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J.W.G.

J. W. P. NICHOLLS* and N. P. CHENEY**

Effect of Experimental and Wild Fires in Pine Plantations on Wood Characteristics

SUMMARY

Sawn timber losses due to degrade were investigated in a 28 year-old stand of radiata pine (*Pinus radiata* D.Don) subjected to a series of experimental fires covering a wide range of intensities. The effect of the burning treatment on radial growth rate and density characteristics was also studied and augmented by 44 year old material of the same species which had been burnt in a wild fire. These wood characteristics were also investigated in 17 year-old trees of maritime pine (*P. pinaster* Aiton).

The experimental fires caused a reduction of 0.4 per cent of the total possible sawn volume. There was no effect on growth rate and only a slight reduction in density in the immediate post-fire year. The accumulation of traumatic resin is discussed.

INTRODUCTION

The intensity and rate of spread of fires in eucalypt forests is governed by the amount of forest floor litter. The cheapest way to regulate litter accumulation is by prescribed burning (McArthur 1962). The effects of such fires on wood characteristics of jarrah are described by Nicholls (1973). Interest is also being shown in the application of this technique as a fire protection measure in pine plantations.

Some debate has centred around the question of site deterioration and decrease in yield due to frequent burning but there is no evidence to support the contention that controlling the amount of forest floor litter by periodic burning is detrimental to either of these factors.

Little has been written on timber defect as a result of forest fire. French and Kierle (1969) and Wright and Grosse (1970) found that sapstain was the most important imperfection in fire-damaged radiata pine. Van Loon (1967) examined degrade in immature *Pinus taeda* and *P. elliottii* stems and observed that differences between species were very marked. Fire damage resulted in localised cambial necrosis, with the subsequent death of the sapwood and traumatic resin formation, both proceeding radially inwards from the site of the injury. Occluded wood was not joined to the inner wood. There is a clear need to extend the examination of fire tolerance to other important exotic pines.

The present study is concerned with the effect of fire on the wood of radiata pine (*P. radiata* D.Don) and maritime pine (*P. pinaster* Aiton). In the first instance, material from a 28 year-old radiata stand which had been subjected to a series of moderate experimental fires was used to compile data on log volume, sawn volumes and recovery percentages. Laboratory examination of specimens from this material and a few 46 year-old trees of the same species which had been burnt in a wild fire was carried out to obtain information on the effect of fire on wood characteristics. Specimens from a 16 year-old maritime pine stand which also had been subjected to experimental burning were studied in the laboratory.

* Forest Products Laboratory, Division of Applied Chemistry, C.S.I.R.O,, Melbourne.
** Forest Research Institute, Canberra.

MATERIAL

Radiata pine

The experimental trees were from the Mt. Stromlo forest (149° 00′ E, 35° 15′ S) in the Australian Capital Territory. This forest is grown on acid volcanic parent material at an elevation of 610 m and an average annual rainfall of 695 mm. Two groups of trees were investigated. Group 1 was planted in compartment 67 in 1943, pruned to 1.2 m in 1951 and from 1.2 m to 2.4 m in 1957, and thinned in 1960-61.

A series of experimental burnings ranging in intensity from 100 kW/m to greater than 3400 kW/m was carried out in October 1965 following a drought from January to July.

(Fire intensity, I, is defined as the product $I = Hwr$, where H is the heat yield of the fuel ($\simeq$ 18,600 kJ/kg for forest litter), w is the fuel quantity (kg/m_2) and r is the rate of forward spread (m/sec). To convert B.T.U./ft./sec. into kW/m multiply by 3.5 and to convert tons/acre into t/ha multiply by 2.5.)

The meteorological conditions during the hottest fire were, temperature 21 deg C, relative humidity 33 per cent, average wind speed in the open 4.5 m/sec and in the forest 2.2 m/sec. Fuel moisture content of the needle litter was 12.6 per cent (oven dry weight) and the total fuel quantity less than 7.5 cm in diameter was 42 t/ha of which the fires consumed between 25 and 32 t/ha. The quantity of fine fuels less than 6 mm in diameter was 26 t/ha, which is the fuel size class commonly used in fire behaviour experiments. However, the seasonal conditions were dry during the experiments (Byram-Keetch drought index 267), and as the fires consumed considerable quantities of the larger fuel components, fuel quantity measurements were made to include all fuels up to 7.5 cm. The fires burnt with flame heights at the head fire ranging from 1.2 m in light fuels to 2.7 m in heavy fuels and with flames to 4.5 m beside some resinous trees.

