CALMScience 1(3): 251–257 (1995)

Wood density and spiral grain of radiata pine and maritime pine grown in Donnybrook Sunkland trial plots

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SUMMARY

A survey of wood density of radiata pine (*Pinus radiata* D. Don) and maritime pine (*P. pinaster* Ait.) grown in trial plots in the Donnybrook Sunkland area, south-east of Busselton, assessed the effects of site type, area within site, and height in tree. Ages varied from 11- to 24-years-old.

The overall mean basic densities for radiata pine and maritime pine were 395 kg m^{-3} and 425 kg m^{-3}, and the mean air-dry densities 520 kg m^{-3} and 570 kg m^{-3} respectively. The expected trends of decreasing density with increasing height in the tree were confirmed. Analysis of the data showed significant differences ($p<0.001$) between species and between different heights in tree with both basic density and air-dry density, but in the former parameter, area and species x site and species x area interactions were also significant at the same level.

Spiral grain showed a decreasing trend from the pith to ten growth rings, but there were no significant differences between species, site, area, or height in tree.

INTRODUCTION

Assessment of wood properties is essential for efficient utilization of the forest resource. Wood density (particularly basic density and air-dry density) is closely related to properties such as bending strength, stiffness, and compression strength, and is the best single indicator of wood quality. Spiral grain has a negative correlation with strength properties (Bamber and Burley 1983).

In the early 1980s the Donnybrook Sunkland plantations south-east of Busselton were planned to include 60 000 ha, and provide a major part of the resource required by the softwood timber milling industry. A change in Government policy in 1983 resulted in a ban on clearing of native forest for plantation establishment, and consequently the current total area planted is about 11 500 ha.

A series of trial plots had been established in the Sunkland, with radiata pine and maritime pine the major species planted. The present trial was initiated prior to the policy change, and was designed to assess variations in wood density resulting from the following factors:

(1) species differences;
(2) site type differences;
(3) area within site type effects;
(4) height in tree.

The spiral grain survey was intended to give some indication of the variations in this parameter in the juvenile core, i.e. up to ten growth rings from the pith.

METHODS

The plots sampled were Molloy plots 9, 11, and 14; Willcock plots 17 and 18; and Ridge Road plot 2. They were randomly selected to represent the three major site types (McCutcheon 1978) used for pine plantations, with two areas of each site type. The silvicultural history of these plots is given in the Appendix.

The individual treatments in the study were:

Species:	radiata pine and maritime pine.
Site types:	Sunkland site types 3, 4 and 5.
Area within site type:	two randomly selected plots relevant to the above. (Originally three were intended, but the changed policy justified reverting to two.)
Heights in tree:	ground line, breast height (1.3 m), 3 m, 6 m, 9 m.
No. of trees:	three randomly selected trees per plot.

Harvesting commenced in 1982-83. The trees were felled, after diameter at breast height over bark (d.b.h.o.b.) was recorded. Tree height was measured on ground. Discs of 40 mm thickness were cut perpendicular to the stem axis at five heights, and immediately marked for later identification and placed in a plastic bag. Two bark-to-bark strips were then cut along the minor axis of the disk, one each side of the pith, to provide matched specimens. One specimen was used for assessment of basic density and one for air-dry density. The minor axis was used instead of the major axis to reduce the possibility of reaction wood affecting the results.

Basic density was calculated from the oven-dried mass (after drying at 103°C until constant weight was achieved) and from green volume (after estimating volume using the displacement method in a graduated cylinder. Accuracy was to 0.5 cm^3). Air-dry density was calculated from air-dry mass and air-dry volume, i.e. at equilibrium moisture content of about 12 per cent. The air-dry volume was also estimated using the displacement method, after reweighing a few specimens after immersion indicated that absorption effects were negligible. The density estimates are an underestimate of the actual cross-sectional density because the use of diametric strips gives less weight to the higher density mature wood.

Spiral grain of every second growth ring was estimated after hitting the transverse section of the specimen with a 5-mm-wide sharp chisel, and splitting off a piece which followed the grain orientation. An engineer's square was then used to estimate the spiral grain angle at each second growth ring from the pith up to the tenth ring. The estimated accuracy was 0.5°.

The data were analysed using analysis of variance, to assess the comparative effects of site type, area, and height in tree on wood density in each species. The main interest with the spiral grain data was the variation in the juvenile core (i.e. up to 10 rings from the pith) and the data were consequently assessed differently from those for wood density.

