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WOOD PROPERTY VARIATIONS IN AN OLD-CROP STAND OF RADIATA PINE

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The study examined 10 52-year-old trees in considerable detail and described variations in moisture content, wood density, and tracheid length. Where meaningful, comparisons were made between properties within trees, between trees, and between density classes (low, medium, and high). An attempt was also made to segregate the trees into major components (sawn timber, pulpwood, and slabwood) and assign values of important wood properties. Basic densities averaged 380 kg/m^3 (range 339 to 419 kg/m^3) for sawn timber, 412 kg/m^3 (364–458 kg/m^3) for pulplogs, and 467 kg/m^3 (403–551 kg/m^3) for slabwood. Tracheid lengths averaged 3.5 mm (3.3-3.8 mm) for pulplogs and 4.0 mm (3.5-4.2 mm) for slabwood.

INTRODUCTION

From time to time concern is expressed in the pulp and paper industry over the possible repercussions of using raw material from crops of progressively younger ages as wood from the modern silvicultural regimes comes on stream. To answer some of the underlying questions, current research at the Forest Research Institute is aimed at investigating:

1. Relationships between silviculture and wood properties; and
2. Effects of varying wood properties on pulp and paper characteristics.

A study of wood and pulp relationships in old-crop radiata pine has recently been completed and the important wood quality aspects will be discussed in this paper.

MATERIALS AND METHODS

In order to ensure a wide range of raw material, it was decided to use old-crop samples, stratified by wood density classes and analysed by corewood and outerwood zones.

The sample crop was located in Compartment 1022 Kaingaroa State Forest planted in 1927 and untended. Initial survival has been good and stocking was high at the time of felling. A preliminary sample of breast height increment cores from 100 trees selected at random established the range in outerwood basic density (362–531 kg/m^3) and was used as the basis for the selection of 10 sample trees (3 low density, 4 medium density, and 3 high density) for intensive analyses of wood properties. Discs were taken from each stem from the 10-ring level to the butt at intervals representing 5 years' growth (5 rings) and used for detailed analyses of:

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(a) green moisture content,*
(b) wood density (green, air-dry, and basic),
(c) tracheid length (by maceration and measurement of whole cells),
(d) shrinkage (volumetric, tangential, radial, longitudinal: green to air-dry and green to oven-dry),
(e) heartwood development and resin content (by methanol extraction).

These properties were assessed on 5-ring wood samples cut from each disc from pith to bark, so that radial and vertical variations could be quantified. Only a, b, and c above are discussed in detail in this report.

RESULTS

Table 1 gives an overall summary of wood properties by tree components and it is readily apparent that wood characterstics vary significantly within stems.

Radial and vertical moisture content (M.C.) variations are shown in Figs 1 and 2. Heartwood M.C. was virtually constant at 40% and sapwood M.C. tended to increase somewhat from 135% in the lower half of the stem to 180% at the 10-ring level. Mean whole-tree M.C. was 95%, with the high density stems having slightly lower values (81%). As the slabwood portion was entirely sapwood it had the highest component M.C. at 140%. Sawn timber, being mostly heartwood, had a value of 60%.

TABLE 1—Summary of results for 50-year-old trees

Property	Sawn timber*	Pulplogs (< 350 mm s.e.d.)	Slabwood*	Whole-tree
Green density (kg/m³)	500	920	1100	816
Air-dry density (kg/m³)	448	489	560	503
Basic density (kg/m³)	380	412	467	420
Moisture content (%)	60	120	140	95
Tracheid length (mm)	2.7	3.5	4.0	3.5
Resin content (%)	4.5	2.3	1.5	2.9
Shrinkage (%)				
1. Green to 12% M.C.				
Volumetric	6.0			
Tangential	4.0			
Radial	2.0			
Longitudinal	0.02			
2. Green to oven-dry				
Volumetric	10.4			
Tangential	7.0			
Radial	3.4			
Longitudinal	0.25			

* Sawn timber and slabwood properties were estimated from sawlogs (> 350 mm s.e.d) using the detailed within-disc data

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* Defined as: $\frac{\text{Weight of water}}{\text{Oven-dry weight of wood}} \times 100$

