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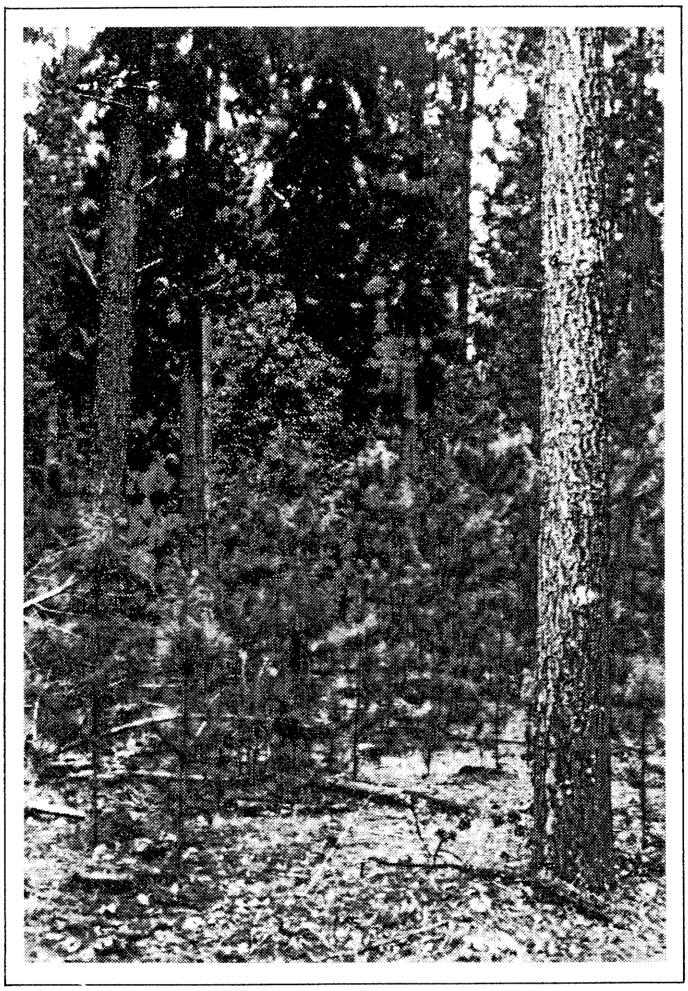

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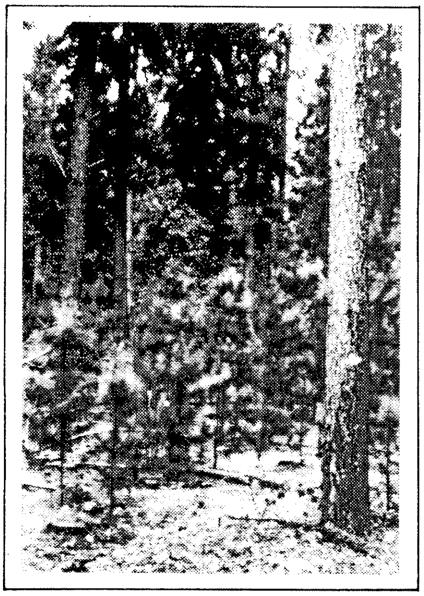

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SUMMARY

Thinning and pruning operations result in considerable restructuring of the fuel distribution in fire sensitive *Pinus radiata* plantations. The removal of lower branches and foliage lessens the likelihood of crown fires, but the addition of up to 30 t/ha of flammable slash can lead to severe fire behaviour under conditions of extreme fire danger. Much of this slash is aerated needles which exist in a highly flammable state for up to three years. Prescribed burning is an option for reducing this hazard, but conditions of fuel and weather must be clearly defined to avoid damage.

Experimental fires were lit in recently thinned 14 year old *P. radiata* plantations over a range of fuel and weather conditions. The aim was to determine whether it was possible to remove the aerated needle component of slash fuels by burning, without causing damage to standing trees.

Aerated needles were successfully burnt under cool, moist conditions when fire intensity did not exceed 200 kW/m. The conditions of weather and fuel moisture over which aerated needles in slash fuels can be burnt without causing damage to standing trees are described.

INTRODUCTION

In the south-west of Western Australia some 27 000 ha of *Pinus radiata* D. Don plantations have been established on land held as State forest, to supplement the production of sawn timber from native hardwood forests. The total standing value of these plantations is in excess of $30 million, while current plantation establishment costs are in the order of $450/ha.