RESULTS AND DISCUSSION

The mean values and standard deviations of total height and d.b.h.o.b. of each of the trees sampled in the wood density and spiral grain survey are given by species and site type in Table 1.

Mean overall basic densities of the radiata pine and maritime pine samples were 395 kg m^{-3} (SD 42 kg m^{-3}) and 425 kg m^{-3} (SD 60 kg m^{-3}) respectively. The comparative air-dried densities were 520 kg m^{-3} (SD 65 kg m^{-3}) and 570 kg m^{-3} (SD 85 kg m^{-3}).

Kingston and Risdon (1961) gave air-dry density values of 593 kg m^{-3} for radiata pine and 596 kg m^{-3} for maritime pine, while Shedley and Challis (1984) quoted air-dry density values of 530 kg m^{-3} for radiata pine and 577 kg m^{-3} for maritime pine. In comparison Siemon (1983) reported a mean air-dry density for maritime pine of 558 kg m^{-3} in a large-scale assessment of strength properties of different provenances.

The lowest mean value for air-dry density was at 9 m height, with 460 kg m^{-3} for radiata pine trees on site types 3 and 4, and 490 kg m^{-3} for maritime pine on site type 5. There would not be problems with utilization at this comparatively large mean density, because the grading rules specify a minimum density of 300 kg m^{-3} (Standards Association of Australia 1986).

The variation in basic density with increasing height in the tree is shown in Figure 1, using the average density value of the six trees at the five heights in each site type. The trends of decreasing mean values with increasing height in the tree are consistent in both species and over the three site types. The air-dry density showed similar trends.

TABLE 1

Mean height and d.b.h.o.b. of sample trees assessed in the wood density and spiral grain survey of radiata pine and maritime pine growing in Donnybrook Sunkland trial plots (N = six trees per site type).

		RADIATA PINE		MARITIME PINE	
Site	Type	Ht(m)	d.b.h.o.b. (cm)	Ht (m)	d.b.h.o.b. (cm)
3	Mean	15.5	16.6	12.6	17.9
	SD	2.1	1.6	0.7	1.9
4	Mean	16.2	17.0	13.8	20.1
	SD	2.3	1.6	3.9	3.8
5	Mean	16.3	16.7	12.9	19.8
	SD	2.0	2.5	1.2	2.8

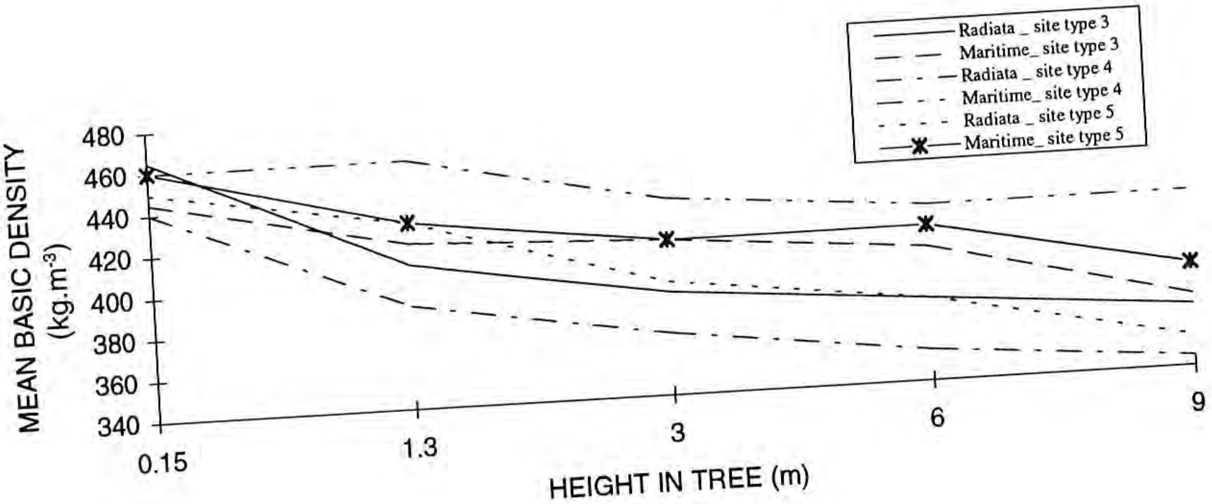

Figure 1. Effect of site type and height in tree on mean basic density of radiata pine and maritime pine grown in Donnybrook Sunkland trial plots.