Under these conditions the maximum intensity was ten times greater than that recommended for prescribed burning of Eucalypt fuels (McArthur 1962). The fires removed a large proportion of the larger fuel components up to 7.5 cm in diameter which resulted in a long residence time at any one point and subjected the trees to a long heat pulse even when the fire intensity was low.

For the study on sawn timber production 39 trees were selected within the area where fire intensity had been measured and a 2.4 m butt log was taken from each in May 1971. For the examination of wood characteristics seven trees were sampled from the burnt portion and five from the unburnt section of the compartment. Details of each of these latter 12 trees, and the heights at which samples were taken, are recorded in Table 1.

TABLE 1

Sampling height, fire intensity and external damage features of sample trees of radiata pine.

Group No.	Tree No.	Specimen height above stump (m)			Fire intensity (kW/m)	Range of external damage (cm from butt)	External resin formation
1	1	0.91	1.82	2.38	Unburnt	Nil	Nil
	2	0.67	1.67	2.38	Unburnt	Nil	Nil
	3	0.79	1.67	2.56	Unburnt	Nil	Nil
	4	0.73	1.65	2.38	Unburnt	Nil	Nil
	5	0.79	1.70	2.38	Unburnt	Nil	Nil
	6			2.21	145	Nil	Medium
	16/2	0.84	1.83	2.38	388	0-195	Copious
	20/2		1.90	2.08	145	172-193	Nil
	21/1		1.55	2.44	235	216-266	Copious
	40/2		1.86	2.44	585	Nil	Nil
	54/1		1.60	1.86	N.A.	147-157	Slight
	56/1	0.61			280	61-70	Copious
2	6/33	0.30	2.89	5.32	Unburnt	Nil	Nil
	1/32	0.30	3.25		Unburnt	Nil	Nil
	2/32	0.30	4.05		Unburnt	Nil	Nil
	1	0.30	3.66		N.A.	0-427	Slight
	2	0.27	3.35		N.A.	0-366	Slight
	3		2.13		N.A.	0-244	Slight

N.A. Fire intensities not available, but from the position of the tree relative to the the fire and the extent of external damage the following are estimated:
Tree 54 < 346 kW/m.
Trees 1, 2 and 3 > 692 kW/m.

Group 2 comprises three trees planted in 1926 which were burnt by a wildfire in January 1952 and three trees planted in 1927 adjacent to the burnt area, two from the unburnt compartment 32 and one from the unburnt compartment 33. These trees were used only for the study of wood characteristics. Details of these six trees are also recorded in Table 1 but it will be noted that only estimates of fire intensity are given.

Maritime pine

The 16 trees for examination originated in compartment 25 of the McLarty plantation (115° 44′ E, 32° 50′ S) situated on a coastal plain in Western Australia. This is an even-aged stand planted in 1954 at 2 m x 2 m spacing and thinned in March 1969 to 3 m x 3 m. Average tree height in 1971 was approximately 9 m. The soil type is a heavily leached limestone sand of low nutrient value and the annual rainfall is approximately 1000 mm. Prescribed burning was carried out in August to September 1970 when litter depth was approximately 5 cm. Four trees were sampled from each of four fire intensities. Details of tree data are set out in Table 2. Flame heights ranged from 0.6 to 1.2 m with sporadic flaming to 3 m. In October 1971 the trees for examination were felled and disks measuring 2.5 cm along the grain were taken at a nominal breast high position between branch whorls.

TABLE 2

Details of maritime pine trees supplying specimens for the examination of wood characteristics.

Fire intensity	Tree No.	GBHOB (cm)	Height (m)	DBHUB (cm)	BTBH (mm)
Unburnt	0-1	48.0	11.4	12.0	17
	0-2	50.1	12.8	12.8	14
	0-3	50.7	12.7	13.6	12
	0-4	60.0	13.1	15.7	17
< 175 kW/m	1-1	48.2	12.2	12.4	16
	1-2	51.0	11.7	12.4	16
	1-3	50.7	11.3	12.8	14
	1-4	59.5	12.0	15.9	15
345 kW/m	2-1	48.5	11.1	13.3	11
	2-2	51.2	11.3	13.1	13
	2-3	50.7	11.1	12.4	19
	2-4	59.8	12.2	17.5	16
> 520 kW/m	3-1	48.5	11.1	12.4	16
	3-2	50.7	13.1	13.6	14
	3-3	50.5	12.2	13.3	13
	3-4	60.0	12.9	15.5	21

GBHOB — Girth breast height over bark.
DBHUB — Mean diameter breast height under bark.
BTBH — Mean bark thickness breast height.

