Fire Management Branch
Department of Conservation & Environment

USING FIRE TO REDUCE FUEL ACCUMULATIONS AFTER FIRST THINNING IN RADIATA PINE PLANTATIONS

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FOREWORD

This report is the second to deal with aspects of fuel reduction burning in *Pinus radiata* plantations. The first (Fire Research Branch Report No 2 - D S Thomson, 1978) was concerned with low intensity burning in 11, 16 and 26 year old stands in the Myrtleford district.

The information contained in this report provides the basis for fuel reduction burning operations in thinned stands that have been low pruned.

The operational and planning principles to be observed in this type of prescribed burning operation are no different to those applying to other burning operations. Good perimeter control, together with careful and continuous monitoring of environmental conditions and fire behaviour, is necessary for a successful operation.

It should be appreciated that the work discussed in this report is confined to one region, and there may be factors not accounted for that will affect burning operations in other regions. Initially, small scale operational trials are suggested so that staff can gain experience with the techniques and fire behaviour necessary for more extensive operations to be successful.

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SUMMARY

Low intensity fire behaviour was studied in a 15 year old stand of *Pinus radiata*, 14 months after first thinning.

The results indicate that low intensity fire can be used to reduce fuel quantities resulting from first thinning operations. Burning guidelines are presented, together with results from a limited investigation of fire behaviour in the crowns of unpruned trees of the same age.

Initial assessment has indicated that damage caused by burning is slight. Current longer term studies are designed to establish whether any damage and growth loss which may occur, is significant.

INTRODUCTION

The fuel properties of young unthinned stands of *Pinus radiata*, and the changes in fuel properties resulting from first thinning, have been described by Williams (1977). Thinning creates a hazardous fuel distribution on the ground, and a reduction of the hazard should be an objective of plantation management.

The study described below was largely conducted in a low-pruned stand of *P. radiata*. The objective was not to provide a complete understanding of fire behaviour in thinned stands, but rather to indicate those conditions under which low intensity fire can be used to reduce fuel accumulations following thinning.

Some work investigated fire behaviour in the crowns of unpruned trees, and this is also discussed.

STUDY AREA

The study was conducted in Compartment 008, Kentbruck Block, Heywood Forest District. Slopes throughout the area are less than 5°.

1 STAND DESCRIPTION

The stand was 15 years old and classified Site Quality II, with a mean stand height of 24 m and a mean diameter (DBHOB) of 23.6 cm.

In 1976, the stand was first thinned to 700 stems per hectare, by removing every sixth row and thinning between outrows.

2 FUEL DESCRIPTION

In September 1977 the thinning slash was approximately 14 months old. Height of the slash was variable to one metre, with most branches and needle fuels elevated 0.5 m above ground.

The fuel quantity added to the forest floor after thinning was not measured. However, Williams (1977) found that in 12 year old stands, thinning to a similar stocking added approximately 8 t/ha of fine fuel. Fine fuels are defined as all fuel particles less than 6 mm diameter, and in this study include needles and duff as well as smaller branchwood material.

Fine fuel quantities prior to thinning ranged from 10-20 t/ha and averaged 15 t/ha. This included the whole of the fuel profile to mineral earth. The transition from surface needle litter to the decomposing duff layer was poorly defined and no attempt was made to differentiate between the two when sampling fuel weights.

The stereoscopic photograph pair shown in Figure 1 illustrates the fuel arrangement existing within the study area.

METHOD

1 PRUNED STANDS

Data were collected from 32 experimental fires within stands that had been thinned and low pruned.

Twenty six fires were ignited at a single point on 10 m x 10 m plots. An additional six plots of 20 m x 10 m were used to study the behaviour of fires lit along a line and allowed to backburn across each plot.

