WOOD PROPERTIES OF *PINUS RADIATA* INFECTED WITH *DOTHISTROMA PINI*

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ABSTRACT

Wood properties were measured on 10 nine-year-old trees from each of the four spraying treatments (aqueous solutions of copper-based fungicides) applied to control **Dothistroma pini** infection of radiata pine in Sample Plot R919, Kaingaroa Forest. Wood samples were cut from levels in the stems corresponding to seven and four annual growth layers, and these were examined for wood density, shrinkage, green moisture content, growth rate, tracheid length, grain angle, resin content, pith diameter and bark thickness.

Significant differences in wood properties that could be related to the spray treatments were limited to some loss of diameter growth in unsprayed, heavily defoliated trees (more apparent in the upper than in the lower stem), and also a trend to increasing wood density in outer growth layers following severe defoliation.

INTRODUCTION

Dothistroma pini Hulbary, a needle blight of pine, probably became established in New Zealand in the late 1950s but was not identified until June 1964 (Gilmour, 1967). Since then the disease has become widespread, and epidemic build-up of this potentially disastrous pathogen has been averted only by extensive spraying with copper fungicides. Spraying schedules are not designed to prevent infestation completely, but to ensure that loss of foliage does not seriously reduce timber production (Gilmour and Noorderhaven, 1973). Thus, even in stands sprayed with fungicide at regular intervals, there will be periods when infection is active and crown foliage may be reduced by 25% to 30%.

Cown (1977) studied the effect of partial defoliation (in this instance by mechanical removal of needles) on wood properties of 5-year-old radiata pine. He found that ring width decreased, and percentage latewood and tracheid length increased, following defoliation. The effects were more marked in the second year after removal than in the first and it was found that removal of the current year's needles and 1-year-old needles had more effect than removal of 2- and 3-year-old needles. Response to defoliation was also greater at breast height than in the butt section.

Cown made the point that the sudden removal of specific ages of needles in the experimental treatment could be expected to have quite different effects on photosynthetic efficiency from those associated with the progressive shedding of needles from the base of the crown upwards as in *Dothistroma* infection. On the basis of the response to artificial defoliation, however, he suggested that increment loss in stands subjected to *Dothistroma* attack could possibly be accompanied by an increase in wood density and tracheid length of up to 25% for the annual rings concerned. At the same time it was pointed out that these "gains" would not compensate for the loss of increment and the longer rotation required to reach merchantable size.

There is another aspect which deserves consideration in regard to the possible effects of *Dothistroma* infection on wood properties. There is a possibility that the phytotoxins produced by the fungus, or the substances produced by the tree in response to infection, may affect wood production in the main stem, far removed from the small loci of infection in the needles. For all these reasons a very wide range of wood properties was examined to assess the effects of *Dothistroma* infection on timber produced by radiata pine.

MATERIAL

The trees used all came from Sample Plot R919 in Compartment 360 Kaingaroa State Forest. This is an area of radiata pine which was naturally regenerated in 1966 following clearfelling of the original crop — and was 9 years old at the time of testing. Four levels of treatment were examined:

Treatment A.T. 1: Sprayed at the rate of 56 litre/ha with 0.05 kg Cu per litre of water when defoliation exceeded 30% (3 times during 7 years).

Treatment A.T. 2: Sprayed at the rate of 56 litre/ha with 0.08 kg Cu per litre of water when defoliation exceeded 30% (3 times during 7 years).

Treatment A.T. 3: No spray; control. Needle loss varied from year to year but sometimes exceeded 60% on severely infected trees.

Treatment A.T. 4: Sprayed every year at the rate of 56 litre/ha with 0.08 kg Cu per litre of water.

Each treatment covered an area of 100 m × 270 m and was sprayed by fixed-wing aircraft. Within each treatment area nine sample plots measuring 20 m × 20 m were set up for assessment of the disease and its control, and 10 trees per treatment were selected at random from within these sample plots for the present study. Average heights of the trees and positions of samples taken from them are presented in Table 1.