The analyses showing the effects of species, site type, area and height in tree on basic density and air-dried density are presented in Tables 2 and 3 respectively.

For basic density, species, species x site type, area, species x area and height in tree, were all significantly different at $p<0.001$. Site type x area was significantly different at $p<0.01$. Site type was not significant.

When air-dry density was assessed, the factors of species and height in tree were significant at the same level ($p<0.001$), and species x area at $p<0.05$, but the other factors were not significant (Table 3). As for basic density, site type was not significant. The variation between areas is more difficult to explain, and possibly is an effect of genetics rather than environment, with a comparatively small sample.

The main significant differences found were between species and height in tree ($p< 0.001$), and between species x site ($p<0.01$). Significance of the species x area interaction ($p< 0.05$) would be attributed to the effect of species. Site type and area and the other interactions were not significantly different.

The magnitude of spiral grain with increasing number of rings from the pith (Table 4) shows an overall decreasing trend. The high standard deviations could be owing to genetic variation, sampling effects, accuracy of measuring angles, environmental variations or a combination of these factors. The data give an indication of the changes in spiral grain with increasing distance from the pith in the first ten growth rings.

Analysis of variance indicated that with spiral grain there were no significant differences between species, site, area, or height in tree, or between any interactions.

Continuous improvements are resulting from changes in silvicultural practices and a very efficient tree breeding program. A research project on the effects of thinning and fertilizing on wood density in radiata pine, is currently being carried out by Mr I. Dumbrell of CALM's Busselton Research Centre.

Overall, the results of the present trial indicated that the density of trees in the Sunkland trial plots would not be a constraint in providing an acceptable product for structural grade timber. The relevant Australian Standard for visually stress-grading softwood timber (Standards Association of Australia 1986) requires a minimum average density (at 12 per cent moisture content) for the species of 360 kg m^{-3}, with no individual pieces below 300 kg m^{-3}. The data from this trial indicated substantially higher density with overall mean air-dry densities of 520 kg m^{-3} for radiata pine and 570 kg m^{-3} for maritime pine. As stated previously, the lowest mean value was 460 kg m^{-3} for radiata pine at 9 m height. The sloping grain estimates in this trial indicated that this parameter should not cause particular problems when grading pine timber to AS2858-1986 (Standards Association of Australia 1986). The allowable sloping grain for F5 stress grade, the major grade separated, is 1 in 5 which is equivalent to 11.3°. It is well documented (e.g. Bamber and Burley 1983) that sloping grain is at a maximum in juvenile wood, and decreases in mature wood.

TABLE 2

Variation in basic density of radiata pine and maritime pine grown in the Donnybrook Sunkland trial plots.

TREATMENT	DF	F VALUE	SIGNIFICANCE[a]
Species	1	44.2	***
Site type	2	0.4	NS
Species x site	2	11.7	***
Area	1	59.4	***
Species x area	1	70.3	***
Site type x area	2	5.9	**
Species x site x area	2	2.1	NS
Height in tree	4	27.3	***
Species x height	4	1.7	NS
Site x height	8	0.4	NS
Species x site x heights	8	0.3	NS
Height x area	4	1.1	NS
Species x height x area	4	1.2	NS
Site x height x area	8	1.0	NS
Species x site x height x area	8	0.1	NS
Error	120		
	179		

*** Significant at $p < 0.00$
** Significant at $p < 0.01$
* Significant at $p < 0.05$
NS Not significant

TABLE 3

Variations in air-dry density of radiata pine and maritime pine grown in Donnybrook Sunkland trial plots.

TREATMENT	DF	F VALUE	SIGNIFICANCE[a]
Species	1	25.3	***
Site type	2	1.0	NS
Species x site	2	4.9	**
Area	1	2.4	NS
Species x area	1	4.0	*
Site type x area	2	2.1	NS
Species x site x area	2	0.4	NS
Height in tree	4	28.0	***
Species x height	4	0.0	NS
Site x height	8	0.2	NS
Species x site x heights	8	0.5	NS
Height x area	4	0.6	NS
Species x height x area	4	2.3	NS
Site x height x area	8	1.0	NS
Species x site x height x area	8	1.0	NS
Error	120		
	179		

*** Significant at $p < 0.001$
** Significant at $p < 0.01$
* Significant at $p < 0.05$
NS Not significant

TABLE 4
Variation in spiral grain (degrees) from stem axis in juvenile wood of radiata pine and maritime pine.

