CALMScience 3(3):309–315(2000)

Wood density of improved compared with unimproved maritime pine (*Pinus pinaster*)

P. HILL*

CALM Timber Technology, PO Box 505, Harvey, WA 6220.
* Present address: CALM, Dwellingup, WA 6213.

SUMMARY

In a preliminary study, wood density was assessed in eleven pairs of seed orchard origin ('pedigreed') and adjacent unimproved ('routine') maritime pine trees (P1973). Although pedigreed trees produced 19 per cent greater volume, basic and air-dry densities of pedigreed and routine maritime pine were similar. The weighted mean basic density for both pedigreed and routine samples was 448 kg m^{-3}, and weighted mean air-dry density was 548 kg m^{-3} and 546 kg m^{-3} respectively.

The trend of decreasing basic and air-dry density with increasing height up the tree, resulting from the increasing proportion of juvenile wood to mature wood with increasing height, was confirmed. The high density observed in growth rings 1–5 was presumably caused by the high concentration of resin-laden heartwood in this area. With resin extracted, the density trend from the pith would presumably increase consistently to the outside of the tree. Shrinkage measurements of the five-ring segments indicated little difference between pedigreed and routine trees.

INTRODUCTION

Maritime pine (*Pinus pinaster*) is a major plantation timber species in Western Australia (WA). Currently there are about 27 000 ha of maritime pine, mainly in coastal regions just north of Perth. CALM's strategic plan is to establish a minimum 150 000 ha of the species over the next 10 years, in 400–600 mm rainfall areas in the Wheatbelt. The plantations would assist in reducing salinity effects while providing a commercial crop.

Since 1972 all maritime pine plantations in WA have been established using genetically-improved trees, and the older plantations are reaching maturity. With the proposal to significantly increase planting, it is important to reassess the wood properties of these improved pines, which were originally selected for vigour, stem straightness, and small branches at right angles to the trunk.

Most sawlogs produced from the genetically-improved maritime pine are expected to be used for structural products. Wood density is generally considered to be the best predictor of strength (Zobel and Talbert 1984), and it is important to know whether the density of improved maritime pine is different from that of the unimproved trees that form the bulk of older plantations. The proposal for a laminated veneer lumber (LVL) plant in WA, which will utilize the current maritime pine plantations as well as future plantations, has increased the need to collect available data on the wood properties of maritime pine.

The aim of this preliminary trial was to assess the basic and air-dry density at different heights in the tree, and distances from the pith, as well as shrinkage rates of improved, seed orchard origin (pedigreed) and adjacent unimproved (routine) maritime pine trees at age 25 years. Tangential and radial shrinkage measurements of improved and unimproved maritime pine were compared.

METHODS

Log Collection

Eleven pairs of trees from Yanchep Compartment 12 (P1973) were selected. One tree of each pair was an improved tree of known pedigree, while the other tree was an unimproved routine tree growing adjacent and having similar dominance status. On average, the pedigreed trees had 19 per cent greater volume, were 35 per cent straighter, and mean branch size was 31 per cent less than the routine trees (Butcher[1], personal communication). All trees selected were at least three rows from the Compartment boundary, and each tree was clearly identified with a number indicating the pair (1 to 11), with a first letter (P or R) indicating pedigreed or routine, and a second random letter.

Prior to felling breast height was marked on each tree (1.3 m above ground, high side). Trees were felled and each was docked into a 10 m butt log and a 4 to 7 m crown log (minimum small end diameter was 100 mm). Each log was clearly marked with its identification number.

[1] Mr T. Butcher, Department of CALM, Kensington WA 6152.

Logs were stored at CALM Timber Technology, with bark on and under water sprays to prevent premature drying.

Disc Sampling

Discs were cut at six or seven heights (1.3, 2.4, 4.8, 7.2, 9.6, 12.0 and 14.4 m above ground). At each sample position a 100 mm thick disc was cut from the logs and clearly labelled with tree identification number and height in the tree. Using the *Wadkin* bandsaw, two vertical cuts were made through the disc at the shortest diameter to produce a 30 mm wide strip with centred pith (the longest diameter was avoided because it generally contains compression wood). The orientation of this cut was changed on occasions to avoid branch stubs.