In order to determine the optimum sampling patterns for assessing wood properties, one tree from the treatment involving annual spraying and one from the control were examined in detail. These trees were selected, following a preliminary survey using

TABLE 1—Average heights of trees and positions of samples taken from them for examination of wood properties

Treatment	Height (m) to:— 7 rings		4 rings		Top	
	Av.	S.D.	Av.	S.D.	Av.	S.D.
A.T. 1	1.8	0.27	6.2	0.68	11.9	0.68
A.T. 2	1.6	0.20	6.2	0.57	12.0	1.05
A.T. 3	1.6	0.40	5.8	0.62	11.7	1.45
A.T. 4	1.5	0.48	5.6	0.77	11.6	1.04

increment cores, as being representative of the two treatments both in respect of growth rate and wood density. The appropriate values measured from these trees were later incorporated into the final sampling pattern for all trees.

METHODS

For the preliminary study cross-sectional discs, 10 cm thick, were cut from about the mid-point of every annual height increment in each tree, to provide eight discs containing from 1-8 annual growth layers. The heights to each disc were recorded, and the following procedures adopted for assessing wood properties:

(i) Diameter i.b., bark thickness, pith diameter, and diameter of the drywood zone were measured on each disc.

(ii) Diametrically opposed sectors, approximately 3 cm thick, were cut from each disc. Samples were prepared to include all growth layers present, but when the disc contained more than five layers the balance was regarded as a second sample. These samples were used to measure basic, green, and air-dry densities, green moisture content, and also dimensional and volumetric shrinkages to air-dry and oven-dry.

(iii) A beta-ray densitometer was used to examine wood density variation from pith to bark along a radial strip taken from the discs containing 8, 6, 4, and 2 growth layers (Harris, 1969).

(iv) Tracheid length was measured on latewood macerations from every annual growth layer in the discs containing 8, 6, 4, and 2 growth layers (Harris, 1966).

(v) Spiral grain was measured in every annual growth layer in all discs using the samples in (ii) above after other measurements had been completed. To overcome problems of disc alignment, grain angle was expressed as the mean of the two values from opposing sectors (Nicholls, 1967).

(vi) Resin content (methanol-soluble extractives) was determined for sectors cut from discs containing 8, 6, 4, and 2 growth layers.

As a result of this preliminary examination it was decided that the two discs containing 7 and 4 annual growth layers would provide an adequate sample with which to assess the 40 trees used in the main study. The same wood properties were measured on these discs, with the exception that tracheid length was measured only for the outermost latewood in each disc, and resin content was compared only for the two extreme treatments A.T. 3 and A.T. 4.

RESULTS

Mean values for all wood properties examined, together with an analysis of variance, are presented in Table 2. Values of F greater than 2.85 indicate that differences associated with spraying treatments are significant at the 95% level of probability. On this basis the only wood properties that may have responded to the different levels of treatment are radial shrinkage and stem diameter in the samples containing four annual growth layers, and grain angle within the second annual growth layer of the seven-ring sample.

In view of the absence of any other significant effects on grain angle, it is probable that the only significant value has arisen by chance, as can be expected to happen once or twice in any array of 40 results. On the other hand it was a matter of simple

TABLE 2—Wood properties of radiata pine grown under different spraying regimes against **Dothistroma pini**