EXPERIMENTAL PROCEDURE

Sawing Study

The radiata pine butt logs were sawn into 2.5 cm flitches. Each flitch was examined for the presence of damage which was checked and noted as being caused by fire or other agents. Each flitch was then edged to produce a 2.5 cm board with the maximum possible width. Of the 39 trees examined, 8 were damaged by fire and 12 showed damage from other factors such as snigging or falling. In some cases fire damage was superimposed on a previous scar and was recorded under both categories. Before edging, each damaged board was examined by an experienced sawyer, who estimated the maximum possible board width that could have been achieved had the fire damage been absent.

Wood Characteristics

Radial strips were cut from the disks and processed for the determination of x-ray densitometric data according to techniques described elsewhere (Nicholls 1971, Nicholls and Brown 1971). In the case of the maritime pine disks the strips were taken along the shortest radius in the expectation that this would include the least amount of compression wood. The radiata pine strips were taken from both sides of the diametrical specimens.

The pieces for examination were radiographed after drying to 10 per cent moisture content and then treated with methanol in a Soxhlet apparatus to remove resinous material. They were dried to 10 per cent moisture content and again radiographed. A comparison of the densitometric scans of the two sets of radiographs taken along the same line in the specimen afforded a measure of the amount of extractive material which had been removed by the methanol treatment.

Determinations were carried out on sufficient annual growth periods prior to the fire treatment to provide adequate data on which to judge the effect of the burn on wood characteristics. The growing season was assumed to extend from August to July.

For each characteristic the data were grouped on the basis of annual growth period and means were calculated for each treatment.

RESULTS AND DISCUSSIONS

Radiata pine Sawing Study

Although 11 per cent of the total number of boards exhibited fire damage, the reduction in sawn volume as a result of this agent was only 0.4 per cent of the total possible sawn volume (see Table 3).

TABLE 3

Number of boards damaged and reduction in sawn volume resulting from fire and other causes in the conversion of radiata pine logs from Mt. Stromlo forest, A.C.T.

Type of damage	Number of trees	Number of 2.5 cm boards	10^4 x Reduction in sawn volume (m^3)	Percentage of total possible sawn volume*
Fire damage	8	26	104	0.39
Other damage	12	18	66	0.25
Undamaged	19	196	—	—
Total	39	**238	170	0.64

* Total possible sawn volume 2.465 m^3.

** Two boards exhibited both fire and felling damage.

It was estimated that the damage in five of the trees would persist and reduce the volume recovery. If the trees after a further five years of growth were to be sawn in the manner described the damage on 11 flitches would be occluded. The remaining 15 flitches would still exhibit fire damage at the edge, and it would possibly reduce the volume of sawn boards which could be taken from them.

It was not possible to find any relationship between the fire intensity at each tree and the fire damage. No reliable estimate of fuel quantity at each tree prior to burning could be obtained and the occurrence of damage is very dependent on the resident time of the fire beside each tree. Even under conditions of a mild burn, damage will result from a fire continuing to burn in a single log against the butt of the tree or from the fire persisting in heavy resin exudations in the bark crevices.

Radiata pine Wood Characteristics

Ring widths of the control trees in Group 1 fluctuated about an average which slowly decreased during the period from 1958, when the trees

were beginning to form mature wood, to 1971 (Figure 1). The trend was modified by increases in ring width due to a thinning treatment carried out in 1960-61, and above average rainfall from 1968 to 1971 (see Table 4). The pattern in the treated trees was similar to the controls but with a greater tendency to respond to variations in rainfall. The rings of the treated trees were slightly wider from 1966 to 1971, possibly due to the effect of the fire treatment during the first two years and to the favourable rainfall after 1968.

Maximum densities of both the treated and control trees decreased in the first growing season after thinning (Figure 1). Apart from this there was