Figure 1

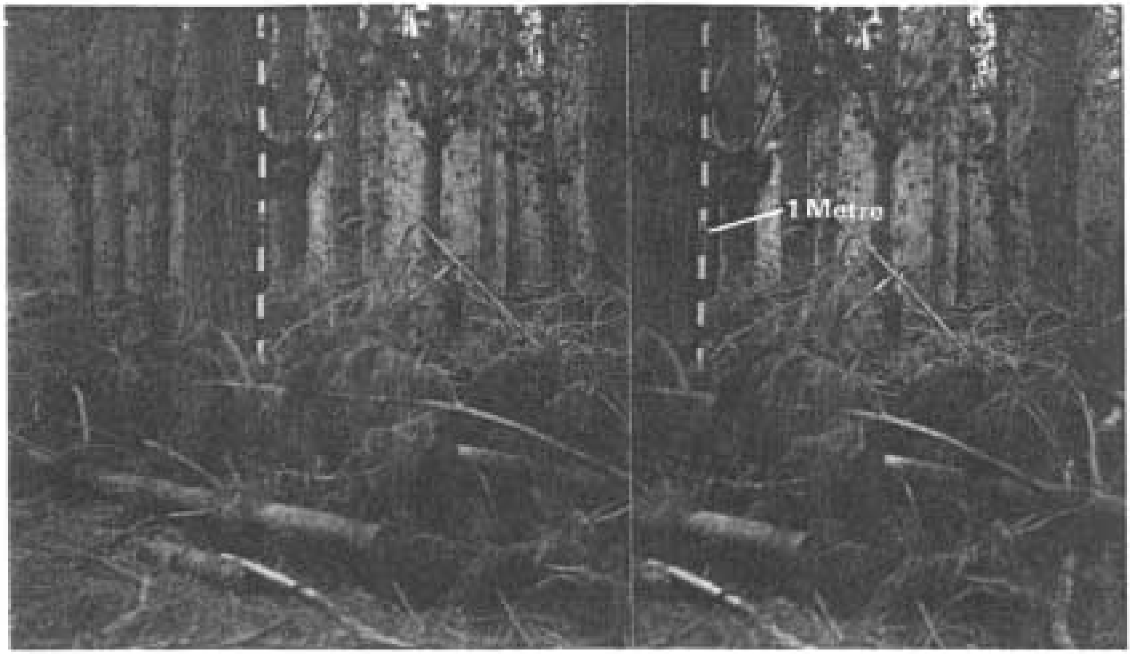

Figure 2

Figure 3

Data collected were

(a) Fuel moisture content

Fuel moisture content was recorded frequently during each burning period. Samples were taken from both the surface needle layer and the elevated needle fuels immediately prior to the ignition of each experimental fire. The moisture content of the duff layer was determined several times throughout each day during which burning was conducted. All moisture contents have been expressed as a percentage of oven dry weight.

(b) Weather

A thermohygrograph provided a continuous record of temperature and relative humidity within the stand. Measurements from two standard 200 mm rain gauges were used to estimate rainfall reaching the forest floor. The temperature and rainfall data were used to calculate the Drought Index (Byram and Keetch, 1968).

An aspirated psychrometer was used during each experimental fire for more accurate measurement of temperature and relative humidity. A sensitive cup anemometer measured wind speed at two metres above ground within the stand.

(c) Fire behaviour

The behaviour of each experimental fire was recorded in a manner similar to that described by Thomson (1978). Markers placed around the perimeter at given intervals were used to map the progress of each fire and allow the spread rate to be calculated. Estimates were made of flame height and flame depth.

2 UNPRUNED STANDS

Fire behaviour was studied within the lower crowns of 30 unpruned trees after ignition of dead needle litter in the crown base of each tree.

Data collected included

(a) Fuel properties

The density of dead needle fuels collected in the crown of each tree was classified as low, medium or high. Fuel quantities were not measured.

(b) Fuel moisture content

Immediately prior to ignition the moisture content of dead needle fuels in the lower crown was determined from samples collected one metre above ground. Measurements were also made of the moisture content of needles (in both thinning slash and on the surface layer), and of the duff layer.

(c) Weather

Weather information was recorded as for studies in the pruned stand.

(d) Fire behaviour

The maximum height of flame penetration from the ignition point, and the time taken to reach maximum height, were used to describe fire behaviour in the crowns of unpruned trees.

3 ASSESSMENT OF POST FIRE GROWTH AND DAMAGE

Following burning, studies were initiated to examine the extent of fire-caused damage and the effect on tree growth.

The diameters (DBHOB) of the 429 pruned trees included in the experimental fires were measured, together with 50 pruned trees on an adjacent unburnt site. These trees will be remeasured to determine if growth has been affected.

All trees were inspected for fire-induced crown and stem damage. Evidence of deep charring of basal bark, cambial damage, unusual resin flow, canopy scorch and any burning of resin associated with scars caused during utilisation was noted.

RESULTS AND DISCUSSION

1 PRUNED STANDS

A summary of data collected for each experimental fire is shown in Appendix 1.