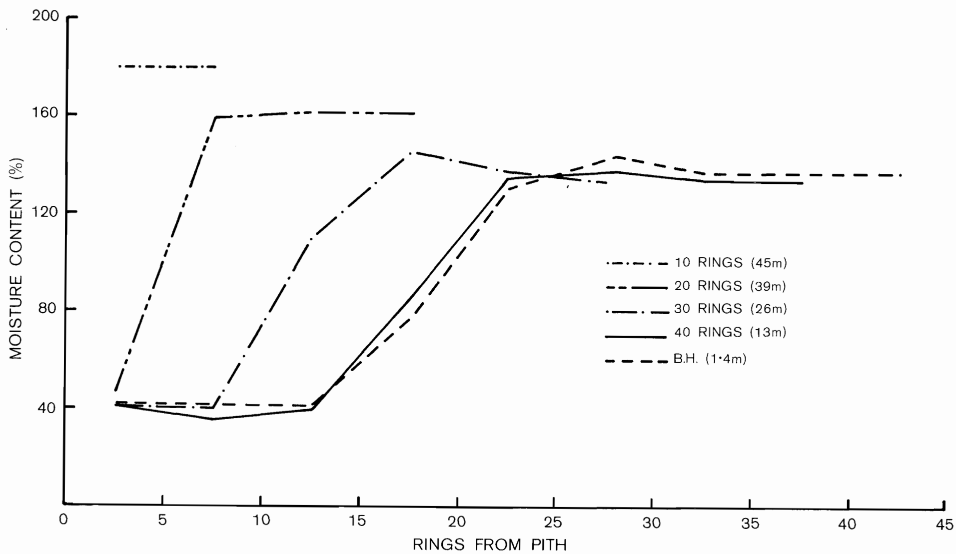

FIG. 1—Radial moisture content distribution.

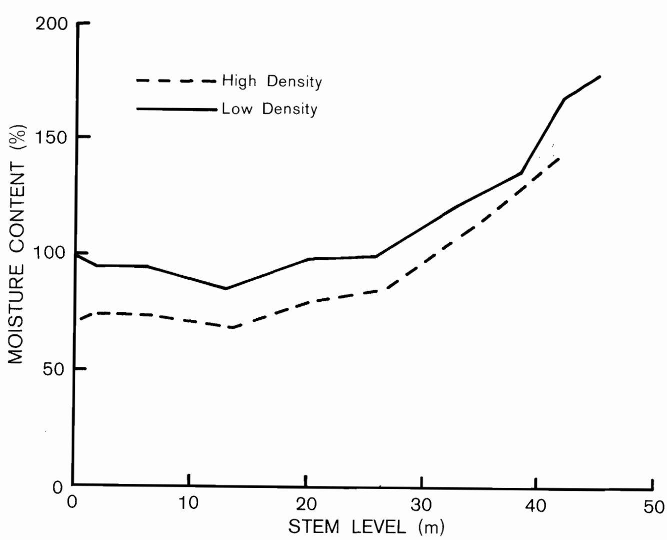

FIG. 2—Vertical moisture content distribution.

Wood density variation is shown in Figs 3, 4, and 5, and tree means are given in Table 2. Green density fluctuated around 800 kg/m^3 in the bottom 20 m of the stems and then rose steeply to around 1000 kg/m^3 at the 10-ring level as the proportion of heartwood decreased. The overall mean was 816 kg/m^3, with relatively little variation

TABLE 2—Tree mean densities

Density group	Tree no.	Density (kg/m³)		
		Green	Air-dry	Basic
Low density	15	802	439	370
	28	815	492	409
	39	753	470	393
Means		790	467	391
Medium density	21	876	519	433
	52	837	481	409
	81	804	487	406
	86	828	513	428
Means		836	500	419
High density	3	817	527	440
	19	805	555	461
	37	830	550	455
Means		817	544	452
Overall means		816	503	420

between trees (coefficient of variation — 3.7%). Basic density increased from the centre of the stem outwards in all cases (e.g., 386 to 480 kg/m^3 at breast height) and cross-sectional mean density decreased with increasing height in the tree (from 438 kg/m^3 at the butt to 367 kg/m^3 at 10-rings). The overall average basic density was 420 kg/m^3 (tree means 370–461 kg/m^3).