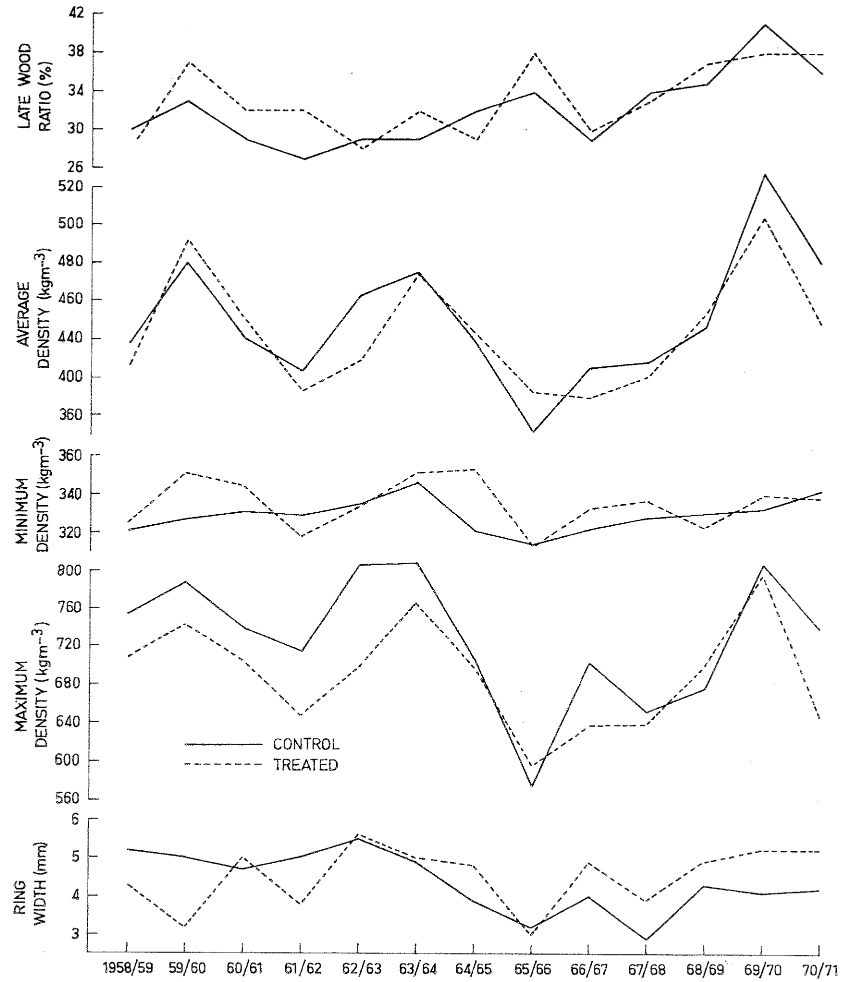

Figure 1

Means of ring widths and densitometric characteristics of radiata pine trees from the Mt. Stromlo forest, A.C.T. The treated trees were planted in 1943, thinned in 1960-61 and subjected to experimental burnings in October 1965.

considerable variation due to other environmental factors. Zahner (1963) has discussed secondary wall thickening in late season growth and ascribed this to changes in the soil-tree-water relations. Polge (1965) found an inverse relationship between maximum density and the precipitation for the last 3 months of the growing season. In the present case a plot of values tended to confirm Polge's observations but there is some indication that the relationship is more complex and may involve other factors. It is suggested that any effect due to control burning is manifest in the immediate post-fire year as a small decrease in this parameter.