The potential exists for large monetary losses directly from wildfires and from the subsequent disruptions in sawlog supply to the timber industry. Timber harvesting, thinning and pruning operations produce large quantities of highly flammable slash (Burrows 1980) which if left untreated, significantly increase the fire hazard and interfere with other plantation operations, such as grazing where it is practised. In Western Australia, considerable emphasis is placed on fuel reduction burning to assist with the protection of native Eucalypt forests and surrounding assets from wildfire (Underwood and Christensen 1981). These Eucalypt forests are far more fire resistant than the fire sensitive *P. radiata.*

The re-arrangement of pine plantation slash caused by thinning and pruning operations can have a considerable effect on fire behaviour (Williams 1977). While thinning and pruning may decrease the probability of the start and spread of crown fires, this may be off-set for several years by increased quantities of aerated and flammable ground fuels (Woodman and Rawson 1982). Reducing the amount and arrangement of this fuel will increase the level of fire protection within a plantation and can considerably reduce the rate of spread and intensity of wildfires (Burrows 1980a).

Prescribed burning has been applied in Victorian pine plantations to remove the flammable needles from aerated slash fuels without damaging crop trees (Billing 1979). A sound knowledge of fire behaviour is essential to successfully carry out these burns. The purpose of this study was to define the range of fuel, weather, stand and fire behaviour conditions over which prescribed burning to remove the aerated needles in logging slash can be safely and economically carried out without damaging crop trees.

METHODS

Thirteen small (0.25 ha) plots were established using a bulldozer to prepare firebreaks in a thinned, 14 year old stand of *P. radiata* near Grimwade, Western Australia. The stand was commercially thinned from 750 stems/ha to 200 stems/ha in January 1979. The thinning operation was carried out using standard chainsaw and forwarder techniques. Considerable quantities of pruned branch wood and non commercial residual tree tops were left on the forest floor.

After the thinning operation, fuel consisted of a uniform layer of compacted ground needles (needlebed fuel) overlain by discontinuous and aerated heaps of non-commercial tree tops and branches (slash). This aerated slash consisted of:

(1) fine needles;

(2) branchwood up to 25 mm in diameter; and

(3) stemwood up to 100 mm in diameter.

The quantities of needlebed and slash fuels were measured separately for each experimental plot. The mean needlebed fuel weight (t/ha) was determined from 30 randomly located needlebed depth measurements from each plot and by using a relationship between needlebed depth and needlebed weight (Sneeuwjagt and Peet 1985). The quantity of slash fuel by particle size, as described above, was measured using van Wagner's (1968) line intercept method and a technique described by Burrows (1980b).

Attempts were made to burn the plots early in the winter of 1979, but these were unsuccessful as fuels were too wet. Towards the end of winter, when the surface needles on the needlebed had dried below about 25 per cent oven dry weight, the plots were lit by a line of fire set at the upwind end. The moisture contents of the needlebed surface needles, the entire needlebed profile and the aerated needles in the slash were measured at regular intervals during the fires.

An on-site weather station provided continuous measurements of air temperature and relative humidity. Wind speed and direction at 1.5 m above the forest floor was measured over 10 minute intervals.

The position of the fire as it burnt through plots was marked with metal tags positioned at predetermined time intervals. Flame height, flame depth and flame angle were recorded from visual estimates.

After all the plots were burnt, quantities of needlebed and slash fuels remaining were remeasured. The height to which tree canopies were scorched was visually assessed. About two years after the fires, the tree boles were inspected for visible signs of fire-caused bole injury.

RESULTS

The flammable aerated needles in the logging slash were burnt without causing crop tree damage providing fire intensity did not exceed 200 kW/m (Byram 1959). Fire intensities experienced throughout the experiment are shown for each fire in Table 1. Generally, a successful result was obtained when the fire consumed the needles in the slash fuels but did not scorch the tree crowns to more than 6 m above ground. Average headfire rates of spread ranged from 24 m/h to 78 m/h, depending on wind strength, fuel quantity and fuel dryness. Generally, fire rate of spread in slash fuels was two to three times greater than that of fire burning in needlebed fuels only. Flames rarely exceeded 2 m when slash fuels burnt, but occasionally flared to 4 m. The height to which the crop trees were scorched was about four times the height of the flames. None of the trees were killed by these fires but several were scorched to within 3 m of their growing tip. From visual estimates, the extent of fire caused bole damage was negligible.

The experimental fires were lit between 1200 and 1500 hours. At this time of year (late winter-early spring) weather conditions outside these times were generally such that fuels were too moist to sustain combustion.

