EFFECTS OF SEVERE THINNING AND PRUNING TREATMENTS ON THE INTRINSIC WOOD PROPERTIES OF YOUNG RADIATA PINE

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ABSTRACT

Growth rates and intrinsic wood properties were examined in 50 trees which had undergone severe silvicultural treatments. Wood density was measured with a beta-ray densitometer, using samples from 10 mm increment cores. Tracheid lengths were determined from whole-ring macerations of the same samples.

Stem diameter growth was reduced by pruning treatments, but the effect was short-lived even in the absence of thinning. Pruning tended to increase mean wood density by up to 7% for 2 to 3 years after treatment. These effects are of little technological significance.

An inverse relationship appeared to exist between ring width and tracheid length, and hence thinning resulted in reduced tracheid length values—the effect of this on strength needs to be considered with that of the higher proportion of corewood to be expected from possible shorter rotations.

INTRODUCTION

Timber from New Zealand's major exotic species, radiata pine (*Pinus radiata* D. Don), has gained acceptance as a general-purpose softwood mainly on the basis of the properties of wood from old untended stands. In view of proposals to reduce rotation ages on high quality sites to around 20-25 yr, accompanied by intensive cultural management (Fenton and Sutton, 1968), it is of some importance to determine whether such treatment will substantially alter the characteristics of the wood products.

The properties most generally accepted as being closely related to the quality of such end products as structural timber and wood pulp are wood density and tracheid length (Fielding, 1968; Ifju and Labosky, 1972). Abundant literature exists on the effects of silvicultural treatments on crop volume and wood quality in the broad sense, i.e., log sizes and grade returns, but data on the resulting intrinsic (clearwood) properties are scarce.

Thinning reduces competition between trees and if effective will increase, or at least maintain, radial growth. Several authors, including Gerischer and de Villiers (1963), have recorded an accompanying decrease in wood density which lasts several years, but many others have failed to reveal any consistent relationship between growth rate and wood density (Spurr and Hsiung, 1954; Fielding and Brown, 1961). Turnbull (1947) maintained that the inherent variations within stems due to corewood/outerwood effects were far greater than any changes caused by cultural treatment.

Tracheid length has often been shown to bear an inverse relationship to growth rate (Bisset *et al.*, 1951; Bannan, 1970) and thinning can thus have deleterious effect on this property (Fielding, 1968; Nicholls, 1971).

The effects of pruning on intrinsic wood properties have not been systematically studied in experiments such as those by Luckhoff (1949) which dealt with diameter and height growth in variously pruned plots of different species. Marts (1951) and Gerischer and de Villiers (1963) reported an increase in latewood percentage and wood density in the outerwood portion of the stem following high pruning in longleaf and radiata pines respectively. Larson (1963) attributed these phenomena to the restriction of crown-formed wood (corewood) to the new crown region and advanced physiological ageing lower down the stem. Gerischer and de Villiers also recorded an increase in tracheid length which lasted for about 5 yr.

It has generally been accepted that the removal of about 30% or less of the live crown has little or no influence on height and diameter growth (Moller, 1960), but Brown (1962) points out that the effect of pruning depends on the crop age and stand density prior to treatment.

The recent development of radiation techniques for measuring wood density variations (Harris and Polge, 1967) allows much more detailed analysis of the effects of silvicultural treatments on wood formation and structure. Nicholls (1971) examined wood samples from a thinning trial in maritime pine by means of an X-ray densitometer and concluded that wood density was unaffected over a wide range of thinning intensities at age 16 yr. A recent New Zealand study (J. M. Harris, pers. comm.) revealed that heavy thinning of sample plots of radiata pine in Ngaumu Forest did not significantly alter the mean wood density of subsequent growth.

MATERIALS

The plots used for this study were located in Compartment 1304, Kaingaroa Forest, and had been planted in 1961 with radiata pine at 2.4 m × 1.8 m spacing. The trial was originally designed by the Economics Section of the Forest Research Institute to demonstrate the feasibility of "one-shot silviculture", i.e., plant; visit the stand once to select the final crop; prune these stems to 6.5 m and thin out the rest.