Tree component densities are given in Table 3. The highest values, naturally, are for slabwood (mean 467 kg/m^3; range 403–551 kg/m^3) and the lowest for sawn timber (mean 380 kg/m^3; range 339–419 kg/m^3). In these trees there was surprisingly little difference between sawlog and pulplog densities (425 and 412 kg/m^3 respectively). This was considered to be due to a combination of tree age and the relatively large pulplog diameter used (350 mm s.e.d.).

An aspect of interest to the pulp industry is the relationship between the green-wood weight and the yield of oven-dry wood. This was investigated on a tree mean basis (Table 4) and found to vary significantly between trees and density classes. The high density group yielded an average of 12% more dry wood than the low density group (553 and 495 kg/tonne respectively). Extreme yield values were 461 and 573 kg/tonne, or a 24% difference. The extent to which this effect operates between sites of varying wood density has not been researched but would clearly have implications for both sellers and buyers of pulpwood.

A summary of the tracheid length data is given in Figs 6 and 7. At all stem levels there was a sharp increase increase outwards within about 15 rings from the pith then a less marked trend in the outer rings. However, unlike the density patterns, there was a distinct increase in tracheid length with tree height, particularly in the outer rings. The culmination of this trend is that the longest cells are found in the outerwood at about half tree height (Fig. 7).