The moisture content of dead pine needles fluctuated rapidly in response to temperature and relative humidity changes. The needlebed fuels would not ignite when their moisture content exceeded 25 per cent oven dry weight (o.d.w.) but the aerated needles in the slash burnt provided their moisture content did not exceed 27 per cent o.d.w. The quantity of each of the fuel types burnt is shown for each fire in Table 2. Occasionally, dead needles on the stems and branches of living trees ignited, but this did not cause any control difficulties. Resin on the outer bark of living trees often ignited and may have caused some bole damage. This could not be reliably assessed visually.

Table 1: Fuel moisture content, weather and fire behaviour during experimental fires in 14 year old *P. radiata* (slash fuels). Burnt August - September, 1979.

Fire No.	(*a*) SMC (%)	(*b*) PMC (%)	(*c*) AMC (%)	Temp (°C)	RH (%)	Wind (km/h)	(*d*) X HFROS (m/h)	(*e*) X HFROS n/bed (m/h)	(*f*) H.F. X Flame Height	(*g*) H.F. X Flame Height	X Fire Intensity (kW/m)	X Scorch Height (m)
1	22	112	20	14	65	2.2	40	22	1.0	.15	159	5.3
2	18	148	16	15	58	1.8	60	35	1.4	.10	258	6.5
3	19	125	17	14	64	2.5	44	21	1.3	.10	118	3.5
4	18	55	17	15	61	2.9	56	40	1.3	.20	205	5.8
5	18	81	16	16	58	3.9	78	39	2.1	.15	455	10.0
6	16	62	16	18	45	2.6	45	23	1.3	.15	258	6.6
7	15	60	14	20	45	3.3	74	34	1.6	.40	455	9.0
8	18	32	17	19	45	3.1	34	22	1.0	.13	35	3.6
9	17	34	16	19	45	3.0	40	25	1.2	.15	57	4.0
10	18	40	17	18	55	3.1	25	15	0.8	.08	26	2.5
11	18	40	17	18	55	3.1	24	15	0.8	.08	26	2.5
12	18	150	17	20	52	3.5	75	30	1.5	.20	383	8.0
13	17	110	16	20	50	3.1	75	30	1.6	.20	383	8.0

(*a*) SMC = surface needle moisture content as a percentage of oven dry weight.
(*b*) PMC = profile needle moisture content as a percentage of oven dry weight.
(*c*) AMC = aerated needle moisture content as a percentage of oven dry weight.
(*d*) Head fire rate of spread in aerated slash fuels.
(*e*) Head fire rate of spread in needlebed fuels.
(*f*) Head fire flame height in aerated slash fuels.
(*g*) Head fire flame height in needlebed fuels.

Table 2: Fuel type and average quantity (t/ha) before and after experimental, low intensity fires in 14 year old *P. radiata* plantations.

Fire No.	Quantity before fire (t/ha)			Quantity after fire (t/ha)			% total fuels burnt
	Needlebed	Aerated Needles	Wood (<25 mm diam.)	Needlebed	Aerated Needles	Wood (<25 mm diam.)	
1	8.9	6.5	8.5	7.2	0	7.8	23
2	9.1	7.4	9.6	7.5	0	8.5	24
3	10.1	5.4	8.2	8.5	0	6.6	22
4	6.2	6.3	7.8	3.9	0	5.8	26
5	5.9	6.6	7.1	3.7	0	4.8	32
6	6.3	5.1	7.0	5.5	0	6.0	23
7	7.0	5.3	7.2	5.8	0	5.4	26
8	4.8	3.6	4.4	3.4	0	4.4	24
9	4.9	3.8	4.9	3.2	0	4.0	30
10	5.2	3.4	4.3	3.5	0	4.0	24
11	4.9	3.0	4.1	3.4	0	3.8	21
12	10.7	4.8	6.0	7.4	0	4.3	30
13	14.0	5.2	6.4	9.8	0	4.8	27

Note: Aerated needles refers to dead needles suspended in slash fuels (tops and branches).

DISCUSSION AND OPERATIONAL BURNING GUIDES

This study shows that prescribed fire can be successfully used to reduce the fire hazard resulting from thinning and pruning operations in *P. radiata* plantations. This supports findings in Victoria by Woodman and Rawson (1982) and Billing (1979) who recommend that fire intensity be less than 250 kW/m to avoid excessive scorch to the canopy. Conditions of fuel moisture and weather are critical for successfully carrying out these burns. If fuels are too moist, then the fuels will not burn or fire will not carry across the needlebed. If fuels are too dry, then fires will be too intense and damage to crop trees is likely. Ideally, fuel moisture conditions should be such that the needles on the surface of the needlebed just sustain fire, which occurs only over a narrow range of conditions.