Wood basic density was to be assessed in five-year age groups, starting from the pith, (i.e., 1–5, 6–10, 11–15, 16–20, 21–25 growth rings). The first two groups represent the juvenile corewood, while mature wood is laid down from age 11 years. Consequently, each five-year group of growth rings was marked on the strip, and specimen sections cut using the radial arm saw. With fewer than four rings in the last group, the specimen was measured with the previous five-year group. Each specimen was labelled with the tree number, height group and cambial age group. The cut specimens were block-stacked and wrapped in plastic to minimize drying.

Density Measurements

Specimens were removed from their plastic wrapping and checked to confirm correct identification and numbering. Green volume for basic density determination was calculated after digital Vernier calipers (accuracy of 0.01 mm) were used to measure the length, width and thickness of each specimen. The data were recorded on an *Excel* spreadsheet.

Specimens were then dried to 12 per cent moisture content (MC) in an environmental moisture content (EMC) controlled room, initially set to obtain an EMC of 10 per cent to provide a drying gradient. When all specimens were around 12 per cent, the EMC setting was adjusted to this figure. After the specimens were air-dried their weight, length, width and thickness were measured and recorded. They were then oven-dried to constant weight at 103±2 °C for 24 to 48 hours, and re-weighed to obtain the oven-dry weight.

From the air-dry and oven-dry weights, the air-dry moisture content of each specimen was calculated. Basic and air-dry density were calculated, and weighted averages were calculated from the cross-sectional area in concentric circles, based on each 35 mm length core section.

Shrinkage Measurements

One radial face (i.e., perpendicular to the growth rings) and one tangential face (i.e., parallel to the growth rings) were marked in the centre of each specimen, for measurement of shrinkage. The centreline along one of the two selected faces was also marked for the measurement of longitudinal shrinkage. The green dimensions at these selected points were also measured using Vernier calipers.

The mass of each specimen was measured to an accuracy of 0.001 g after the shrinkage measurements had been taken. Extra sections were used as sample boards to monitor the moisture content loss. The specimens were placed on strip sticks and allowed to dry in the EMC room, with a circulation fan operating to provide air flow around the samples.

When the sample boards were air-dry (mean 12 per cent MC) the dimensions at the three selected points and the mass of each specimen were re-measured. Specimens were then oven-dried as described above.

RESULTS AND DISCUSSION

The mean weighted basic densities for both pedigreed and routine samples were 448 kg m^{-3}, and the mean weighted air-dry densities were 548 kg m^{-3} and 546 kg m^{-3} respectively. These results indicated that the increased volume production, improved stem straightness, and smaller branches of pedigree maritime pine did not affect either basic or air-dry density. The pedigreed samples obviously had five-ring specimens that were longer than those of the routine samples.

Table 1 shows that mean weighted values of both basic and air-dry density decrease with increasing height up the tree, as expected. Basic density for pedigree and routine maritime pine decreased from 512 kg m^{-3} and 496 kg m^{-3} respectively at the base of the tree to 394 kg m^{-3} and 375 kg m^{-3} respectively at the highest measured point of 14.4 m. Similarly, air-dry density of pedigree and routine maritime pine decreased from 614 kg m^{-3} and 600 kg m^{-3} at the base of the tree to 468 kg m^{-3} and 499 kg m^{-3} respectively at 14.4 m above ground level.

Juvenile wood in conifers has shorter, thinner-walled, larger diameter fibres, with lower percentage latewood and lower density than in the more mature outer wood (AFRDI 1997). Generally the first 10 years of growth is considered to produce juvenile wood, with mature wood produced after that age. The proportion of juvenile wood to mature wood increases with increasing height in the tree, and the mean density at each height therefore decreases with increasing height up the tree as shown in Table 1.

The mean wood density results for samples taken at different cambial ages (1–5, 6–10, 11–15 and 16+ rings) are shown in Table 2. The density of samples is lowest between growth rings 6–10, with basic densities 435–440 kg m^{-3} and air-dry densities 521–536 kg m^{-3}, increasing with age to 524–526 kg m^{-3} and 608–618 kg m^{-3} respectively at 16+ growth rings. The higher densities of growth rings 1–5 can be explained by the higher resin contents close to the heart. Extracting resin would be expected to result in a pattern of uniform increase in density from the pith (rings 1–5) to the circumference (rings 16+).