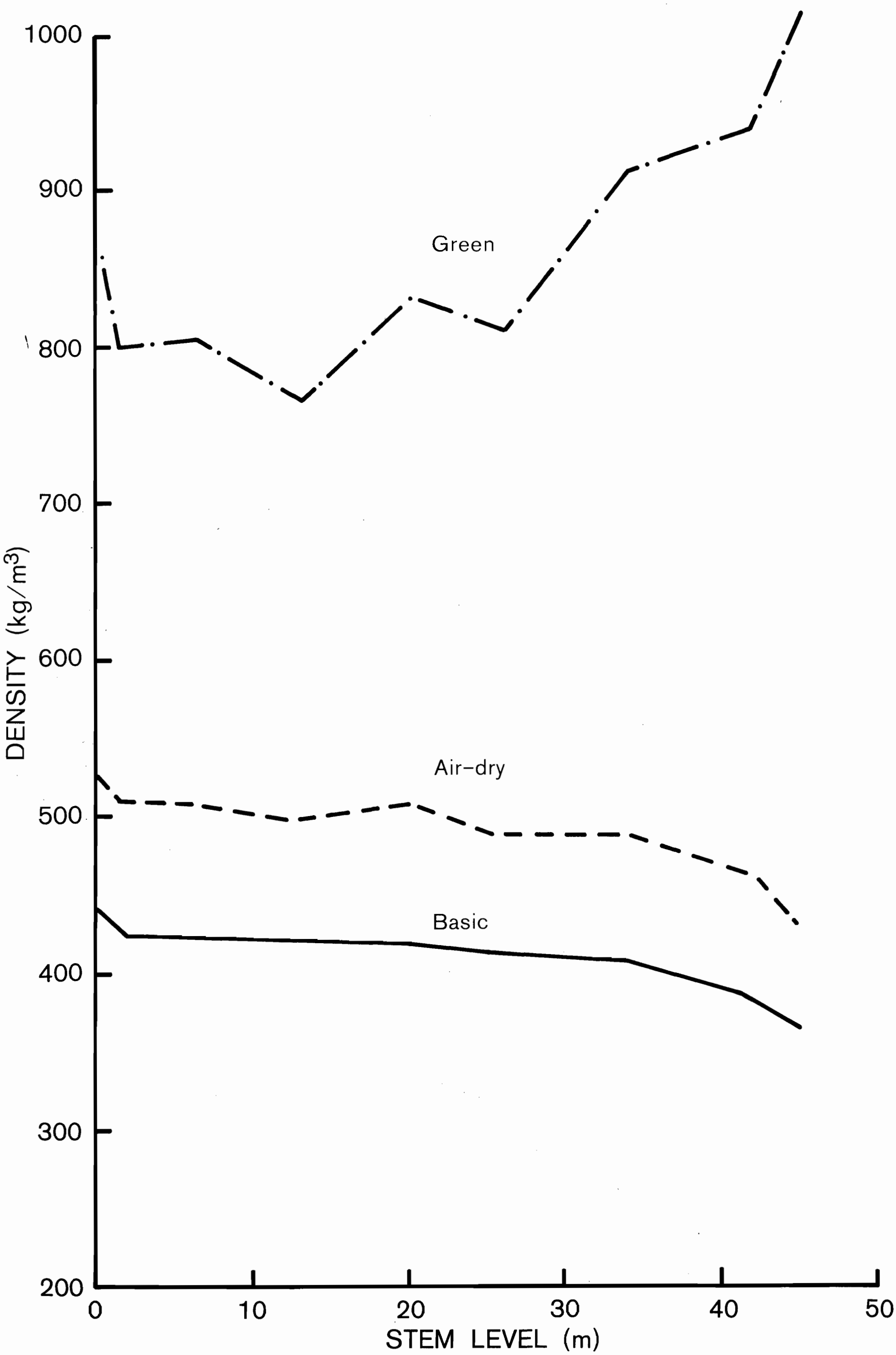

FIG. 3—Vertical density distribution.

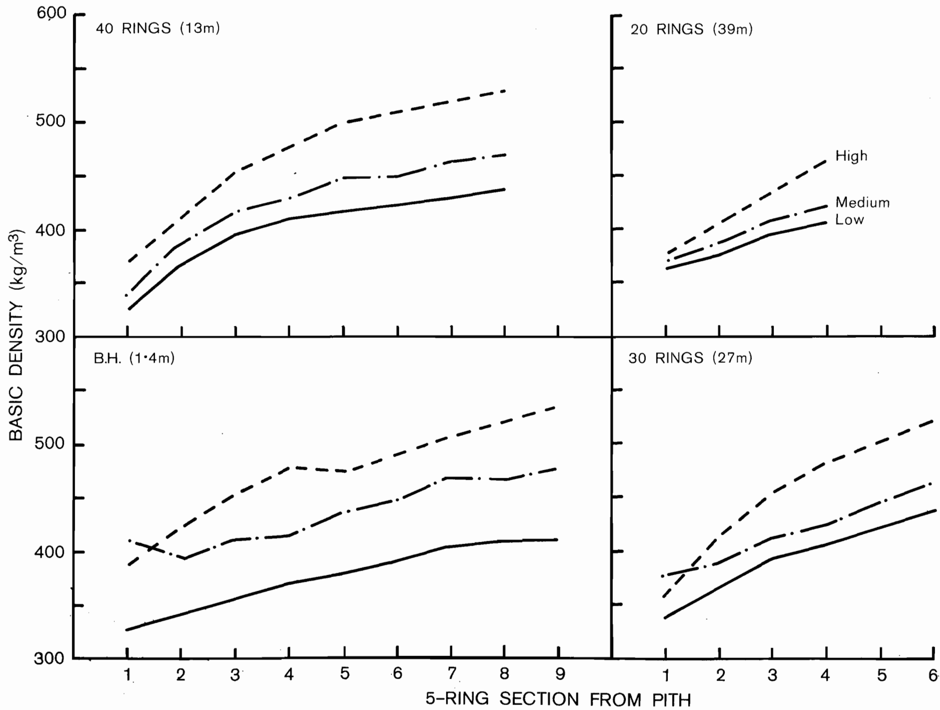

FIG. 4—Radial density variation by stem level and density class.

Table 5 gives estimates of tracheid lengths for the slabwood and pulplog components and shows an average difference of 0.5 mm in this material (4.0 and 3.5 mm respectively).

Tables 6 and 7 give tree mean wood properties and a correlation matrix for wood characteristics. Tree volume was inversely related to basic density to the extent that 40% of the variation in tree density was associated with stem size. This correlation is stronger than was anticipated on the basis of previous work and warrants further investigation in view of its implications for tree breeding. Air-dry and basic densities were prefectly correlated but green density was not significantly related to either of these. Only heartwood content was found to influence green density in this sample ($r^2 = 0.49$). Moisture content and density (air-dry and basic) were strongly negatively related, a reflection of the fact that the sapwood percentage saturation (M.C. as a percentage of the maximum possible M.C. at a given basic density) was virtually constant in all trees at 90%. Despite the fact that heartwood percentage and moisture content were highly related, the amount of heartwood did not appear to have affected the M.C./density relationship to an important degree. Neither tracheid length nor resin content were significantly associated with the other variables on a tree mean basis.

