Fire Management Branch
Department of Conservation & Environment

FUEL PROPERTIES BEFORE AND AFTER THINNING IN YOUNG RADIATA PINE PLANTATIONS

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SUMMARY

Studies at Myrtleford have described the fuels both on the ground, and within tree crowns, in unthinned 12 year old stands of *P. radiata*.

Changes in fuel properties as a result of four different thinning regimes are defined.

The results obtained are a basis for continuing research into fire behaviour in *P. radiata* plantations.

INTRODUCTION

Fire behaviour is a function of site, weather and fuel factors. Countryman (1969), Wilson and Dell (1971) and Dodge (1972) noted that the fire manager can manipulate the fuels (including all living and dead cellulose material on the forest floor and in tree crowns) to reduce the fuel hazard, but has little influence over site or weather conditions.

Before developing plans for fuel management and hence fire management, fuel properties must be fully described and understood. This has generally been a neglected aspect of fire research in Australia. Notable exceptions are descriptions for the jarrah forests (Peet 1971) and maritime pine stands (McCormick 1973) of Western Australia.

This report describes the quantity and distribution of fuels on the forest floor, and in tree crowns, in unthinned 12 year old *Pinus radiata* D. Don stands. The effects of thinning on fuel properties are also examined.

SIGNIFICANCE OF STUDY

The fuel hazard created by widespread areas of young stands, combined with the fire environment of south-eastern Australia, creates a situation of major concern to plantation managers in Victoria, and in south-eastern Australia generally.

Plantations are gaining in economic importance through increased contribution to forest production as well as to economic development of rural areas. For example, the standing value of State owned *P. radiata* plantations as at January 1976 was $124 million. (This estimate was based on discounted expected revenue, using an interest rate of 7 per cent with 3 production thinnings and a 35 year rotation.)

A characteristic of the plantations is that the distribution of age classes is skewed towards younger stands. This poses unique problems because of the fuel hazard created by young stands following canopy closure. Such stands form a three dimensional fuel complex, which under the right conditions facilitates crown fire development. Fires in such stands may result in complete loss because of the very low proportion of commercial timber sizes present.

METHODS

1 Fuel Quantity and Distribution in Unthinned Stands

One hundred and seventy hectares of unthinned 12 year old *P. radiata* in Merriang Plantation, north-east Victoria were studied. Mean stand details are listed in Table 1.

TABLE 1 - STAND DETAILS

Stem diameter	17.1 cm
Number of stems per hectare	1 407
Top height	16.64 m
Stand basal area	27.5 m^2/ha
Stand volume	139.5 m^3/ha

1.1 Fuels on the Forest Floor

In this study, fine fuels include woody material less than 6 mm. diameter, needle litter (whole or partly decomposed pine needles) and duff (needles fully decomposed or in an advanced state of decomposition). Coarse fuels include all woody material greater than 6 mm diameter.

Fine fuel quantities were estimated using one hundred, 0.5 m^2 randomly located plots (Munger and Matthews 1941, Dell and Ward 1971). Fuels were collected and oven-dried at $105^{o}C$.

Bulk density of needle litter and duff was derived from volume and weight measurements on the plots.

The line intersect technique described by Van Wagner (1968) was used for coarse fuels. One hundred 30 m transects were randomly located through the area.

1.2 Fuels in Tree Crowns

The method previously used by Kittredge (1944), Loomis et al (1966), and Landis and Morgen (1975) was adopted for determining the quantity and distribution of fuel components in tree crowns. The technique involved the collection and oven-dry weight determination of all fuel, excluding merchantable stem (i.e. stem wood greater than 10 cm diameter), in the tree crown from 12 randomly selected trees.

Oven-dried weights of merchantable stems were determined using a wood density figure of 395 kg/m^3 (Wright pers. comm.) and measurement of stem volume.

Each sample tree was considered to comprise ten sections of equal height. Measurements were made of both sectional crown volume and non-merchantable fuel weight.

Regression equations were developed to predict, from DBHOB, the weights of various non-merchantable crown fuel components. A regression was also developed relating DBHOB and crown volume (Williams 1976).

Regression equations were developed to predict, from DBHOB, the non-merchantable crown fuel weight and the crown volume for each section.

These equations were used, together with the known diameter distribution, to make estimates for the study area as a whole.

Three other parameters (Sando and Wick 1972), were used to define fuel distribution within crowns.