The treatments chosen for the examination of wood properties were as follows:—

1. Moderate pruning—80 final crop trees selected and pruned to 6.5 m at height 11.3 m (a minimum of 35% live crown removed).
2. Moderate pruning plus thinning —80 final crop trees selected and pruned as above. Other trees poison-thinned.
3. Severe pruning —80 final crop trees selected and pruned to 6.5 m at height 9.1 m (a minimum of 60% live crown removed).
4. Severe pruning plus thinning —80 final crop trees selected and pruned as above. Other trees poison-thinned.
5. Control —Unpruned dominants located within treatments 1 and 3.

The severe pruning was carried out in October 1967 and resulted in an average live crown removal of 76%. Moderate pruning took place in August 1968, when an average of 54% live crown was removed.

METHODS

During October and November 1971, ten trees chosen at random from each plot were sampled by removing one 10 mm increment core from the breast height position and another from the 6.5 m level (at the base of the remaining live crown). In the laboratory, the cores were conditioned to 10% moisture content in a controlled environment room prior to machining to a size suitable for use in the beta-ray densitometer described by Harris (1969).

Wood characteristics were determined for each growth ring from the pith to bark as follows:—

1. Annual growth ring widths were measured and used to calculate mean tree diameter and basal area increments for each treatment.
2. The machined strips were resin-extracted in methanol for 48 hr, re-conditioned to 10% moisture content, and analysed for wood density components in the beta-ray densitometer. Within each year's growth, the following parameters were measured:
   (a) Minimum (earlywood) density
   (b) Maximum (latewood) density
   (c) Weighted mean ring density
   (d) Latewood percentage, defined as that portion of the ring width with a density equal to or greater than 400 kg/m^3 at 10% moisture content.
3. Small whole-ring wood samples were obtained from the used densitometer strips, macerated for 2 hr in a 50 : 50 mixture of glacial acetic acid and hydrogen peroxide; 50 unbroken tracheids were then measured for length using a projection microscope.

Wood property values were averaged within each treatment by growth rings, so that differences in treatment means could be related to the effects of the various schedules.

The graphical presentation of the data is complicated by the fact that the treatments took place in consecutive years, and that the trees are in a growth phase during which wood properties change rapidly from year to year. It was decided, therefore, to express wood density values as a percentage of the control tree values and to adjust the abscissa so that the treatment year is a common point. In this way the quantitative effects of the cultural regimes are demonstrated more clearly.

RESULTS

Radial Growth

Table 1 gives the mean ring widths for the thinning and pruning treatments as determined from the increment cores.

All treatments resulted in an initial reduction in ring width relative to the control trees, but within three years the thinned plots were forming rings appreciably wider than those of the control trees at breast height irrespective of the degree of pruning. In the unthinned plots, growth recovery depended on the severity of pruning; the 60%-pruned trees showed an initial reduction in radial increment of about 75% from the control, which had decreased to 15% in 1970·71, whereas the 35%- pruned stems were fully recovered after 3 years.

The effects of the treatments, particularly pruning, were much less apparent at

TABLE 1—The effect of thinning and pruning on ring width

Sampling Position	Treatment		Ring Width mm							
	Thinning	Pruning	63/64	64/65	65/66	66/67	67/68	68/69	69/70	70/71
Breast height	Nil	Nil	9.5	16.4	18.0	16.2	13.0	8.9	7.0	5.0
	Nil	35% 68/69	11.3	15.8	19.2	17.6	14.0	5.5	6.3	6.6
	Nil	60% 67/68	13.1	18.9	19.0	15.0	3.6	4.5	4.7	4.3
	68/69	35% 68/69	10.9	17.5	21.7	16.3	13.2	8.0	11.4	13 5
	67/68	60% 67/68	14.8	14.7	19.3	15.1	8.5	12.2	14.2	17.2
6.5 m level	Nil	Nil			9.3	8.5	13.5	13.0	11.0	8.8
	Nil	35% 68/69			9.5	8.3	16.0	11.7	10.2	7.8
	Nil	60% 67/63			9.7	17.4	13.3	10.0	8.9	7.1
	68/69	35% 68/69			8.4	18.8	17.0	13.3	14.6	12.8
	67/63	60% 67/68			9.2	17.5	17.0	15.3	15.5	15.8

the base of the live crown than at breast height. Fig. 1 shows how diameter growth was affected at the two stem levels.