The yield of dry wood was very highly significantly correlated with density (air-dry and basic only), heartwood content, and moisture content. It is of some interest that green density and yield were not related.

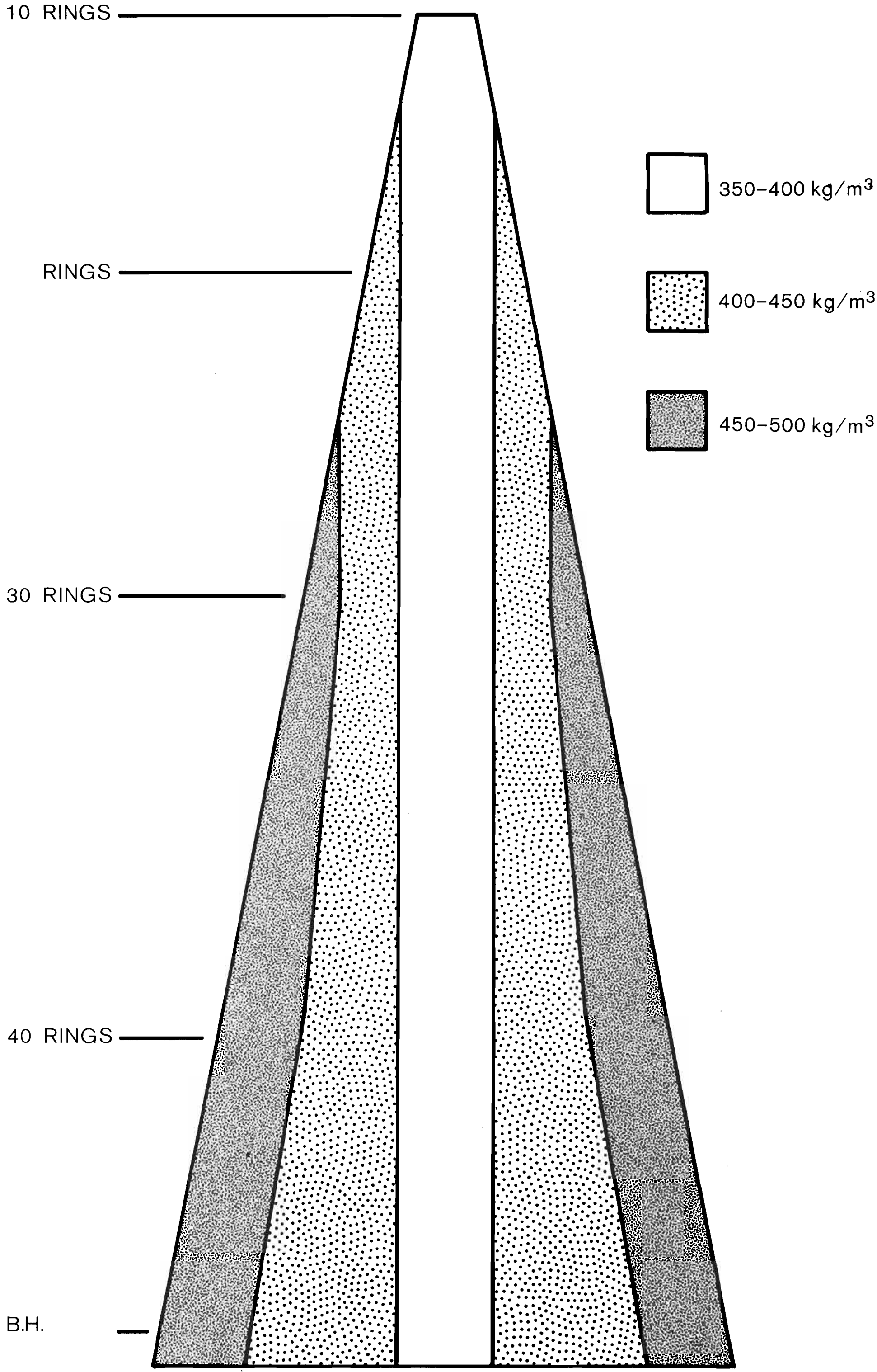

FIG. 5—Within-tree density distribution.