Table 1 gives the range of data associated with fire behaviour for both single point and line ignition techniques.

TABLE 1 DATA SUMMARY

	Single Point Ignition (26 fires)	Line Ignition (6 fires)
Drought Index	31 - 68	39 - 68
Temperature (°C)	13 - 25.5	18 - 22
Relative Humidity (%)	48 - 82	68 - 78
Wind Speed (Km/hr)	0 - 5.8	0
Moisture Content (% O.D.wt)		
Duff	40 - 60	40 - 60
Elevated needle fuel	14.3 - 24.3	19.5 - 22.8
Max. rate of spread (m/hr)	6 - 42	12 - 30
Max. flame height (m)	0.2 - 2.5	0.2 - 1.5
Flame depth (m)	0.1 - 0.8	0.1 - 1.0

On all but one of the 26 point ignition fires, flame heights remained less than 1.2 m. Even on the one fire, when flame heights in excess of 2 m were recorded, the spread rate remained very low. In this instance increased fuel elevation was probably responsible for the increased flame height. Although in a few instances dead fuels within tree crowns were ignited control problems did not occur. On all fires the maximum recorded rates of spread were very low, with an overall maximum of 42 m/hour. The mean maximum spread rate was approximately 20 m/hour.

During the six fires lit using the line ignition technique, maximum spread rates and flame heights were of the same order as those obtained for point ignition fire development.

Each of the experimental fires achieved a significant reduction in the quantity of fine fuel. All needle fuel in the elevated thinning slash was removed as well as 40 - 70% of the quantity of fine fuel present at ground level. Even if very little ground fuel had been burnt, removal of the elevated fuel would have meant a substantial reduction in the existing hazard.

Under almost calm conditions, fires allowed to develop from a single ignition point will give excellent results in terms of reducing fuel quantities. However, a technique that relies on the development of a number of individual spot fires is very sensitive to changes in wind conditions. Alternatively, backfires are very tolerant of changes in both wind speed and direction. The backfire cannot move away under increased wind speed from the same direction, and a significant wind shift is required to turn the backfire into an active headfire. The relatively unpredictable increase in fire intensity associated with the joining of fire fronts is avoided when a backfiring technique is applied.

Therefore, although the guidelines shown in Table 2 are largely the result of observations on spot fire development, the *lighting pattern recommended for operational use is a line of fire allowed to backburn across the area to be treated.* Such a technique would probably prove unsatisfactory if broad scale burning was planned, but as will be discussed in more detail later, the areas to be fuel reduced should not be of great depth.

TABLE 2 - BURNING GUIDELINES

DI	Moisture Content (%) O.D.wt) Duff	Elevated Fuel	Wind (Km/hr)	Temp (°C)	RH (%)
<70	>40	17-21	<5	< 20	> 50

The conditions specified in Table 2 should give a fire with very low rate of spread and acceptable flame heights. Although acceptable fire characteristics were obtained at fuel moisture levels lower than 17%, the fact that a line ignition technique is recommended has made it desirable to increase the minimum fuel moisture level as an added safety margin.

Fires lit when the duff layer is likely to ignite and remain alight could be difficult to control and may cause unacceptable butt damage. The moisture content of the duff layer is therefore an important factor in deciding the likely success of operations in this fuel type. At duff moisture levels greater than 40% burning in the duff layer was not a problem during the experimental fires. The moisture status of the duff layer has also been represented in Table 2 by the drought index. All experimental fires were successful at drought indices less than 70. On an operational basis it is recommended the drought index be used to indicate when duff moisture conditions are likely to be suitable for burning, and that the final test be an examination of duff moisture content, using the Speedy moisture meter if necessary. Although not strictly applicable to the decomposing fuel of the duff layer, the meter can be used to indicate if the duff moisture content is high.

The drought index is also an indicator of the dryness of heavy fuels within the stand. Burning under high drought indices could result in large fuel components, including old stumps, igniting and remaining alight for long periods.

Most experimental burns were conducted under almost calm conditions within the stand and therefore the full effect of wind speed cannot be evaluated. However, on the basis of Thomson's work (1978), burning should only be carried out when wind speed within the stand is less than 5 Km/hr, even though a backfiring lighting technique is recommended. Any control problems are likely to be magnified by increasing wind speed.