Mean crown height was used to examine the vertical distribution of fuel weight. The quantity of non-merchantable fuel required to support combustion within each crown was arbitrarily selected as 200 kg/ha for each 30 cm section of crown. If, for example, the fuel complex had greater than 200 kg/ha for each 30 cm section at all levels except the lowest two metres, the mean crown height would be two metres.

Fuel bed void volume/fuel volume is the volume of empty space within tree crowns, divided by the fuel volume within crowns. The fuel volume was calculated assuming an average fuel density of 570 kg/m^3 (Sando and Wick 1972).

Crown volume ratio is the ratio of total fuel bed volume to total crown volume. Total fuel bed volume is calculated using the mean stand height. e.g. If stand height is 17.0 m, the total fuel bed volume equals 170 000 m^3/ha.

2 Fuel Quantity and Distribution Following First Thinning

Fuel properties were sampled on three 0.5 ha plots, following which two plots were thinned. Plot 1 was mechanically thinned with an outrow spacing of one in three (third row outrow). Plot 2 was mechanically thinned with an outrow spacing of one in six (sixth row outrow) and selection thinning within bays. Plot 3 remained unthinned.

The effects of two other thinning treatments were simulated. The first was mechanical thinning of half the standing trees (50 per cent thinning). The second treatment was removal of one third basal area by smallest stems (33 per cent basal area by smallest stems).

RESULTS

1 Fuel Quantity and Distribution in Unthinned Stands

1.1 Fuel Quantity

Table 2 gives the fuel weights sampled on the forest floor and within tree crowns.

TABLE 2 WEIGHT OF FUEL COMPONENTS (T/HA-ODWT)

Fuel Component	Fuel Weight	Percent of Total
1 Tree Fuels		
Merchantable stemwood	64.2	46.5
Non-merchantable stemwood	20.9	15.1
Living needles	7.7	5.6
Dead needles	2.4	1.7
Branchwood	20.3	14.7
(a) fine, living branchwood	4.3	
(b) fine, dead branchwood	2.6	
(c) coarse, living branchwood	8.3	
(d) coarse, dead branchwood	5.1	
Total Tree Fuels	115.5	
2 Ground Fuels		
Coarse fuels	7.3	5.3
Duff	9.8	7.1
Needle litter	4.9	3.5
Other fine fuels	0.7	0.5
Total Ground Fuels	22.7	
Total Fuels	138.2	100.0

Duff and needle litter samples showed little variation compared with other fuel components. In the study area, the needle litter/duff ratio was 0.50 compared with 0.12 and 0.75 for 38 year old and nine year old stands respectively (Williams unpub. data). The duff layer is therefore still building up.

On average, living needles in tree crowns comprised three years growth, so that the mean annual increase in needle weight in tree crowns was 2.6 t/ha. The quantity of dead needle litter on the forest floor represented two years needle growth.

1.2 Fuel Distribution

1.2.1 Fuels on the Forest Floor

Measurements of bulk density of needle litter and duff components showed that although the depth of each layer was approximately 2 cm, the needle litter layer was better aerated than the duff layer. The bulk density of needle litter was 0.020 g/cm^3, and for duff 0.048 g/cm^3. This is important since Brown (1968) found that compactness of fuel influences ignition probability, rate of combustion, fire spread and the drying pattern of fuel.

1.2.2 Fuels in Tree Crowns

Vertical Distribution of Crown Weight

The distribution of non-merchantable fuel weight within crowns is shown in Figure 1.

There is a concentration of weight at 45 percent of tree height.

Vertical Distribution of Crown Volume

The mean stand height for the study area was 16.64 m. The volume per hectare available for expansion within each section of the tree crown is therefore 16 640 m^3. A lesser volume indicates crowns are not fully occupying the available space. A larger volume represents intermingling of tree crowns.

Figure 2 shows intermingling of tree crowns between 17 and 54 percent of total tree height.

The crowns of unthinned 12 year old *P. radiata* therefore form a continuous fuel complex for much of the stand height.

