	84	68	45	Across slope
39.7	100	0	0	80	Up slope

The average scar area prior to the burn was 540 cm^2 and afterwards was 640 cm^2 which is an increase in area of 20%.

Stone and Coulter (1975) found that thinning in a 14 year old plantation caused butt damage to between 1.3% and 4.1% of trees, depending on the thinning method used. The effects of burning on these few butt scars would be unlikely to significantly affect the merchantable volume of timber obtained from the plantation.

4 FUEL ACCUMULATIONS AFTER FIRE

Method

Weights of fine fuel (< 6 mm diameter and excluding the duff layer) were sampled in each stand by collection of fuels on plots 0.33 m^2, and weighing after oven drying at 105°C. One hundred and forty four samples were taken at random from the burnt plots in each of the 11 and 16 year old stands, with 32 samples from each of the unburnt plots. In the 26 year old stand thinning subsequent to burning made sampling difficult. Nevertheless, 32 samples were taken from burnt plots and 81 samples from unburnt plots approximately 21 months after burning (cf. 18 months in the other stands).

Results and Discussion

In the 11 year old stand there was no significant difference in fuel weight between burnt and unburnt plots after 18 months. There was a small but significant difference in the 16 year old stand. In the 26 year old stand the fuel weight on burnt plots was less than half that on unburnt plots.

Table 6 - Fine Fuel Weights (t/ha)

Stand Age	Unburnt	Burnt	% of unburnt
11	4.84	4.64	96
16	5.13	4.24*	83
26	4.11	1.90*	46

* Significant at 95% level.

Although it cannot be shown in statistical form, burning has caused a change in fuel distribution in the two younger stands. The elevated fine fuel resulting from low pruning has been removed, leaving a more compact fuel arrangement.

The needle fall, which was calculated as the difference between the current fine fuel weight and the fine fuel weight measured immediately after burning, was found to be 2.40 t/ha/annum and 2.15 t/ha/annum for the 11 and 16 year old stands respectively. These figures approximate the value of 2.6 t/ha/annum recorded by Williams (1977) for a 12 year old stand in the Myrtleford area. The rate of fuel accumulation following burning does not appear to have increased.

Conclusion

In the 11 and 16 year old stands, 18 months after burning, fuel quantities were close to those for unburnt plots, although a change in distribution was evident. Weight is not the only fuel property affecting fire behaviour, and the change in fuel distribution has reduced the level of hazard existing within each stand.

STUDY 2 - SOUTH-WEST VICTORIA

INTRODUCTION

Experimental low intensity burning of thinning slash in a 15 year old *P. radiata* plantation in the Kentbruck Block, Heywood District has been described by Billing (1979). Maximum recorded fire intensities were less than 200 kW/m.

In October 1977, at the completion of the burning program, a trial was established to examine the effect of burning on diameter increment. Some data were also collected on stem damage and the rate of fuel accumulation following burning. The results from remeasurement in October 1978 are given in this report.

METHOD

The diameters (DBHOB) of 397 trees within the burnt plots were measured. In adjacent unburnt plots the diameters of 64 trees were measured as a control.

The severity of burning on each tree was assessed. Trees were classed as severely burnt if stem blackening covered more than one-eighth of the circumference of the tree at the base and if there was evidence of resin exudation, charring of basal bark to a depth greater than 5 mm, or cambial death.

The accumulation of fine fuel (< 6 mm diameter) over the 12 month period was measured on 40 plots of 0.36 m^2, established in both burnt and unburnt plots.

RESULTS AND DISCUSSION

Thirty-eight trees (9.6% of the total number measured on burnt plots) were assessed as being severely burnt.

Details of the diameter growth over the one year period are shown in Table 1.

Table 1 - Mean Diameter Increment

Tree Class	No of Trees	Mean Diam. Inc. (cm)	't'
Unburnt	64	0.98	1.3
Burnt	397	1.07	1.4
			1.5
Burnt (severe)	38	0.90	1.9
Burnt (other)	359	1.08	

The values of '*t*'shown in Table 1 indicate there is no significant difference (95% confidence level) between the mean diameter increments shown for each class. Even those trees classified as severely burnt showed no significant increment loss compared with the trees from unburnt plots.

The extent of damage caused by burning was not evaluated by felling and sectioning individual trees. However, several trees salvaged from the burnt area after windthrow, that would have been classified as severely burnt, showed little evidence of damage. The stumps had no significant areas of cambial death although there were several small 1-2 cm sections of dead cambium under the bark fissures.

The results from sampling of fine fuel accumulations are shown in Table 2.

Table 2 - Fine Fuel Accumulation (Oct '77 to Oct '78).

	No of Plots	Mean Wt (t/ha O.D.Wt)
Unburnt	40	2.5
Burnt	40	2.1*

*Significantly different at 95% confidence level.

The results in Table 2 indicate that burning has not increased the fuel accumulation rate and this is probably a reflection of the low fire intensity and low level of crown scorch associated with burning. There is no apparent reason why the accumulation rate on burnt plots should be significantly less than on unburnt plots. Future measurements may help further explain the process of fuel accumulation after burning.

CONCLUSION

One year after establishment the study has shown that low intensity burning, used to remove thinning slash in a 15 year old *P. radiata* plantation, has not caused a significant reduction in diameter increment.

An intensive examination of stem damage was not made. However it does appear that although damage associated with low intensity burning will occur it will generally be minor.

Fuel accumulation rates on burnt plots were significantly less than on unburnt plots.

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The study in north-east Victoria was established by Mr D Williams.

REFERENCES

Billing P R 1979 — Using fire to reduce fuel accumulations after first thinning in radiata pine plantations.
For. Comm. Vic. - Fire Research Branch Report No 4. Unpublished.

Fielding J M 1967 — Some characteristics of the crown and stem of *Pinus radiata*.
Bulletin No 43 Forestry and Timber Bureau.

Jones P 1974 — *Pinus radiata* scorch trials.
In Fire Research News.
Research Working Group No 6.
Bushfire Research No 5.

McArthur A G 1968 — Fire resistance of eucalypts
Proc. Ecol. Soc. of Aust. Vol 3. 83-90.

Nicholls J W P and N P Cheney 1974 — Effect of experimental and wildfires in pine plantations on wood characteristics.
Aust. For. 36 (3) 164-177.

Stone R J C and I M Coulter 1975 — Mechanical damage to retained *Pinus radiata* in a first thinning operation.
Forestry Technical Papers No 23 11-23.

Thomson D S 1977 — Low intensity prescribed burning in three *Pinus radiata* stand types at Myrtleford
Thesis submitted for Dip. For. Vic.

Thomson D S 1978 — Low intensity prescribed burning in three *Pinus radiata* stand types.
For. Com. Vic. - Fire Research Branch Report No 2.
Unpublished.

Williams D F 1977 — Effects of thinning on forest fuels in young *Pinus radiata* plantations.
Thesis - Master. For. Science. Melbourne University