Wood density of pedigree and routine maritime pine samples at different heights and ages is shown in Figures 1 and 2, and detailed data are given in Appendix 1.

TABLE 1

Weighted wood density of samples from different heights up the tree (kg m^{-3}).

	HEIGHT IN TREE (m)													
	1.3		2.4		4.8		7.2		9.6		12.0		14.4	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Basic density (kg m^{-3})														
Pedigreed	512	31	482	25	470	22	453	25	438	23	409	19	394	23
Routine	496	45	473	32	464	19	445	16	432	27	396	12	375	25
Air-dry density (kg m^{-3})														
Pedigreed	61	438	585	30	565	25	575	102	550	96	487	24	468	29
Routine	600	44	575	31	560	47	533	18	512	28	503	77	508	100

TABLE 2

Wood density (kg m^{-3}) of pedigreed and routine maritime pine at different cambial ages.

	GROWTH RINGS							
	1–5		6–10		11–15		16+	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Basic density (kg m^{-3})								
Pedigreed	458	51	440	44	464	44	524	51
Routine	452	53	435	43	463	51	526	74
Air-dry density (kg m^{-3})								
Pedigreed	567	81	536	78	556	68	618	56
Routine	559	59	521	50	549	50	608	86

The Figures show there was little difference in density between pedigree and routine maritime pine, but that both basic and air-dry density decreased with increasing height in the tree. The increasing density with increasing cambial age from growth rings 6–10 through to 16+ and the high density of the resin-laden growth rings 1–5 are shown. The extraneous high density figure for the 16+ samples at 4.8 m in both basic and air-dry density for the routine maritime pine is owing to a single sample, with obvious localized high resin content.

Regression analysis (including calculating coefficients of determination) was used to determine the linear relationship between the density at breast height and overall density, and whether the former measure could be used as an accurate predictor of overall density. A weak relationship ($R^2 = 0.43$) was found between air-dry density at breast height and the air-dry density of the whole tree. A much stronger relationship ($R^2 = 0.86$) was found between basic density at breast height and the basic density of the whole tree, suggesting that the former is a satisfactory predictor of whole tree density.

The mean tangential, radial and longitudinal shrinkages at 12 per cent MC for pedigreed maritime pine were 7.0 per cent, 4.3 per cent and 0.1 per cent respectively. For routine maritime pine the mean tangential, radial and longitudinal shrinkages were 6.8 per cent, 4.3 per cent and 0.1 per cent respectively. The mean tangential and radial values are greater than standard published figures of 5.0 per cent and 3.0 per cent respectively before reconditioning (Kingston and Risdon 1961), because of the small size of five-ring segments.

The tangential and radial shrinkages of each five-ring segment are given in Table 3 with detailed data in Appendix 2, indicating a trend of increasing shrinkage with increasing distance from the pith. While the five-ring specimens from pedigreed trees were slightly longer than those from routine trees, because of faster growth rates, there is little difference overall. The high standard