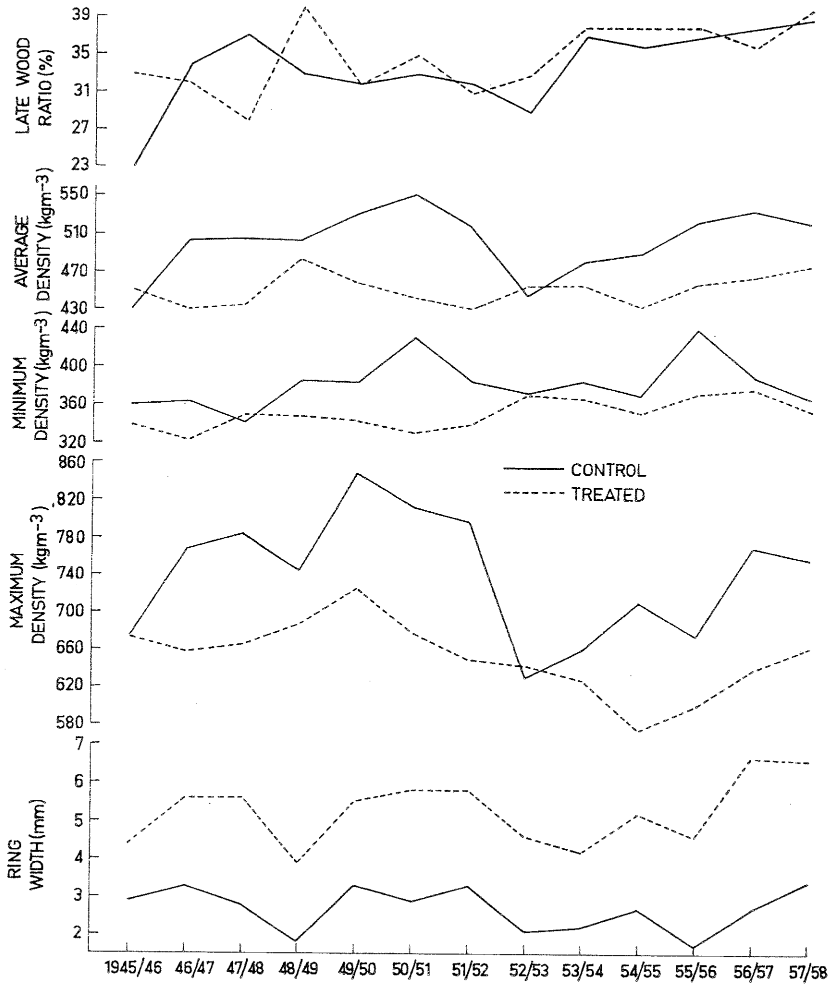

Figure 2

Means of ring widths and densitometric characteristics of radiata pine trees from the Mt. Stromlo forest, A.C.T. The trees were planted in 1926-27, and burnt by a wild fire in January 1952.

TABLE 4
Monthly rainfall totals from August 1944 to July 1971 for Yarralumla, A.C.T.
Rainfall (mm)

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
1944/45	9	10	32	39	33	61	67	19	95	20	47	29	462
1945/46	80	16	48	70	16	85	73	40	47	32	30	47	584
1946/47	20	3	59	110	20	2	66	53	30	24	30	45	463
1947/48	70	72	29	65	224	116	153	26	56	156	59	19	1042
1948/49	20	43	83	22	64	22	88	87	22	95	38	41	625
1949/50	9	75	117	92	17	83	82	322	87	59	18	91	1053
1950/51	44	50	137	113	15	46	42	30	20	40	69	45	651
1951/52	82	61	74	33	16	26	21	142	132	58	118	43	806
1952/53	58	57	144	60	102	55	18	22	30	130	20	17	713
1953/54	26	57	36	48	33	79	70	0	38	8	48	17	461
1954/55	30	23	57	71	36	30	90	34	27	113	62	27	599
1955/56	113	27	134	59	69	79	62	236	90	107	144	77	1196
1956/57	44	44	116	25	5	22	36	28	21	5	31	52	428
1957/58	49	11	16	31	64	103	37	69	71	42	70	62	623
1958/59	65	58	71	40	81	33	144	124	77	14	102	31	841
1959/60	16	38	177	90	25	74	22	51	19	94	10	129	747
1960/61	35	115	59	65	114	30	66	154	64	3	38	77	819
1961/62	35	40	34	152	129	139	50	42	13	53	16	37	738
1962/63	64	110	56	34	123	82	49	70	61	55	34	36	772
1963/64	46	55	47	43	67	14	29	41	116	46	30	108	641
1964/65	37	90	128	33	57	2	2	3	17	16	25	18	428
1965/66	58	67	133	33	40	55	78	70	6	45	45	38	666
1966/67	52	80	86	90	102	61	17	30	9	20	20	15	581
1967/68	79	36	51	30	0	57	1	26	45	165	30	29	548
1968/69	68	16	52	34	106	22	113	55	120	51	53	43	733
1969/70	59	26	131	96	37	80	72	48	64	30	30	6	678
1970/71	69	139	28	123	90	123	215	16	24	26	5	19	877

Mean annual rainfall 695 mm.

The present study confirmed previous work which showed that minimum density is much more conservative than maximum density (see for example, Nicholls and Brown 1971). Control burning did not have any effect on minimum density.

The effect of thinning was to reduce the late wood ratio in both the control and treated trees. The overall trend was an increase throughout the period from 1958 to 1971. Late wood ratio was not affected by the prescribed burning.

Maximum density exercised a major influence on average density. Both decreased in the year after thinning, and the overall trends in the two parameters are similar. The only effect of the burning treatment appears to be a decrease in average density in the first year after the fire.

The pattern of variation of wood characteristics in the material associated with the trees in Group 2 is shown in Figure 2. The treated trees were faster grown than the controls. This is not regarded as disadvantageous as the differences in growth rate are small and the trends of the two groups were similar. There was no discernible effect of the 1952 fire on growth rate.

As for the Group 1 trees there was considerable variation in maximum density. The faster grown treated trees showed less variation and lower