A surprising feature of the results is that despite the severity of the pruning treatments, growth recovery was very rapid.

Growth Ring Components

The relative proportions of so-called earlywood and latewood have long been held to be a major factor influencing wood quality. However, until recently, methods of defining latewood have been unsatisfactory (Harris, 1969). With the development of radiation techniques for recording wood density variations across growth rings, new criteria for defining the earlywood/latewood boundary have been adopted (Rudman, 1968; Harris, 1969). The method used in this study is similar to that proposed by Rudman in that a fixed density level was chosen above which the wood substance is classified as latewood. Previous experience of density analysis in the corewood region of radiata pine in this laboratory has indicated that 400 kg/m^3 (at 10% moisture content) is a suitable level.

Fig. 2 shows the variations in mean ring widths and in the components of these variations—earlywood width, latewood width and percentage latewood—at breast height. Strong trends characteristic of the corewood of radiata pine were apparent, i.e., the rapid increase in ring width outwards from the pith to a maximum in ring No. 3, followed

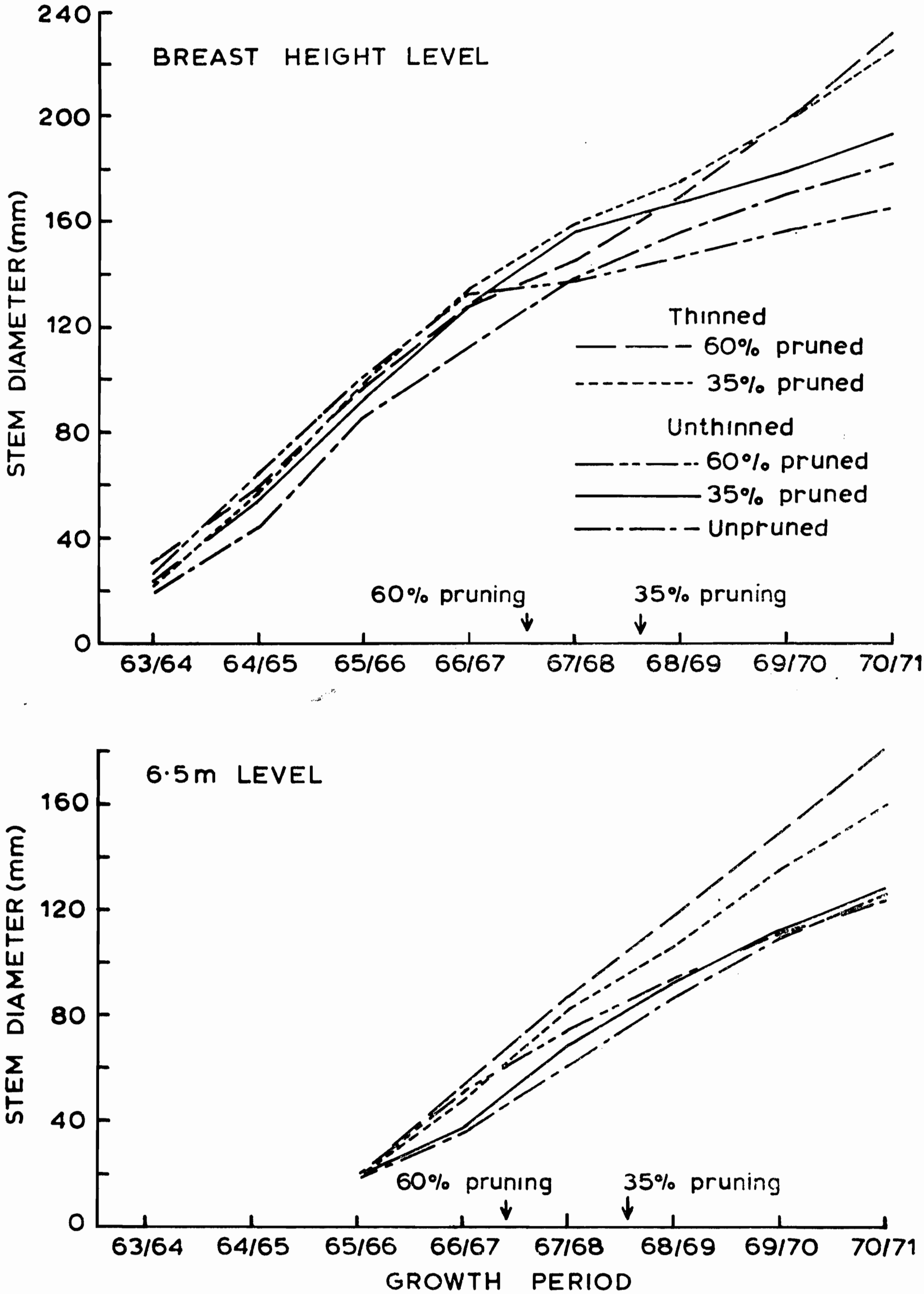

FIG. 1—The effect of thinning and pruning treatments on stem diameter.