The following procedures will assist fire managers in implementing prescribed burns in pine plantations.

Planning

(1) If the total area of slash fuels to be burnt exceeds the district's capacity to burn then areas must be given a priority based on factors such as strategic importance (e.g. fuel reduced buffers should be treated where they contain logging slash). Slash burns should only be carried out in stands older than 12 years.

(2) Thinning and pruning operations must be supervised to ensure slash is not heaped but is evenly distributed. Ideally, slash heaps should be less than 1 m in height and at least 1 m from crop trees.

(3) Thinning and pruning should take place in summer or autumn and the resulting slash should be burnt the following winter or spring when the needles in the slash are red in colour.

(4) Stands to be burnt should have a vertical fuel break of at least 2 m between ground level and the suspended fuels in lower sections of tree crowns.

(5) Burns must be confined to small, homogenous units of about 5-10 ha. Variations in slope and aspect will cause variations in fire behaviour and hence, difficulties in achieving a successful burn.

Fuel Quantity Measurements

(1) This description for measuring fuel quantity applies when fuels consist only of needlebed and logging slash, as the objective of prescribed burning is to remove all aerated needles in the logging slash and the top few millimetres of the needles in the needlebed.

(2) The total quantity of needlebed fuel can be estimated before burning by measuring the needlebed depth using a fuel gauge. For a burn area of up to 10

ha thirty to forty measurements are needed. The total quantity of needlebed fuel (expressed in t/ha) is then determined from Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt and Peet 1985).

(3) The total quantity of slash fuel is also determined from Forest Fire Behaviour Tables for Western Australia.

(4) The quantity of fuel actually available for burning, i.e. that fraction of the total fuel complex which is dry enough to burn or which is of small enough dimensions to burn, will influence fire behaviour, hence the level of damage to crop trees.

(5) Forest Fire Behaviour Tables for Western Australia can be used to determine the quantity of needlebed which is likely to burn (available fuel). The available fuel (for burning) from the needlebed must be less than 3.0 t/ha/ If more of the needlebed is burnt, then crop tree damage will occur.

(6) In the slash there are three readily recognizable fuel types based on the particle size of the fuel: these are aerated needles, branchwood (branches <25 mm in diameter) and stemwood.

(7) The total quantity of fuel available for burning must not exceed 10 t/ha.

Fuel Moisture Measurements

(1) Soil Dryness Index (S.D.I.) reflects the dryness of the deep needlebed, logs, stumps and bark on standing trees (Mount 1972). It reflects both the total quantity of fuel which will burn and the likelihood of re-ignition of logs, stumps and unburnt needlebed (Burrows 1987).

(2) In winter and spring, burning must only be carried out when the S.D.I is <250. In autumn, do not burn until the S.D.I. has fallen by 400 from its summer maximum. S.D.I. records should be maintained throughout the year, using temperature and rainfall figures from as near to the burn site as possible.

(3) When conditions are within the above S.D.I. limits, then regular field checks on fuel moisture content should be made in anticipation of burning.

(4) Fuel moisture content prediction systems (Sneeuwjagt and Peet 1985) must be maintained throughout the year. Predictions must be corrected weekly by actual field measurements.

(5) When fuel moisture contents are approaching the limits described in Table 3 below, then the moisture content of aerated needles and surface needles on the needlebed should be monitored daily in the field, at about 1500 hours.

(6) On possible burning days, fuel moisture contents should be monitored several times during the day, commencing at 1000 hours, to determine when conditions are ideal for a prescribed burn.

(7) The results of field measurements of fuel moisture contents should be used in conjunction with the fuel moisture prediction system in Forest Fire Behaviour Tables for Western Australia to determine the approximate ignition time. Generally, suitable burning conditions will not occur on exposed, northerly sites until two to three days after rain, and on sheltered sites until four to six days after rain.

Weather Measurements Before Burning

(1) Initially, daily weather forecasts are adequate to decide whether closer monitoring of weather conditions is necessary. If, on the basis of forecasts, weather conditions may be suitable for burning then weather and fuel conditions on the burn site should be measured and recorded prior to ignition and during burning. Wind speed is measured using a hand held anemometer under the canopy. Temperature and and relative humidity are measured using a whirling or aspirated psychrometer.