FIGURE 1 - DISTRIBUTION OF NON-MERCHANTABLE FUEL WEIGHT WITHIN CROWNS

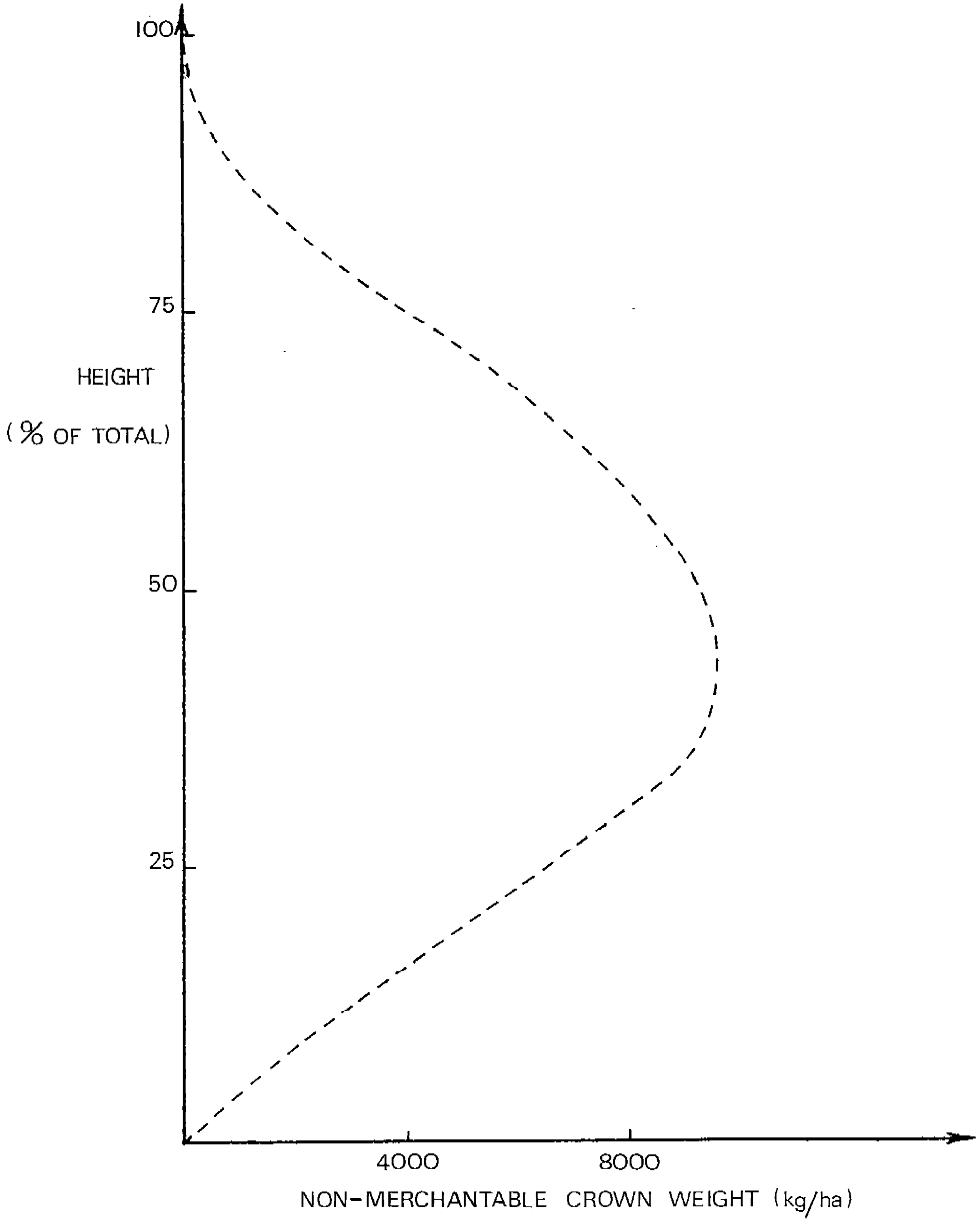
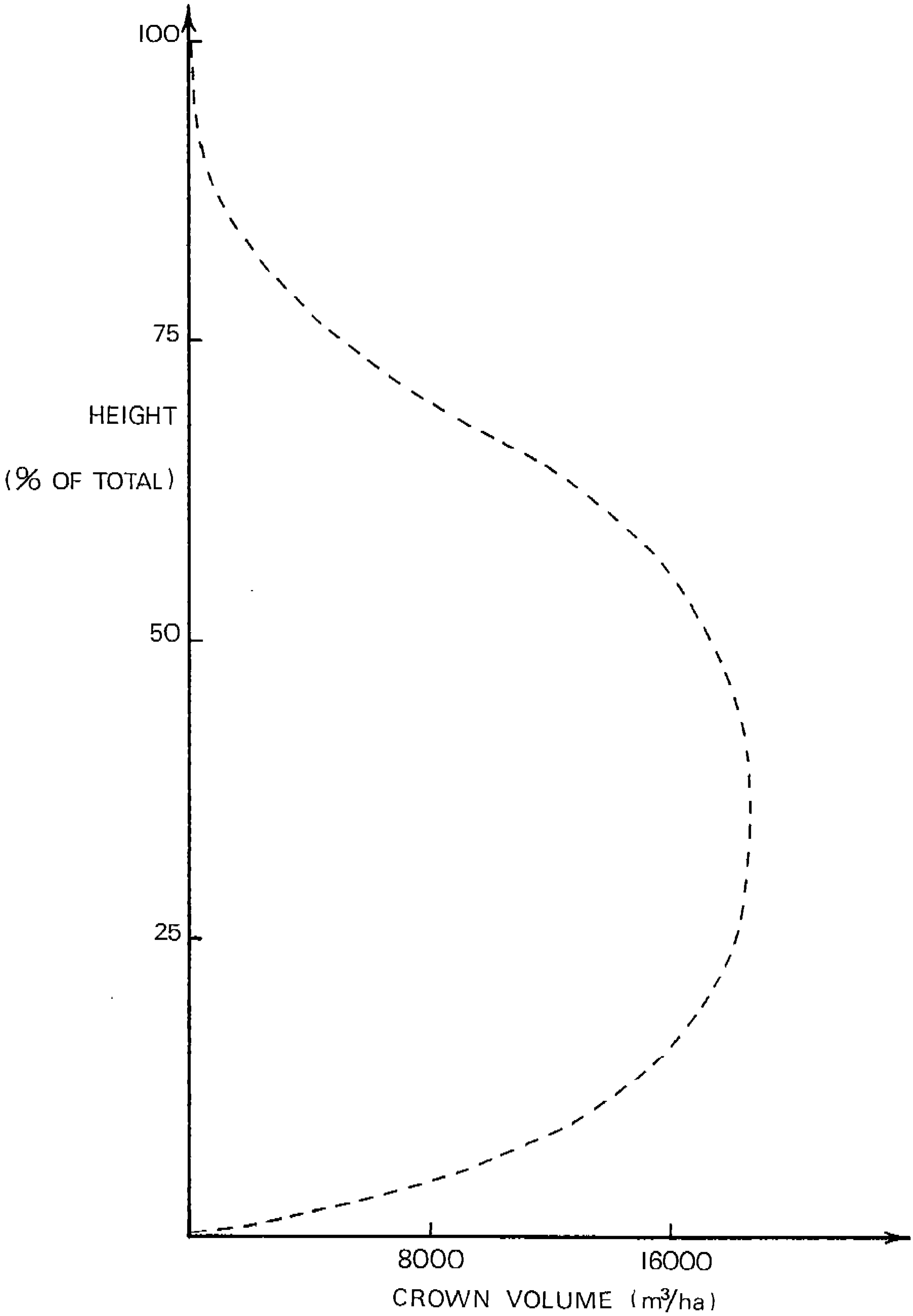