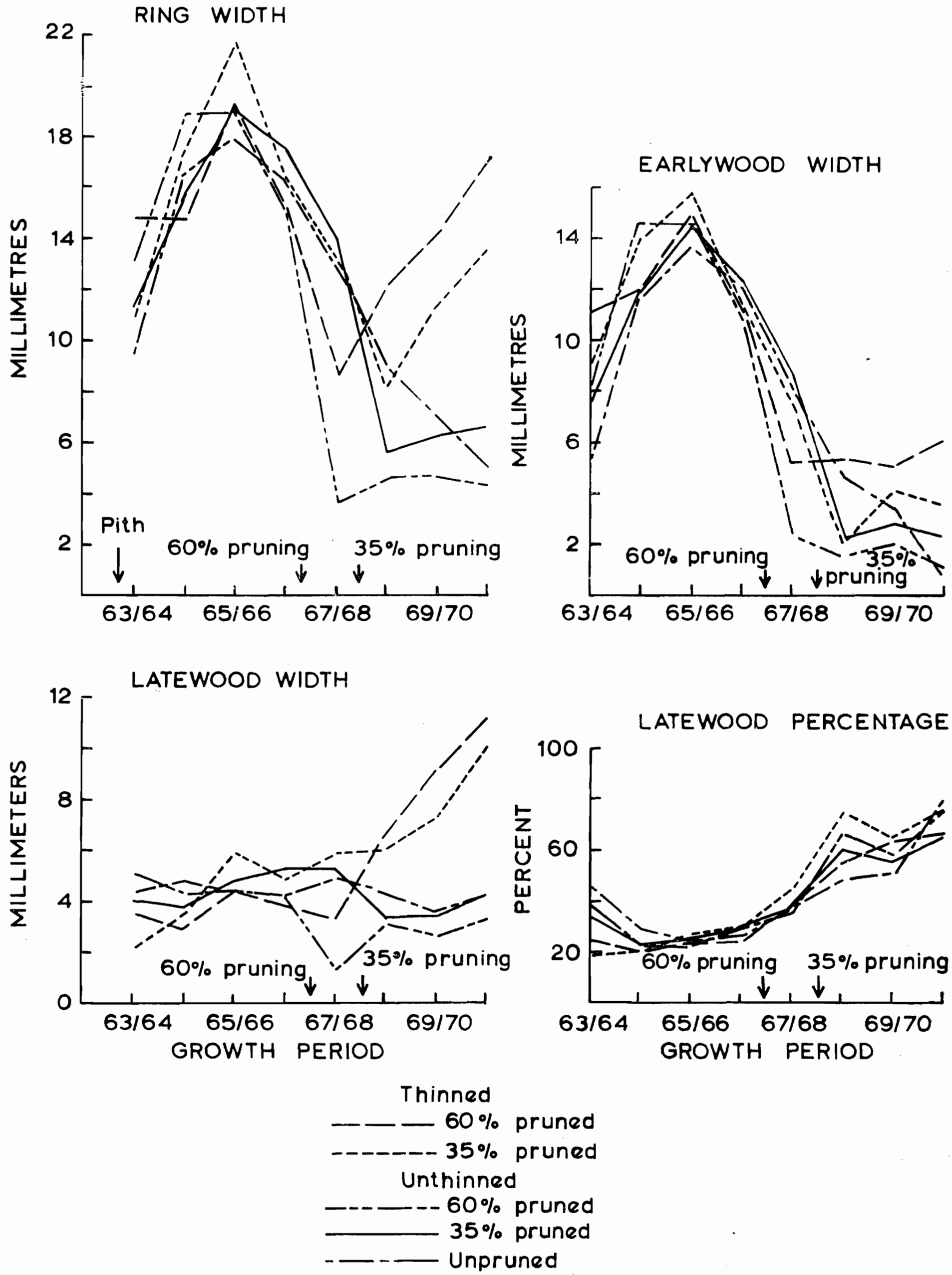

FIG. 2—The effect of thinning and pruning treatments on growth ring components at breast height.

by an equally rapid decrease in subsequent rings. The effects of the various treatments are superimposed on this pattern.

Earlywood followed a trend almost identical to that for ring width prior to treatment whereas latewood width remained fairly constant during the same period. Following thinning and pruning, each treatment had its own characteristic trend, e.g., a large portion of the increased growth after thinning was accounted for by an increase in latewood. An examination of the trends in latewood percentage revealed that there was a substantial increase in all treatments over the controls for 2 to 3 years following pruning and thinning.

Wood Density

Table 2 gives the mean annual wood density values.

TABLE 2—The means of average wood density from pith to bark in the thinning and pruning treatments

Growth Period	Control	Density kg/m³ Unthinned		Thinned	
	Unthinned Unpruned	35% Pruned	60% Pruned	35% Pruned	60% Pruned
Breast height					
1963/64	380	380	370	380	370
64/65	380	360	360	350	350
65/66	360	360	360	370	340
66/67	380	390	380	390	370
67/68	410	410	400	420	390
68/69	440	460	470	460	450
69/70	450	470	480	470	460
70/71	490	490	510	490	470
6.5 m level					
1965/66	320	350	360	380	330
66/67	350	340	360	340	340
67/68	350	350	390	350	380
68/69	370	390	390	400	400
69/70	390	380	400	400	390
70/71	440	410	450	430	410

Mean density increased rapidly with distance from the pith since the analyses were carried out in young stems which consisted exclusively of corewood. Some variation was apparent between treatment means, and the transformed data in Fig. 3 suggested that it could have been at least partly attributable to the silvicultural regimes.

There appeared to be a response to pruning intensity independent of growing space. At both breast height and the 6.5 m level the moderately pruned stems showed an