The major influence of temperature and relative humidity will be reflected in the levels of fuel moisture existing in the fine fuels. However, both variables have been included in the guidelines to emphasise the importance of selecting mild burning conditions. Air temperature also plays a part in determining the level of crown scorch - at a given fire intensity, the extent of crown scorch is likely to increase with increasing air temperature. (Van Wagner, 1973).

Despite its significant effect on fire behaviour, slope has not been included in the guidelines. Because backfiring is the recommended lighting technique this is not a significant omission. If slopes are important in areas to be treated the lighting technique should result in milder fire behaviour than described above. In fact, on steep slopes and at the higher levels of fuel moisture recommended, fire spread may not be sustained when burning downhill.

Planning for low intensity prescribed burning should be concentrated on the areas of greatest hazard. With large areas of thinning slash the objective should be to break up the continuity of fuel. Strips along plantation boundaries, internal access routes and between outrows in recently thinned stands would be most suitable. Strips 20 - 30 m deep are recommended as being most desirable in an operation. Extra protection can obviously be achieved by burning additional adjacent strips.

Although mineral earth control lines are required they need not be very wide. One metre wide lines proved satisfactory during experimental burning.

Suitable moisture contents for both the elevated fuels and the duff layer are most likely to occur in spring, and operations should be conducted then in preference to autumn.

The moisture content of the elevated needle fuel in the thinning slash is very responsive to changes in atmospheric temperature and relative humidity. During the conduct of burning operations, temperature, relative humidity and fuel moisture content should be monitored frequently to ensure early recognition of deteriorating burning conditions.

Experimental burning was conducted over a very limited range of conditions, and it is possible that the range of suitable burning conditions is greater than shown in Table 2. It is also possible that the results given are misleading for areas other than Kentbruck. The guidelines should therefore be used as a starting point for operations on the fuel type described. Careful monitoring and recording of conditions during operations should indicate where and if the guidelines need to be modified for different plantation areas.

Figures 2 and 3 illustrate the type of fire behaviour experienced during experimental burning.

2 UNPRUNED STANDS

A summary of the data collected is given in Appendix 2.

Crown scorch was evident in three of the thirty trees only, where flames penetrated 12, 12 and 15 m respectively into tree crowns.

On all other trees flame penetration was 10 m or less, and even in trees where the fuel distribution was subjectively assessed as heavy, flame penetration was limited to 3 - 4 m when the moisture content of dead fuel in the lower crown was 40 - 45%.

The implication of these results is that it may be possible in the future to use fire to remove much of the hazardous fuel existing in the lower sections of tree crowns. Low pruning is an expensive operation which has the disadvantage of adding to the fuel at ground level for a considerable period. Also the depth of vertical fuel break from pruning is small (≃ 2 m) compared with the break possible if fire is used.

The relationship of fuel distribution to flammability has been clearly demonstrated by the results shown in Appendix 2. In the elevated, well aerated fuels in the lower tree crowns, fires were being sustained at moisture contents far in excess of those which limit fire spread in fuels at ground level.

3 FIRE DAMAGE

In the pruned areas, soon after burning, there were few obvious signs of fire-induced damage. On some trees, where fire had been more intense, there were signs of bark charring around the butt. Burning of resin associated with damage from thinning operations may extend the damage already present.

In the unpruned stands where burning was conducted within individual crowns, there was no apparent stem damage. Crown scorch was evident in three of the thirty trees burnt.

Four months later, stem damage was not apparent on any of the trees burnt apart from those already damaged during thinning. Only two trees still showed signs of lower canopy scorch. Pruned and unpruned trees displayed resin flow from branch nodes, and the pruned trees from pruning scars. This feature was also present, although on fewer trees, in the unburnt control area.

Regular inspection and measurement will continue to allow any effects not immediately apparent to be identified.

CONCLUSION

This short trial has proved that low intensity fire can be used to reduce the hazard associated with fuel accumulations from thinning operations.

The guidelines presented should be used as the basis for the development of burning operations. They should be applied with careful monitoring of burning conditions to allow identification of any modifications required for the plantation area concerned.

Preliminary evidence is that fires of the intensity described will cause little damage to retained trees.

At this stage burning should not be attempted in thinned areas that have not been low pruned.

ACKNOWLEDGEMENTS

The assistance and co-operation of the staff and employees of the Heywood Forest District is acknowledged.