TABLE 3—Tree component densities

Density group	Tree no.	Basic densiy (kg/m³)					
		BH outer	Slab-wood	Sawlogs (>350 mm)	Pulpwood (<350 mm)	Sawn timber	Whole tree
Low	15	369	403	371	364	339	370
	28	395	443	409	418	375	409
	39	400	438	394	389	350	393
Means		388	428	391	384	355	391
Medium	21	460	461	435	425	409	433
	52	462	459	412	394	401	409
	81	464	453	413	391	373	406
	86	461	463	431	416	399	428
Means		462	459	423	407	381	419
High	3	522	510	456	423	402	440
	19	521	551	469	439	387	461
	37	511	489	454	458	419	455
Means		518	517	460	440	403	452
Overall means		456	467	425	412	380	421

Prediction equations for tree component densities		r	SE
Slabwood	= B.H. outerwood density × 0.69 + 154	0.90	18
Sawlogs	= B.H. outerwood density × 0.53 + 184	0.94	11
Pulpwood	= B.H. outerwood density × 0.39 + 234	0.75	18
Timber	= B.H. outerwood density × 0.38 + 213	0.78	16
Tree	= B.H. outerwood density × 0.47 + 205	0.90	12

TABLE 4—Yield of dry wood/green tonne

Tree class	Tree no.	Basic density (kg/m³)	Green density (kg/m³)	Moisture content (%)	Yield/green tonne* (kg)
Low density	15	370	802	117	461
	28	409	815	99	502
	39	393	753	92	522
Means		391	790	103	495
Medium density	21	433	876	102	494
	52	409	837	105	489
	81	406	804	98	505
	86	428	828	93	517
Means		419	836	99	501
High density	19	461	805	75	573
	37	455	830	82	548
Means		452	817	81	553
Overall means		420	816	95	515

$$* \text{ Yield/green tonne} = \frac{\text{Basic density}}{\text{Green density}} \times 100$$

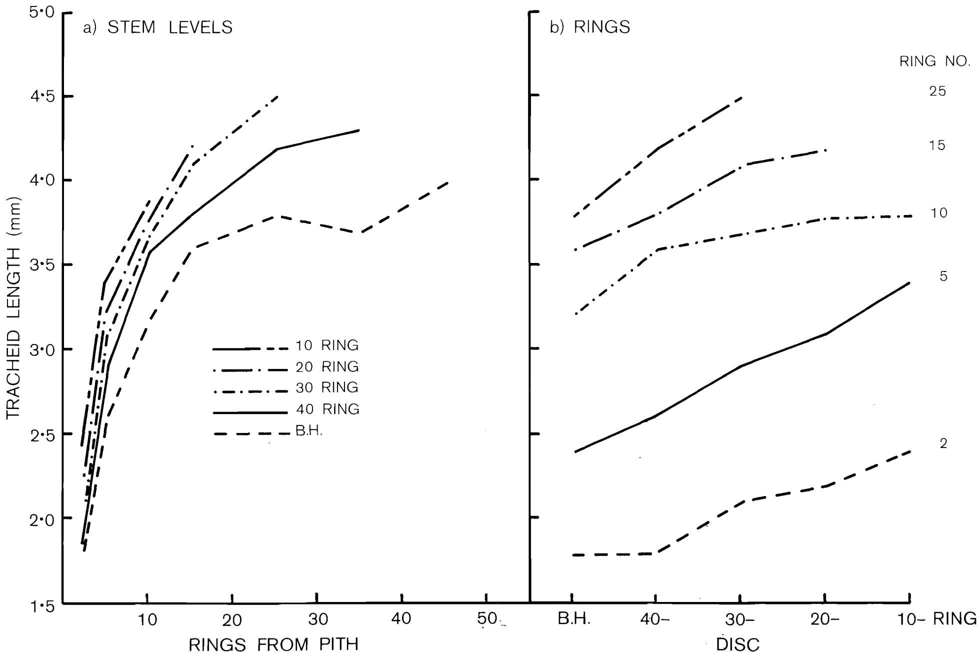

FIG. 6—Tracheid length distribution.