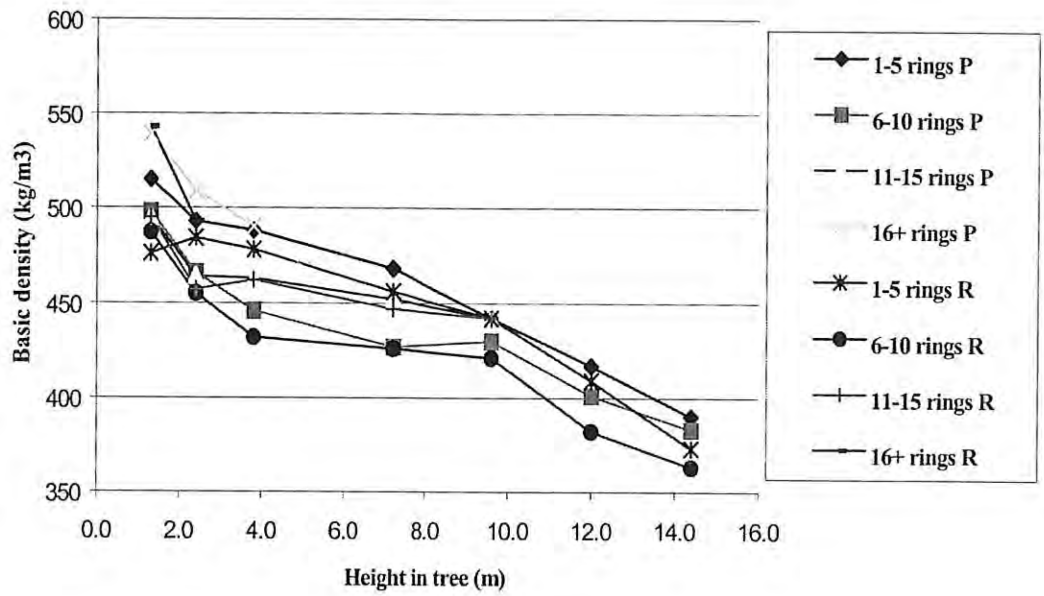

Figure 1. Effect of height in tree on basic density of pedigreed and routine maritime pine (P73).

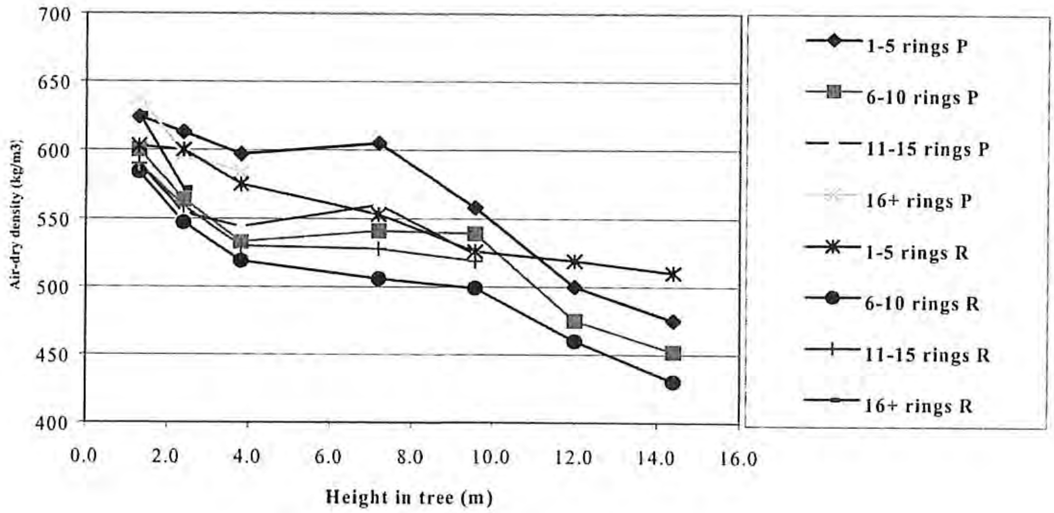

Figure 2. Effect of height in tree on air-dry density of pedigreed and routine maritime pine (P73).

TABLE 3

Shrinkage (%) of pedigreed and routine maritime pine at different cambial ages .

	GROWTH RINGS							
	1–5		6–10		11–15		16+	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Tangential shrinkage (%)								
Pedigreed	5.3	1.4	7.2	1.2	8.5	1.2	8.9	1.3
Routine	5.5	1.2	7.0	1.1	7.7	1.0	7.5	0.8
Radial shrinkage (%)								
Pedigreed	3.9	1.2	4.6	1.3	5.1	2.0	5.4	2.5
Routine	3.8	1.0	4.3	1.3	4.8	2.0	5.5	1.9

deviations indicate that there was considerable variation between trees.

In summary, the wood density and shrinkage assessment of eleven maritime pine trees (P73) of seed orchard origin and eleven adjacent unimproved trees gave similar results, which is encouraging. Although there has been significant improvement in volume production and significant increase in timber volume in pedigreed trees, the basic and air-dry density between pedigreed and unimproved maritime pine has remained the same.

There was the expected trend of decreasing basic and air-dry density with increasing height up the tree, because of the decreasing proportion of mature to juvenile wood with increasing height. The high density observed in growth rings 1–5 was presumably caused by the high concentration of resin-laden heartwood in this area. There was little difference in either tangential or radial shrinkage between pedigreed and routine pine.