Wood property	Disc	Mean Value	Analysis of variance: Treatment or residual	df	MS	F*
Density (kg/m3)						
Green	7	1083	T	3	176.62	0.21
			R	36	824.75	
	4	1079	T	3	82.33	0.52
			R	35	158.10	
Air-dry	7	420	T	3	611.96	0.78
			R	35	784.20	
	4	379	T	3	1,001.97	1.92
			R	35	520.80	
Basic	7	350	T	3	436.16	0.86
			R	35	506.50	
	4	321	T	3	632.87	1.82
			R	35	347.13	
Moisture Content						
% Green	7	212	T	3	302.82	0.73
			R	36	412.62	
	4	237	T	3	776.69	2.33
			R	36	332.23	
Air-dry Shrinkage						
% Tangential	7	4.1	T	3	0.2169	0.93
			R	36	0.2330	
	4	2.8	T	3	0.1042	0.90
			R	36	0.1152	
% Radial	7	2.2	T	3	0.1089	0.92
			R	36	0.1184	
	4	1.9	T	3	0.1756	3.59
			R	36	0.0490	
% Longitudinal	7	0.07	T	3	0.009760	0.52
			R	36	0.018930	
	4	0.01	T	3	0.014970	1.12
			R	36	0.013300	
Oven-dry Shrinkage						
% Tangential	7	6.4	T	3	0.3963	0.82
			R	36	0.4858	
	4	4.7	T	3	0.7825	0.28
			R	36	0.2788	
% Radial	7	3.4	T	3	0.1817	0.79
			R	36	0.2309	
	4	3.1	T	3	0.3269	2.60
			R	36	0.1258	
% Longitudinal	7	0.18	T	3	0.034930	0.74
			R	36	0.046950	
	4	0.07	T	3	0.024280	0.98
			R	36	0.024870	
% Volumetric	7	9.5	T	3	0.2829	0.28
			R	36	1.0042	
	4	7.6	T	3	0.3029	0.59
			R	36	0.5138	
Tracheid Length (mm)	7	3.0	T	3	0.0553	0.59
			R	36	0.0935	
	4	2.7	T	3	0.1068	1.94
			R	36	0.0550	

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TABLE 2—Continued

Wood property	Disc	Mean Value	Analysis of variance: Treatment or residual	df	MS	F*
Bark Thickness (mm)	7	7	T	3	7.36	2.11
			R	36	3.49	
	4	3	T	3	0.17	0.45
			R	36	0.39	
Diameter i.b. (mm)	7	170	T	3	572.09	1.21
			R	36	473.21	
	4	106	T	3	507.30	2.91
			R	36	174.06	
Pith Diameter (mm)	7	4	T	3	6.16	1.92
			R	36	3.21	
	4	9	T	3	11.20	1.50
			R	36	7.44	
Grain Angle (°)						
Ring 2	7	4.0	T	3	18.7807	4.02
			R	36	4.6693	
Ring 3	7	4.1	T	3	4.3182	0.55
			R	36	7.8102	
Ring 4	7	4.2	T	3	0.7271	0.12
			R	36	6.0497	
Ring 5	7	4.1	T	3	4.4415	1.06
			R	35	4.1866	
Ring 6	7	3.0	T	3	3.1266	0.88
			R	36	3.5536	
Ring 7	7	3.5	T	3	3.0224	0.56
			R	36	5.3957	
Ring 2	4	6.6	T	3	4.0623	0.61
			R	35	6.6618	
Ring 3	4	5.4	T	3	8.0604	1.39
			R	36	5.7997	
Ring 4	4	4.2	T	3	19.4224	2.82
			R	36	6.8932	
Resin Content %		2.4	T	1	0.2392	1.77
			R	16	0.1348	

° F 2.85 for 95% probability

observation that annual growth layers were becoming narrower in the unsprayed trees of treatment A.T. 3 than in those from the sprayed areas, and that this effect was most marked in the discs containing 4 rings.

More detailed examination of wood density development using the beta-ray densitometer shows that, although the mean wood density values of Table 2 may not yet reflect differences due to treatment, there is nevertheless a trend towards production of higher wood density with increasing levels of *Dothistroma* infection (Fig. 1). Maximum density of the outer growth layer in the control trees is 680 kg/m^3 at the seven-ring level and 650 kg/m^3 at the four-ring level, compared with 650-660 kg/m^3 at seven rings and 570-610 kg/m^3 at four rings in trees that have been sprayed. Minimum density and mean density also tend to be 10 to 20 kg/m^3 higher in the control trees than in the sprayed trees.