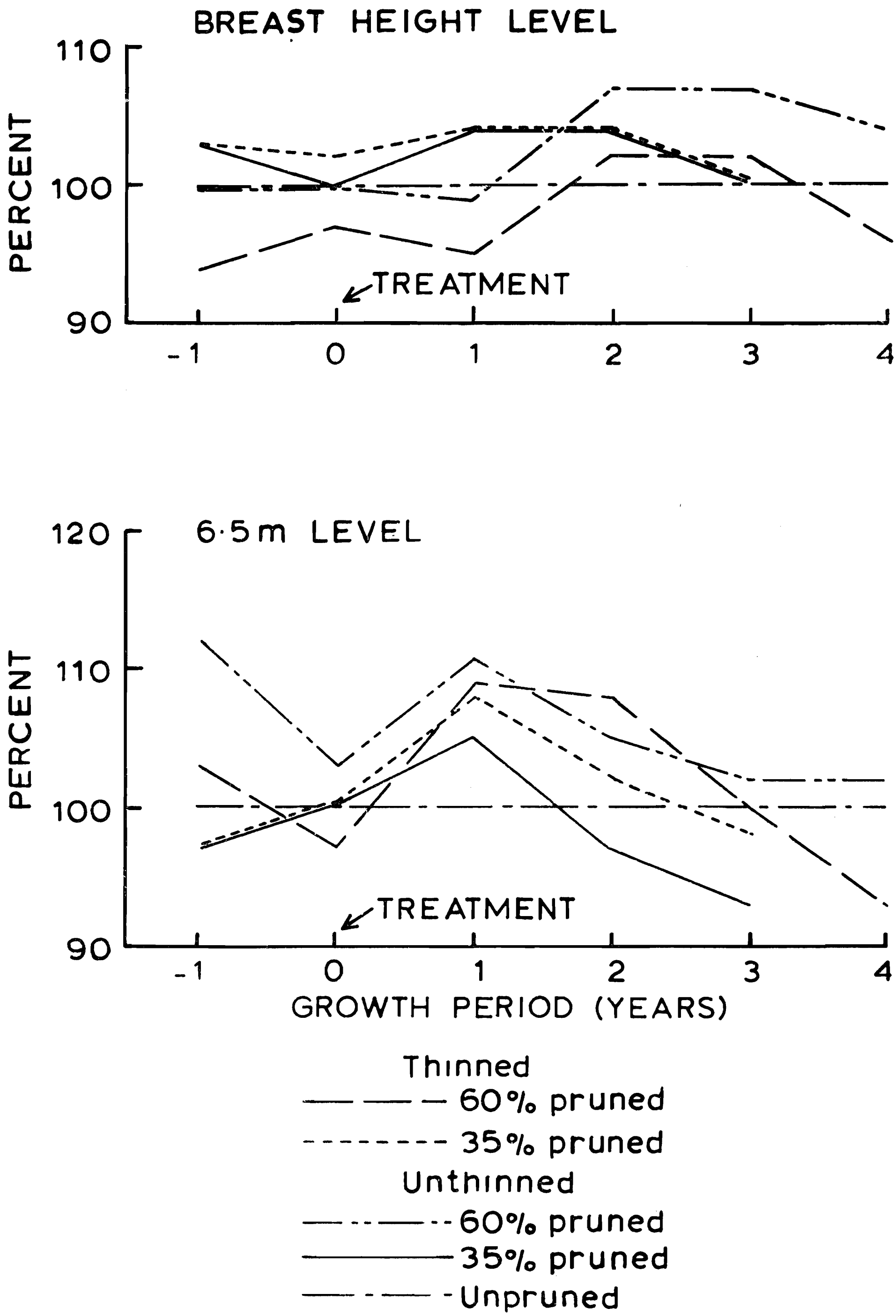

FIG. 3—The effect of thinning and pruning treatments on mean wood density, expressed as percentages of the control tree values.

increase of about 5% in density during the growth period following pruning which was maintained for 2 years. A similar trend occurred in the severely pruned trees at 6.5 m, but at breast height an increase of about 7% was apparent in the second year after treatment.

The means for density minima and maxima were examined in the same way, but no discernible differences could be attributed to the treatments. Thus the density variations observed were most likely a direct result of the changes in latewood percentage noted earlier.

Tracheid Length

The values determined for mean tracheid lengths are shown in Table 3.