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APPENDIX 1 - SUMMARY OF FIRE BEHAVIOUR - PRUNED STANDS

1 Single Point Ignition

Fire No	Date	DI	Temp (°C)	RH (%)	Max Wind (Km/hr)	Moisture Content Duff	Elev.Fuel	Max ROS (m/hr)	Fl. Ht (m)	Fl. Depth (m)
1	27/9/77	31	13.5	64	-	50-60	18.0	15	1.0	0.5
2			14.0	57	-	50-60	16.8	16	0.8	0.3
3			17.0	51	-	50-60	17.1	32	1.0	0.6
4			15.0	58	-	50-60	14.5	26	0.5	0.4
5			15.0	58	-	50-60	14.4	24	0.5	0.2
6			15.5	58	-	50-60	14.3	24	0.8	0.4
7			16.0	54	-	50-60	16.0	20	1.0	0.3
8			15.5	58	-	50-60	14.5	20	1.0	0.4
9			15.0	61	-	50-60	15.0	24	1.0	0.4
10			14.5	60	-	50-60	15.9	16	1.0	0.4
11			15.0	61	-	50-60	15.9	14	1.0	0.4
12			14.0	65	-	50-60	16.4	16	1.0	0.5
13			14.0	65	-	50-60	15.6	20	1.0	0.5
14			13.0	69	-	50-60	16.8	20	0.5	0.2
15			13.0	69	-	50-60	18.0	17	0.4	0.2
16	28/9/77	39	14.5	61	5.8	50-60	22.8	30	0.3	0.2
17			15.5	62		50-60	21.1	26	1.2	0.3
18			16.0	54	4.7	50-60	19.4	42	0.8	0.3
19			17.5	55	1.8	50-60	18.0	24	1.0	0.3
20	11/10/77	39	17.0	77		40-50	19.8	10	0.2	0.1
21			22.0	54		40-50	17.5	30	1.2	0.5
22	12/10/77	49	24.0	49		40-50	17.7	18	1.0	0.2
23			25.5	48		40-50	16.6	30	2.5	0.8
24	13/10/77	68	19.5	82		40-50	22.5	18	1.2	0.3
25			19.5	78		40-50	22.0	12	0.2	0.1
26			20.5	70		40-50	16.3	18	1.2	0.3

2 Line Ignition

Fire No	Date	DI	Temp (°C)	RH (%)	Max Wind (Km/hr)	Moisture Content Duff	Elev.Fuel	Max ROS (m/hr)	Fl. Ht (m)	Fl. Depth (m)
1	28/9/77	39	18	77	-	50-60	19.5	24	0.8	0.3
2	13/10/77	68	20	78	-	40-50	22.8	16	0.4	0.2
3			20	78	-	40-50	21.2	20	0.8	0.2
4			20	78	-	40-50	21.6	24	1.5	0.5
5			21	75	-	40-50	20.3	10	0.8	0.2
6			22	68	-	40-50	21.0	30	1.5	1.0

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APPENDIX 2 - SUMMARY OF FIRE BEHAVIOUR - CROWNS OF UNPRUNED TREES

Date	Temp (^{o}C)	RH (%)	Wind (Km/hr)	Moisture Content Duff	Elev. (Slash)	Lower Crown	Lower Crown Needle Density *	Max Flame Penet^{n} (m)	Time for Penet^{n} (sec)
8/9/77	15	70	5	65	48	21	M	5	21
						21	M	6	20
						21	M	7	27
						21	L	4	23
						21	M	7	24
						21	M	6	24
9/9/77	12.5	90	0	130	60	45	H	4	28
						45	H	3.5	26
						43	H	4.5	22
						43	H	3.5	29
						46	H	3.5	30
	16.0	63	0	100	70	22	H	5.5	18
						22	H	6	16
	13.8	93	3	100	80	28.3	M	5	30
						28.3	M	5	29
						28.3	M	6	33
	13.8	93	3	100	80	28.5	M	4.5	30
						28.5	L	3	48
						28.5	H	12	30
						28.5	H	10	35
						28.5	H	15	20
	13.6	92	2	100	80	29.0	M	5	25
						29.0	L	2	65
						29.0	H	9	20
	13.6	92	2	100	80	30.1	M	6	25
						30.1	M	7	32
						30.1	M	4	16
	13.6	92	2	100	80	30.4	L	3	25
	13.6	92	2	100	83	30.6	H	12	22
	13.2	96	2	100	83	30.6	H	8	25

* H = High density with continuous stem needles

M = Medium density, some stem needles

L = Low density, no stem needles