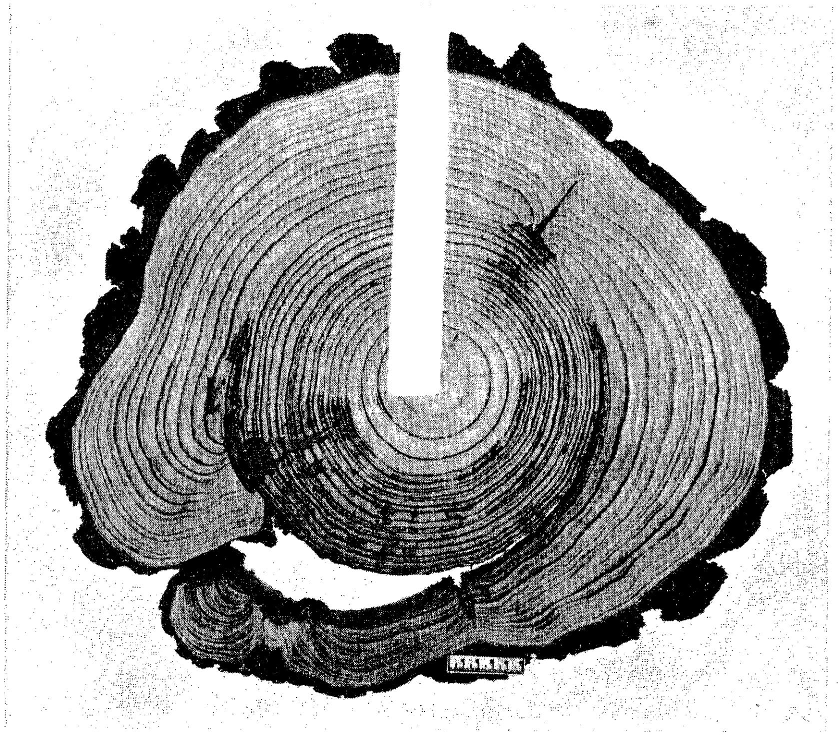

Figure 3

Cross-sections at a height of 2 m from a radiata pine tree burnt by a wild fire, showing occluded wood separated from the remainder of the stem and pockets of resin.

density values than the controls. Zahner (1963) has commented on the relationship between the rate of cell production and the probability of cell wall thickening. No conclusion could be arrived at from these data concerning the effect of fire on this parameter.

The patterns for minimum density show minor variations about a nominal constant value. There is no indication however that fire treatment has influenced the observed results.

The overall trend in late wood ratio was a slight increase from the 1945-46 to the 1957-58 growing season. There was no indication of change due to the 1952 fire.

As for the Group 1 trees maximum density would play a large part in determining variation in the average density values. However judged on the overall data there is no evidence to suggest that the fire treatment has affected the average density pattern.

A cross-section taken at a height of 2 m from one of the badly damaged trees from Group 2 is shown in Figure 3. More than half of the cambium has been killed by the wild fire and the separation of the occluded wood from the remainder is clearly seen. Considerable resin accumulation has taken place adjacent to the damaged areas. Estimates of resin content obtained from the differences between the densitometric scans before and after treatment with methanol correlate well with the extent of fire damage recorded for individual trees in Table 1. For all specimens sapwood only was included in the study material. Figure 4 depicts the densitometric scans

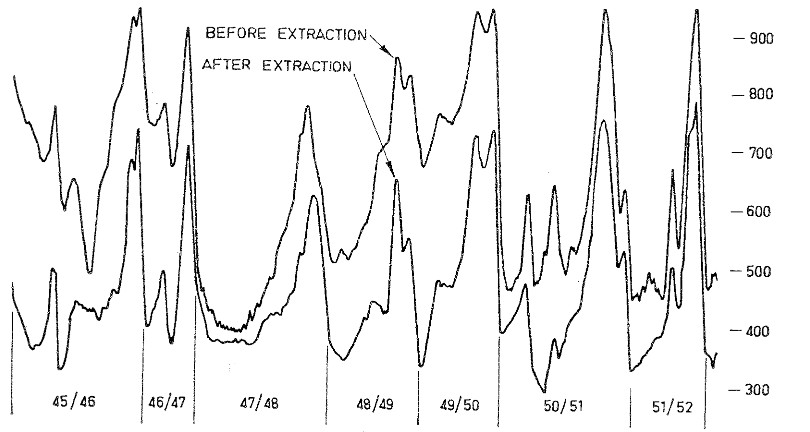

Figure 4

Densitometric scans from a radiata pine specimen before and after methanol treatment. The copious resin accumulation caused by fire damage is shown over 7 growth periods.

before and after methanol treatment for one of the group 2 specimens illustrating the extent of resin accumulation. This was one of the worst resin affected strips and shows that resinous extractives are equally distributed throughout any given growth ring.