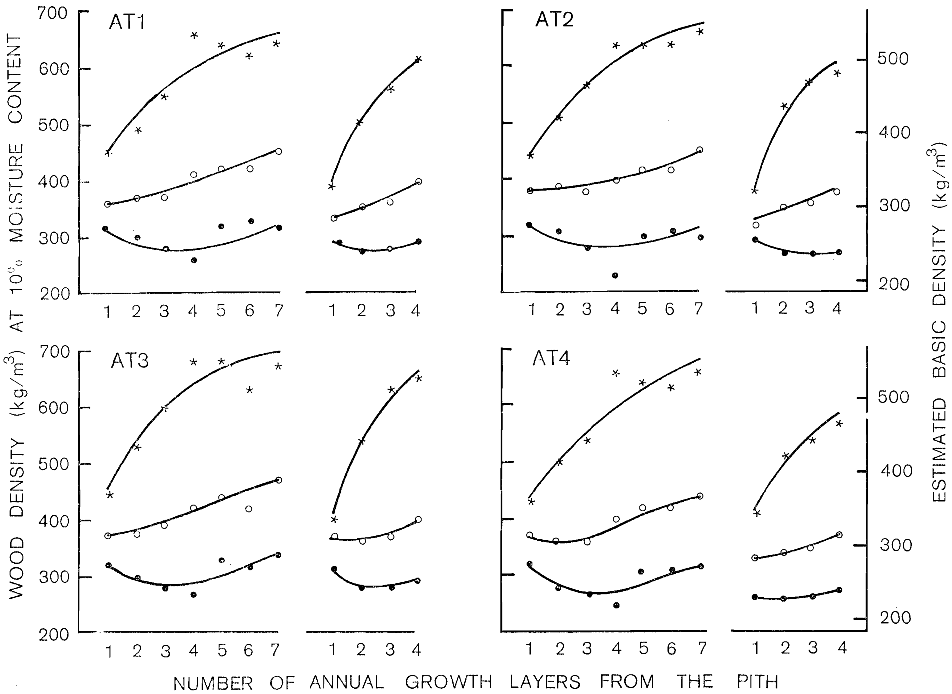

FIG. 1—Patterns of wood density variation by individual annual growth layers from the centre of the stem outwards. Each pair of graphs shows average values for the discs containing seven and four annual growth layers, for the 10 trees sampled in each treatment.
* * * maximum latewood density; ● ● ● minimum earlywood density; o o o mean density

DISCUSSION

Strictly speaking it is not possible to use the present study to assess the effects of *Dothistroma* infection on wood properties of radiata pine. All trees examined have been infected by *Dothistroma,* and most have at some time lost at least one quarter of their foliage in consequence. However, it is possible to compare the wood from these trees with that from trees which grew in the same forest before the advent of *Dothistroma* (e.g., Harris, 1965; Harris and Nash, 1972). Wood density values of the trees from the sprayed treatments are then seen to be very similar to those of uninfected trees. The same is true of tracheid length.

Turning to comparisons within the present study, the most notable feature is the very small effect that severe defoliation has had on wood properties when compared with that from the low levels of defoliation achieved by repeated spraying. The effects of losing all needles from the base of the crown up to 50 or 60% of crown volume are much less than those induced by mechanical removal of current year's or one-year-old needles (Cown, 1977). It appears that trees are able to adapt much more readily to progressive loss of lower crown foliage than to the sudden removal of young or developing needles.

One feature of the densitometric studies is also worth noting. Variations of wood density development about the smoothed trend lines that have been drawn in Fig. 1 are remarkably consistent. Every graph of wood density variation in the discs containing seven growth layers shows the same feature of high latewood density and low early-wood density in the fourth growth layer from the pith, followed by inverse patterns in the succeeding growth layers. Wood density patterns of this sort have often been associated with climatic variation (Polge, 1965; Nicholls and Wright, 1976): in this instance interest derives from the fact that different levels of defoliation have not interfered with this response.

The effects of severe *Dothistroma* infection on wood properties of young (9 years old) radiata pine are remarkably few, and appear to be limited to (a) some loss of diameter growth which is more marked in the upper than in the lower stem, and (b) a trend towards increasing wood density as growth rates decrease; this can be detected throughout the annual growth layer but effects are most marked in maximum (latewood) density. It is possible that the increase in wood density could be associated with a slight increase in radial shrinkage, but this is not regarded as being of any technological significance.

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