The Burn Prescription

Slash burns will be successful if they are carried out under the conditions described in Table 3.

Burning Technique

(1) Use drip torches and commence with a line of backfire. If conditions are suitable (Table 3) then a line of spots can be placed 50 m downwind of the first fire. Best burning conditions are usually between 1200 and 1500 hours. Therefore, with a maximum of about three hours burning time, spacing of spot fires should be positioned to allow for burnout in this time.

(2) Use headfiring when wind speeds are low and fuels are moist (Table 3).

(3) Proceed with caution if weather and fuel conditions are approaching the upper limits (Table 3).

Weather, Fuel and Fire Behaviour

(1) A fire weather officer must be responsible for measuring and recording fuel moisture content, temperature, relative humidity, wind speed/direction, fire rate of spread and flame height.

(2) Fire behaviour and wind speed/direction observations should be half-hourly or more frequently if wind conditions are variable.

(3) Other weather observations should be made hourly.

(4) Aerated and surface needlebed fuel moisture content should be measured hourly using a marconi moisture meter.

(5) Note and record any unusual fire behaviour such as torching (crown of individual trees catching alight) or spot fires.

(6) Record results of all observations and communicate these to the fire boss.

(7) When conditions deteriorate, cease lighting and prepare to mop-up or extinguish fires.

Mop-up

(1) There should be little or no mop-up necessary under winter/spring conditions. Mop-up may be necessary in autumn.

(2) Slash burns must be left black-out to prevent later re-ignition.

(3) In autumn it may be necessary to extinguish fire on individual trees if the resinous bark ignites. This can be done using pack sprays or by throwing sand onto the fire.

Post Burn Assessment and Reporting

(1) Assess the results of the burn two to three weeks later.

(2)

Repeat the pre-burn fuel sampling procedure to determine the quantity and type of fuel removed.

(3) Visually assess the level of scorch, tree deaths and stem damage.

(4) Record all observations and place on appropriate file.

(5) Submit reports according to standing orders.

(6) Recode fuel and hazard plans.

Table 3: Prescribed conditions for slash burning under radiata pine plantations.

SDI		SMC %	PMC %	AMC %	Temp. °C	R.H.	Wind km/h	Max. rate of spread (m/hr)		Max. flame ht (m)	
Spring	Autumn							Tops	Needlebed	Tops	Needlebed
< 250	SDI to fall 400 units from summer max.	17-24 (*a*) (19-25) (*b*)	> 45 (*a*) (> 60) (*b*)	16-24 (*a*) (18-25) (*b*)	< 22 (*a*) (< 20) (*b*)	> 50 (*a*) (> 55) (*b*)	< 5 (*a*) (< 3) (*b*)	50	30	1.8	.20

(*a*) Conditions suitable for backfiring.
(*b*) Conditions suitable for headfiring.

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REFERENCES

BILLING, P.R. (1979). Using fire to reduce fuel accumulations after first thinnings in radiata pine plantations. Forests Commission, Victoria, Fire Research Report No. 4 (unpublished).

BURROWS, N.D. (1980a). Crushing the thinning slash problem. Forests Department of Western Australia, Research Paper 62.

BURROWS, N.D. (1980b). Quantifying *Pinus radiata* slash fuels. Forests Department of Western Australia, Research Paper 60.

BURROWS, N.D. (1987). The Soil Dryness Index for use in fire control in the southwest of Western Australia. Department of Conservation and Land Management, Western Australia Technical Report 17.

BYRAM, G.M. (1959). Combustion of forest fuels. In: *Forest Fire: Control and Use* 1st edn. (K.P. Davis, ed.). McGraw-Hill Book Co., New York 61-89.

MOUNT, A.B. (1972). The derivation and testing of a soil dryness index using run-off data. Tasmania Forests Commission, Bulletin No. 4.

SNEEUWJAGT, R.J. and PEET, G.B. (1985). *Forest fire behaviour tables for Western Australia*. 3rd edn. Department of Conservation and Land Management, Western Australia.

UNDERWOOD, R.J. and CHRISTENSEN, P.E.S. (1981). Forest fire management in Western Australia. Forests Department of Western Australia. Special Focus No. 1.

WAGNER, C.E. van (1968). The line intercept method in forest fuel sampling. *Forest Science* 14: 20-26.

WOODMAN, M. and RAWSON, R. (1982). Fuel reduction burning in radiata pine plantations. Forests Commission, Victoria, Division of Forest Protection, Fire Research Branch Report No. 14 (Unpublished).