Maritime pine

Data were collected for six growing seasons prior to the fire treatment. This interval corresponds to the transition period between juvenile and

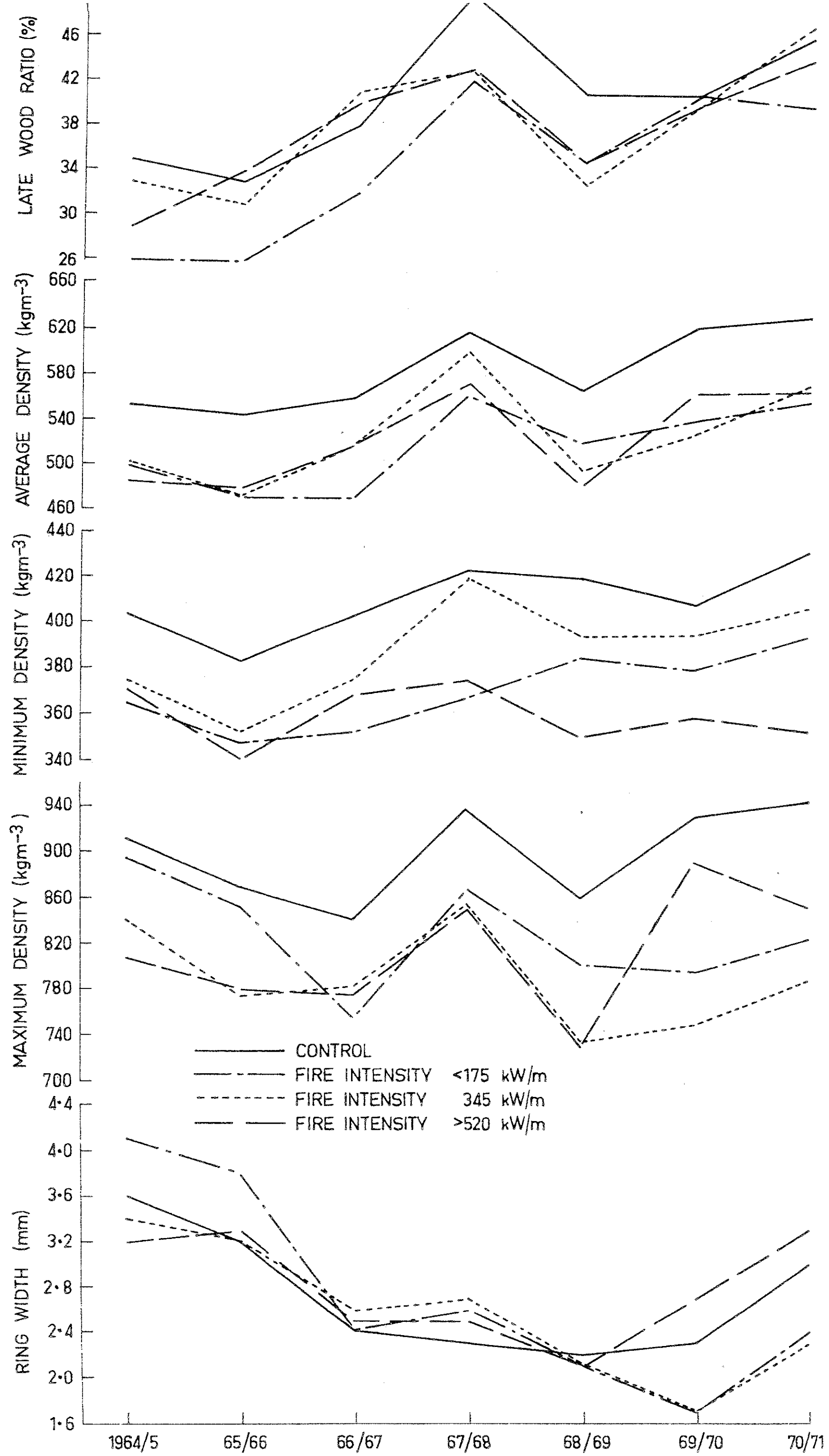

Figure 5

Means of ring widths and densitometric characteristics in maritime pine trees from the McLarty plantation in Western Australia. Treated trees were planted in 1954, thinned

TABLE 5

Monthly rainfall totals from August 1965 to July 1971 for Mandurah, W. Australia.
Rainfall (mm)

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
1965/66	189	85	125	50	21	21	3	5	37	80	314	246	1176
1966/67	78	81	35	5	13	7	10	5	47	195	272	202	916
1967/68	134	30	39	13	19	54	3	63	85	86	238	152	916
1968/69	95	137	60	12	7	3	0	11	58	108	174	86	751
1969/70	58	32	1	25	8	2	NA	3	53	95	254	148	679
1970/71	64	118	52	17	3	6	17	95	3	110	131	170	786

mature wood formation (Nicholls and Dadswell 1965), and therefore wood characteristics should indicate some correlation with environmental factors.