TABLE 5—Tree component tracheid lengths

Density group	Tree no.	Tracheid lengths (mm)		
		Slabwood	Pulplog	Tree mean
Low density	15	3.9	3.4	3.5
	28	4.2	3.6	3.5
	39	4.2	3.4	3.5
Means		4.1	3.5	3.5
Medium density	21	4.1	3.3	3.4
	52	4.1	3.6	3.5
	81	4.0	3.5	3.5
	86	4.1	3.5	3.6
Means		4.1	3.5	3.5
High density	3	3.5	3.5	3.3
	19	4.4	3.8	3.7
	37	3.7	3.4	3.3
Means		3.9	3.6	3.4
Overall means		4.0	3.5	3.5

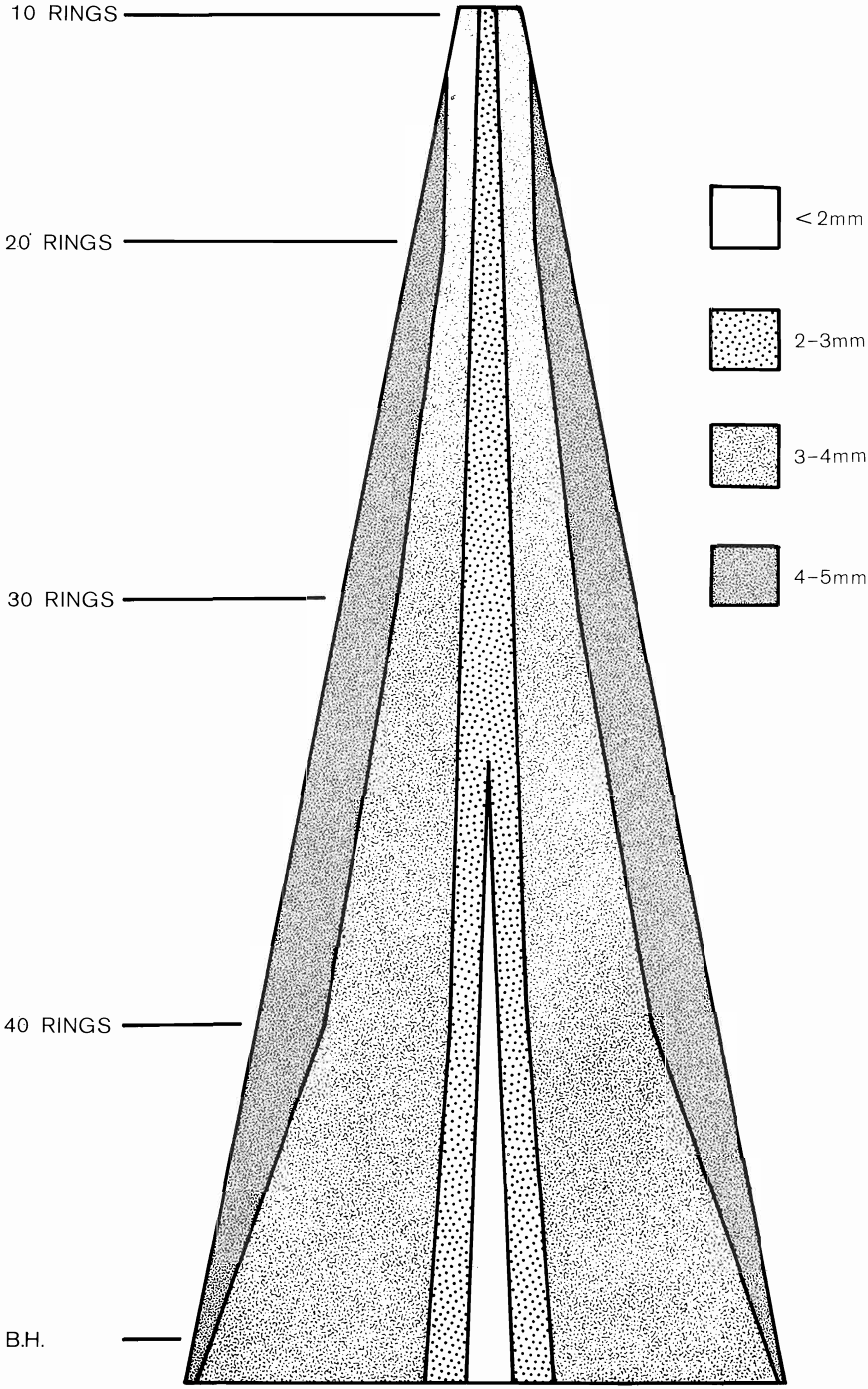

FIG. 7—Within-tree tracheid length distribution.

TABLE 6—Sample tree mean properties

Density group	Tree no.	DBH (cm)	Vol. (m^3)	Density (kg/m^3) Green	Air-dry	Basic	Tracheid length (mm)	Heart-wood (%)	Moisture content (%)	Resin content (%)	Yield (kg/tonne)
Low density	15	79.0	8.25	802	439	370	3.5	40	117	2.3	461
	28	75.0	6.74	815	492	409	3.5	44	99	1.8	502
	39	81.0	8.36	753	470	393	3.5	51	92	5.5	522
Means		78.3	7.78	790	467	391	3.5	45	103	3.2	495
Medium density	21	71.5	7.13	876	519	422	3.4	36	102	3.6	494
	52	63.0	4.72	837	481	409	3.5	40	105	2.3	489
	81	54.0	4.25	804	487	406	3.5	45	98	1.9	505
	86	74.0	6.63	828	513	428	3.6	45	93	2.5	517
Means		65.6	5.68	836	500	419	3.5	42	99	2.6	501
High density	3	54.0	4.03	817	527	440	3.3	46	86	2.7	538
	19	63.5	4.63	805	555	461	3.7	52	75	2.8	573
	37	62.0	4.74	830	550	455	3.3	48	82	3.7	548
Means		59.8	4.47	817	544	452	3.4	49	81	3.1	553
Overall means		67.7	5.95	816	503	420	3.5	45	95	2.9	515

TABLE 7 — Wood properties correlation matrix

Variable	Density			Tracheid length	Heartwood	Moisture content	Resin	Yield
	Green	Air-dry	Basic					
DBH	— 0.25	— 0.50	— 0.53	0.30	— 0.12	0.42	0.36	— 0.41
Volume	— 0.25	— 0.60*	— 0.63*	0.17	— 0.23	0.53	0.40	— 0.52
Green density		0.48	0.41	— 0.28	— 0.70*	0.14	— 0.34	— 0.16