REFERENCES

AFRDI (1997). *Australian Timber Seasoning Manual*. 3rd edn. Australasian Furnishing Research and Development Institute Ltd, Launceston.

Kingston, R.S.T. and Risdon, C.J.E. (1961). Shrinkage and density of Australian and other South-west Pacific woods. CSIRO Division of Forest Products. *Technological Paper* No. 13.

Zobel, B and Talbert, J. (1984). *Applied forest tree improvement*. John Wiley and Sons, New York.

APPENDIX 1

Basic and air-dry densities (kg m^{-3}) of five-ring segments of pedigreed and routine maritime pine at different heights (m) in the tree.

	1.3		2.4		4.8		7.2		9.6		12.0		14.4	
GROWTH RINGS	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
							Basic density (kg m^{-3})							
Pedigree														
1–5	515	46	493	40	488	31	468	28	442	26	417	23	390	24
6–10	498	40	466	34	446	37	427	21	430	24	401	24	383	18
11–15	495	43	464	31	463	38	452	54	442	45				
16+	539	58	509	42	490	50								
Routine														
1–5	476	80	484	39	478	28	456	25	442	26	409	23	373	43
6–10	487	47	455	31	432	24	426	20	421	37	382	10	363	
11–15	495	56	457	61	462	47	447	30	442	47				
16+	543	93	493	52	595									
							Air-dry density (kg m^{-3})							
Pedigree														
1–5	624	61	613	52	597	39	575	37	558	83	500	31	475	35
6–10	600	41	564	51	533	48	512	27	506	28	475	28	452	23
11–15	590	51	554	26	544	42	529	66	524	52				
16+	638	64	597	37	584	63								
Routine														
1–5	603	50	600	40	575	37	553	26	526	32	519	74	510	98
6–10	584	46	547	35	519	32	506	24	499	37	460	17	430	-
11–15	590	53	559	47	530	37	528	34	519	51				
16+	595	74	572	75	686									

APPENDIX 2

Tangential and radial shrinkages (%) of five-ring segments of pedigreed and routine maritime pine at different heights (m) in the tree.

	1.3		2.4		4.8		7.2		9.6		12.0		14.4	
GROWTH RINGS	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
							Tangential shrinkage (%)							
Pedigree														
1–5	5.7	1.5	5.6	1.9	5.0	1.4	5.2	1.6	5.1	1.5	5.4	0.8	5.3	1.1
6–10	7.9	1.2	8.4	1.1	7.6	1.4	7.3	1.3	6.7	1.4	6.8	1.4	6.0	0.9
11–15	9.1	1.1	9.1	0.8	8.2	1.3	8.1	1.2	7.9	1.6				
16+	8.5	1.3	9.0	1.5	9.3	1.2								
Routine														
1–5	5.8	1.6	5.9	1.4	5.6	1.4	5.4	1.0	5.2	1.2	5.3	1.0	5.2	0.7
6–10	7.7	0.9	7.9	1.3	7.3	1.1	6.9	1.1	6.6	1.2	6.3	1.0	6.0	-
11–15	8.4	0.8	8.2	1.0	7.9	0.9	7.7	1.0	6.5	1.4				
16+	8.2	0.8	7.9	0.8	6.6	-								
							Radial shrinkage (%)							
Pedigree														
1–5	3.8	1.7	4.1	0.9	3.4	1.0	3.4	1.0	3.7	1.2	4.4	1.4	4.3	1.1
6–10	4.0	1.3	4.1	0.8	4.0	1.4	3.7	1.3	4.0	1.1	5.4	2.0	6.9	1.3
11–15	4.8	1.9	5.2	1.5	5.0	2.2	5.3	2.9	5.2	1.6				
16+	5.5	2.6	6.3	2.3	4.6	2.6								
Routine														
1–5	3.8	1.3	4.0	0.6	3.6	1.1	3.9	0.8	3.9	0.9	4.1	1.0	3.3	1.2
6–10	4.3	1.5	4.2	1.0	3.9	1.0	3.9	0.8	3.5	1.2	3.6	2.2	6.6	-
11–15	5.3	2.2	5.1	2.4	4.8	1.9	4.5	2.4	4.2	1.0				
16+	5.8	1.9	6.6	1.8	4.0	-								