		NUMBER OF RINGS FROM PITH				
		2	4	6	8	10
Radiata pine	Mean	8.4	7.3	6.3	5.8	7.5
	S.D.	2.0	2.2	3.0	2.3	4.5
Maritime pine	Mean	8.1	8.8	7.4	7.0	6.1
	S.D.	2.5	3.0	2.6	3.8	3.9

ACKNOWLEDGEMENTS

The staff of Busselton Research Centre, particularly Bob Hingston and Beth Read, are thanked for technical assistance, with sampling and assessments and providing plot data. Thanks to Richard Siemon and Matthew Williams for the statistical analysis.

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APPENDIX

Silvicultural history of the Donnybrook Sunkland trial plots sampled for the pine wood density and spiral grain survey.

Molloy 9 : *Pinus radiata* and *P. pinaster*.
Planted 1970. (2.44 m x 1.82 m spacing (2000 stems ha^{-1})).

1978	Culled to 750 stems ha^{-1} low pruned to 2 m.
1974	(*P. radiata*) 2.5% Zn SO_4 + Mn SO_4 foliar spray.
1974	(*P. pinaster*) 5.0% Zn SO_4 + Mn SO_4 + 0.2% Cu SO_4 foliar spray.
1974	200 kg ha^{-1} Super Broadcast.
1977	400 kg ha^{-1} Agras No. 1.
1980	400 kg ha^{-1} Super Copper Zinc B Mix.

Molloy 11 : *P. radiata*.
Planted 1971 (2.74 m x 1.82 m spacing).

1971	Whole area (4.0 ha) set up as initial fertilizer trials.
1977	Northern 2.0 ha set up at rates of Agras 18:18 refertilization trial. This trial was terminated in 1982.
1977	Southern 2.0 ha was thinned to 500 stems ha^{-1} and received 400 kg ha^{-1} Agras 18:18.

Other details - 1974 - 5% Zn SO_4 + Mn SO + 0.2% Cu SO_4.

1974	2.5% Zn SO_4 + Mn SO_4.
1975	200 kg ha^{-1} Super.
1982	250 kg ha^{-1} Agras No. 1 + Super Copper Zinc B and 250 kg ha^{-1}.
1985	400 kg ha^{-1} Agras + Super Copper Zinc B 3:1 mix.

Molloy 14 : *P. radiata*.
Planted 1972 (2.74 x 1.82 m spacing).

1974	Research trial set up in northern 4.0 ha of *P. radiata* - various fertilizer treatments.
1974	200 kg ha^{-1} Super + 2.5% Zn + Mn SO_4 + 0.2% Cu SO_4 foliar spray.
1980	Super Copper Zinc B mix at 400 kg ha^{-1}.
1979	Low pruned to 2 m.
1980	High pruned to 5 m at 20 stems ha^{-1} (except Research area).

Willcock 17 : *P. radiata* planted 1967, *P. pinaster* planted 1969.
(2.74 x 1.82 m spacing)

P. radiata area :

1967	57 g/tree at planting.
1970*	10 kg Super broadcast.
1975*	227 g/tree of Super + 227 g/tree Urea.
1980*	400 kg ha^{-1} Super Copper Zinc.
1982	As per 1980 + 400 kg ha^{-1} Agras.
1975*	Low pruned to 2 m and culled to 741 stems ha^{-1}.
1980*	High pruned to 5 m.
1985	Thinned to 250 stems ha^{-1}.

* Applied to *P. pinaster* also.

Willcock 18 :	*P. radiata* and *P. pinaster*. Planted 1971 (2.74 x 1.82 spacing).
	P. radiata area :
1973	74 g/tree Zn SO_4 + Mn SO_4 2.5% foliar spray.
1974	5% Zn SO_4 + Mn SO_4 + 0.2% Cu SO_4 foliar spray.
1974	200 kg ha^{-1} Super.
1974, 77	400 kg ha^{-1} Agras 18:18.
1982	400 g/tree Agras + 400 g/tree Super Copper Zinc No. 2.
	P. pinaster area :
1986	250 kg ha^{-1} Agras + Minerals.
Both Species :	Low pruned to 2 m and culled to 750 stems ha^{-1} (unknown, but probably 1976/77)
1982/83	High pruned to 5 m.
1985	Thinned to 250 stems ha^{-1}.
Ridge Road Plot 2 :	*P. pinaster* planted 1958
1962	180 kg ha^{-1} Super. Also scrub control.

No other details were found in the records.