Air-dry density			0.99**	—0.11	0.38	— 0.86**	0.08	0.85**
Basic density				—0.10	0.35	— 0.84**	0.06	0.83**
Tracheid length					0.26	— 0.04	— 0.20	0.08
Heartwood						— 0.79**	0.36	0.81**
Moisture content							— 0.29	— 0.99**
Resin content								0.28

* Significant at the 5% level

** Significant at the 1% level

DISCUSSION AND CONCLUSIONS

The 10 trees examined in this study were deliberately chosen to cover the range of wood properties in a stand of old-crop radiata pine and thus provide the background against which the produce from intensively managed stands can be compared.

The examination of tree stems in terms of their major components is considered to be a valuable extension of the descriptive work carried out in the past (radial and vertical patterns). However, the type of results obtained depend on the definitions used for sawlogs and pulplogs.

The results presented above refer to a specific site and a specific tree age and it is clear from the within-tree patterns described that properties are significantly affected by tree age. In particular, the slabwood component, comprising the oldest wood at each stem level, will be sensitive to stand age. In general, the younger the trees the lower will be the slabwood basic density and the shorter the cells. As trees age, the basic density increases but green density decreases as heartwood develops. The data emphasise the fact that the green weight of wood is not a good indicator of the yield of dry wood, as moisture content and basic density are closely negatively related.

Future studies will continue to examine the influence of rotation age, silviculture, and site on tree component properties and their relationships with pulp and paper quality.