FIGURE 2 - VERTICAL DISTRIBUTION OF CROWN VOLUME



2 Fuel Quantity and Distribution following First Thinning

2.1 Fuel Quantity added to the Forest Floor during Thinning Operations

Merchantable volume, number of stems and average diameter of stems removed during the two thinning operations are shown in Table 3. Third row outrow thinning involved removal of less merchantable volume and fewer but larger stems than sixth row outrow with bay thinning.

TABLE 3 - MERCHANTABLE VOLUME, NUMBER OF STEMS, AND AVERAGE DIAMETER OF STEMS REMOVED DURING THINNING

	Plot 1 Third row outrow thinning	Plot 2 Sixth row outrow with bay thinning
Merchantable volume removed (m^3/ha)	9.32	10.34
Stems removed (No/ha)	495	707
Average DBHOB of removed stems (cm)	15.1	13.2

Additional fuel quantities on the forest floor resulting from third row outrow and sixth row outrow thinnings are shown in Table 4.

TABLE 4 - ADDITIONAL FUEL QUANTITIES ON THE FOREST FLOOR AFTER THINNING (T/HA - ODWT)

FUEL COMPONENTS	PLOT 1 Third row outrow thinning	PLOT 2 Sixth row outrow with bay thinning
Fuels derived from removed stems		
Non-merchantable stemwood*	7.1	13.8
Branchwood		
(a) living, fine	1.5	1.7
(b) dead, fine	0.9	1.1
(c) living, coarse	3.0	2.0
(d) dead, coarse	1.8	2.5
Total branchwood	7.2	7.3
Needles		
(a) living	2.7	2.8
(b) dead	0.9	1.1
Total needles	3.6	3.9
Fuels derived from retained stems		
Dead needles	1.2	1.0
Total Fuels	19.1	26.0

* Merchantable limit is 10 cm diameter small end.