The means of ring widths in the specimens from the control trees decreased from the 1964-65 growth period until 1968-69 and then increased during the next 2 years (Figure 5). Annual rainfalls at the Mandurah station, some 30 km along the coast to the north (Table 5), show a similar pattern of variation. The means of ring width of the trees subjected to fire treatment closely followed those for the controls. In view of the similar rates of increase of the four means after burning it is concluded that any immediate effect of treatment is not evident as a change in radial growth rate. Individual trees within the control group exhibited markedly different increases in ring width as a result of the thinning treatment carried out in March 1969. Similar differential response to thinning is the most likely cause of the differences between groups in the 1969-70 and 1970-71 periods.

The mean maximum density in the control trees appears in part to be inversely related to rainfall for May. The trends for the treated trees are similar to the controls excepting the group associated with the most intense fires which apparently responded to the thinnning treatment with a rapid increase in maximum density. It is possible that in this group there has been a slight diminution in this parameter as the result of the experimental burning but in the other groups no effect is perceptible.

Minimum densities of the control trees were higher than in other groups, but the overall patterns were similar. The two mildest burning treatments did not affect the trees, but there was a decrease in minimum density in the fire year in the group subjected to the most intense burn.

The treated groups had different late wood ratios from the controls in the first growth period after thinning; but only the group associated with the mildest burning treatment exhibited any difference in this feature in the fire year.

Average density depends on maximum and minimum density and late wood ratio and the effect of each of these can be seen in the mean for the separate groups for average density. There is however no overall observable influence of burning treatment on average density.

CONCLUSIONS

Sawing Study

The fires associated with this study resulted in higher maximum intensities and a greater reduction in large fuels than recommended for prescribed burning, and while causing physical damage to some trees, the losses in terms of sawn volume were slight. A prescription for burning *P. radiata* would need to specify milder conditions and a lower drought index than that associated with this study so that the large fuel components would be moist and not consumed by the fire. A fire which removes the fine fuels up to 6 mm in diameter, and only a small proportion of the larger fuels, would suitably reduce litter accumulation for protection purposes and could have a maximum intensity of less than 200 kW/m. From the results reported herein such a fire would be unlikely to cause significant damage to a stand of this age.

Wood Characteristics

With only minor exceptions the results from the three groups of trees are consistent. The burning treatments within a wide range of fire intensities did not have any effect on ring width. In two of the three groups where it was possible to form a conclusion the effect of fire treatment was to cause a small reduction in maximum density in the first year immediately after the burn. A small decrease in minimum density in the young maritime pine occurred only in the trees subjected to the most intense of the fires. No change in late wood ratio could be attributed to fire treatment in any group. Average density was slightly decreased in the first year after the fires in one of the groups of radiata pine. Prescribed burning may therefore be used for these two important species without prejudice to growth rate or density characteristics.

Where fires were severe enough to cause mechanical or physiological damage copious resinous accumulations occurred; but there was not an overall increase in resin content within the stem. Careful attention to maintain the severity of the burn below the threshold value associated with such damage would prevent the production of these resinous pockets.

ACKNOWLEDGEMENTS

The authors thank the Director, Forestry Branch, Department of the Interior for radiata pine material used in this study, and the Conservator of Forests, Western Australia for the maritime pine specimens.

Appreciation is recorded of the assistance of Mrs. D. Dixon in carrying out the detailed measurements on which the results of the wood characteristics study is based.

REFERENCES

French, J. R. J. and Rosalie M. Kierle (1969).—Studies in fire-damaged radiata pine plantations. Aust. For. 33: 175-180.
McArthur, A. G. (1962).—Control burning in eucalypt forests. Leafl. No. 80. For. and Timb. Bur., Canberra.
Nicholls, J. W. P. and Dadswell, H. E. (1965).—Assessment of wood qualities for tree breeding. III. In *Pinus radiata* D.Don. Div. of For. Prod. Technol. Pap. 37, C.S.I.R.O., Aust.
Nicholls, J. W. P. (1971).—The effect of environmental factors on wood characteristics. I. The influence of irrigation on *Pinus radiata* from South Australia. Silv. Genet. 20 (1-2): 26-33.
Nicholls, J. W. P. and Brown, A. G. (1971).—The ortet-ramet relationship in wood characteristics of *Pinus radiata*. Appita 25 (3): 200-209.
Polge, H. (1965).—The use of curves of density-variation for the study of environmental factors and in particular of climatic factors. Paper presented to Mtg. of IUFRO Section 41, Melbourne.
Van Loon, A. P. (1967).—Some effects of a wild fire on a southern pine plantation. For. Comm. of N.S.W. Res. Note No. 21.
Wright, J. P. and Grosse, R. J. (1970).—Wood degrade due to fire. Aust. For. 34: 149-160.
Zahner, R. (1963).—Internal moisture stress and wood formation in conifers. For Prod. J. 13 (6): 240-247.