TABLE 3—The effect of thinning and pruning on tracheid length

Sampling Position	Treatment		Tracheid Length mm				
	Thinning	Pruning	66/67	67/68	68/69	69/70	70/71
Breast height	Nil	Nil	2.30	2.50	2.65	2.89	3.10
	Nil	35% 68/69		2.70	3.09	3.22	3.24
	Nil	60% 67/68	2.29	2.57	2.85	3.09	3.17
	68/69	35% 68/69		2.77	2.87	2.97	2.96
	67/68	60% 67/68	2.39	2.69	2.50	2.48	2.57
6.5 m level	Nil	Nil	1.92	2.30	2.46	2.92	3.08
	Nil	35% 68/69		2.16	2.60	2.98	3.24
	Nil	60% 67/68	2.06	2.50	2.76	3.12	3.22
	68/69	35% 68/69		2.56	2.72	2.88	2.94
	67/68	60% 67/68	2.16	2.36	2.60	2.88	3.00

Tracheid lengths are increasing ring by ring in this part of the stem and the effect of thinning has been to reduce the rate of increase at breast height. Whereas the control tree values rose by 24% between 1967/68 and 1970/71, the thinned plots showed a combined mean increase of about 1%. The pruned but unthinned plots increased by 21% over the same period. It must therefore be concluded that pruning had no significant effect on tracheid length independent of thinning.

At the 6.5 m level, treatment differences were much less marked and of doubtful statistical significance.

DISCUSSION

The current trend in the management of radiata pine plantations is to increase value production through intensive cultural treatment and earlier harvesting (Fenton and

Sutton, 1968). It is inevitable that shorter rotations will yield wood of lower mean density and smaller mean tracheid length values, and the magnitude of this effect will depend on (a) the relative proportions of corewood and outerwood, and (b) the effects of the silvicultural treatments *per se* on intrinsic wood properties.

As far as wood density is concerned, the results presented here and in other studies confirm that the proportion of corewood to outerwood is likely to be by far the more important factor governing stem mean values in radiata pine. The greatest deviation in density from the control tree values recorded in this study was a temporary increase of about 7% in the severely pruned stems. This must be compared to the genetically controlled increase of 29% from pith to bark in the unthinned and unpruned trees. Over a rotation length of, say, 25 yr the effect of severe pruning or thinning on stem mean wood density (and, by inference, on intrinsic strength) would be insignificant at breast height and probably undetectable further up the stem. If, however, rotation length is to be determined by tree size rather than the number of years since planting, it is clear that heavily thinned stands will be ready for clearfelling at an earlier age than untended stands and will hence contain a greater proportion of low density corewood. Pruning would tend to counteract this trend towards lower mean density but the short-lived nature of the response would greatly reduce its effectiveness.

In contrast, tracheid length can be appreciably altered by the rate of radial growth. An examination of the ring width and tracheid length data for the years following treatment confirmed that some sort of negative relationship existed between the two properties at breast height. By 1970-71, the thinned trees were producing tracheids about 20% shorter on average than those in the unthinned trees. Thus both factors (a) and (b) above contribute towards a reduction in mean tracheid length in short rotation crops.

In the absence of data on the effect of tracheid length on timber strength or pulp quality in radiata pine, the significance of these results cannot be quantitatively evaluated. However, studies by workers overseas (e.g., Ifju and Labosky, 1972) have indicated that reduced tracheid length values are associated with reduced strength properties, at least as far as wood pulp is concerned.

The silvicultural treatments examined in this study were applied to young trees which were still within the corewood production phase at breast height, whereas previous reports have dealt with older and more slow-growing crops (Marts, 1951; Gerischer and de Villiers, 1963). Larson (1963) has suggested that environmental factors may operate differently on corewood and outerwood and that this effect is related to the distance between the tree crown and the site of wood formation. The results obtained from this study confirmed that responses to thinning and pruning treatments were far less apparent near the live crown than at breast height. This puts a restraint on the findings of workers using breast height samples only.

CONCLUSIONS

The results presented here have shown that the only significant change in intrinsic wood properties following thinning in young radiata pine was a reduction in tracheid length. Pruning did not have any consistent effect on tracheid length but tended to increase wood density slightly.

In practice, thinning and pruning schedules are likely to be less severe than those studied here and the resultant influence on intrinsic wood properties can be expected to have little technological significance. However, the effects of altering the proportion of corewood to outerwood (and probably also the proportion of heartwood to sapwood) could have important consequences with regard to timber strength and pulp characteristics, and this will be the subject of further study.

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