2.2 Total Fuels Following Thinning

Fuel quantities before and after thinning are presented in Table 5.

TABLE 5 - PRE AND POST-THINNING FUEL QUANTITIES (T/HA - ODWT)

FUEL COMPONENT	PLOT 1 Third row outrow thinning Pre-thinning	 Post thinning	PLOT 2 Sixth row outrow with bay thinning Pre thinning	 Post thinning	PLOT 3 No thinning
Tree Fuels					
Merchantable stem	75.1	55.3	73.8	56.3	64.8
Non-merchantable stem	19.2	12.1	21.0	7.2	20.1
Branchwood	20.7	13.5	21.1	13.8	19.2
Living needles	7.9	5.2	8.0	5.2	7.2
Dead needles	2.6	0.5	2.6	0.5	2.3
Total Tree Fuels	125.5	86.6	126.5	83.0	113.6
Ground Fuels					
Fine and coarse fuels	26.7	45.8	22.2	48.2	22.9
Total Fuels	152.2	132.4	148.7	131.2	136.5

Compared with the prethinned situation, total fuels were reduced by 15 and 13 per cent for plots 1 and 2 respectively. As a result of the extraction of merchantable timber, crown fuels were reduced by 45 and 52 per cent in plots 1 and 2 respectively. However, non-merchantable components resulted in a 72 per cent increase in ground fuels in plot 1 and 117 per cent increase in plot 2.

On average, smaller diameter trees were removed during sixth row outrow thinning. The larger percentage increase in ground fuels on plot 2 was largely due to the greater proportion of non-merchantable stemwood in small diameter trees.

2.2 Changes in Fuel Distribution following Thinning

2.2.1 Fuel Distribution on the Forest Floor

The distribution of fuel following thinning varied with terrain, contractor and extraction method. The importance of these variables overshadowed any effects of the different thinning treatments.

2.2.2 Fuel Distribution in Tree Crowns

The effects of thinning on fuel distribution within crowns are shown in Table 6.

TABLE 6 - MEAN CROWN HEIGHT, FUEL BED VOID VOLUME/FUEL VOLUME, AND CROWN VOLUME RATIO FOR THINNED AND UNTHINNED STANDS

Treatment	Mean crown height (cm)	Fuel bed void volume/fuel volume	Crown volume ratio
1 Unthinned	90	1 848	1.51
2 Third row outrow and sixth row outrow with bay thinning*	134	2 772	2.26
3 50 per cent thinned	170	3 697	3.01
4 33 per cent BA by smallest smallest stems	125	2 772	2.14

* Results for third row outrow and sixth row outrow with bay thinnings were almost exactly the same, so that the average of the two is included in this table.

Fifty per cent thinning had the most dramatic effect on crown fuel distribution. The larger mean crown height of 170 cm indicates a more effective fuel break between the ground and crown than created by the other treatments. Similarly, the within crown fuel volume is reduced compared with the other treatments and the crown volume ratio indicates more space between the crowns themselves.

DISCUSSION

A discussion of the effect of thinning on fire behaviour must, at this stage of our knowledge, be qualitative. Apart from changes to fuel properties, changes in microclimate resulting from thinning will also be responsible for changes in fire behaviour compared with behaviour in unthinned stands. Quantification will requre considerable measurement and observation of wildfires and experimental fires.

The elevated fuel distribution and increased ground fuel quantity following thinning will create conditions under which very intense fast spreading ground fires are possible.

Even under very mild weather conditions, fires in unthinned stands of the type studied will move rapidly into tree crowns . The thinning operation does cause some increased separation of crown fuels from ground level (Table 6), but the increased elevation of ground fuels after thinning may offset this factor to some extent. The possibility of fire moving into tree crowns in a 12 year old thinned stand remains very high, although increased crown separation (Table 6) will reduce the likelihood of fire spreading through crowns independently of fire spread at ground level.

Irrespective of the level of hazard created by a thinning operation, the opportunity exists after thinning to modify the fuel and therefore reduce the hazard. Low intensity prescribed fire is one option that needs to be examined as a means of achieving that objective.

CONCLUSION

The studies described have quantified the fuel properties, in young stands of *P. radiata*, before and after thinning.

Further research is required to determine the relationship between the fuel properties described, and fire behaviour.

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