CALMScience 3(4):487–498(2001)

Wood basic density surveys of pedigreed Maritime Pine in Gnangara, Pinjar and Yanchep plantations

G.R. SIEMON

Forest Products Commission, 117 Great Eastern Highway, Rivervale, Western Australia 6103

SUMMARY

Maritime pine (*Pinus pinaster*) growing in Gnangara, Pinjar and Yanchep plantations north of Perth was assessed to compare the basic density of wood from genetically improved (pedigreed) trees, planted routinely from 1972 to 1987 (P72 to P87), with that of older unimproved trees. Over 500 trees were sampled initially, with the minimum sample of 20 trees (5 plots x 4 trees) in each planting year of the pedigreed material. An additional 20 trees from each of P82 to P87 plantings were sampled because these would be harvested soon. Smaller samples of older material, and 30 trees from research trials established from 1965 to 1972, were included. A bark-to-pith core was extracted at breast height (1.3 m), and basic density of each 35 mm section from the pith assessed. Basic density (unextracted) increased from pith to bark and decreased with decreasing age. Mean basic density in 70–105 mm sections of P72 to P80 plantings was about 500 kg m^{-3}.

Effects of height in tree on basic density of five pedigreed maritime pine trees from each of P72 to P87 plantings were assessed. Mean basic density of cores from 1.3 m, 3 m, 6 m and 9 m decreased with decreasing age and with increasing height in the tree. Sample cores from edge and internal trees of P80, P82 and P84 stands showed that edge trees had basic density about 30 kg m^{-3} less than that of internal trees.

The initial survey indicated that resin content continued to increase with age, and a further study compared mean basic density of cores from trees planted in 1957 and 1984. Matched cores from either P57 or P84 were either left unextracted or extracted with an acetone : ethanol : toluene solution (4:1:1 ratio) for 48 hours before measuring basic density. The results showed that 0–35 mm sections of cores from P57 trees had 13.9 per cent resin content compared with 3.7 per cent in cores from 1984 plantings, and there was a decreasing trend of resin content with increasing distance from the pith.

Comparative basic density data from previous assessments of Western Australian-grown maritime pine are given.

The survey results indicated that pedigreed maritime pine material has acceptable basic density for a range of uses, e.g. sawlogs, MDF or LVL production.

INTRODUCTION

Maritime pine (*Pinus pinaster*) is one of the major plantation species in Western Australia, with a current area of about 27 000 ha. This species will become significantly more important with planned establishment of 150 000 ha in the semi-arid areas of the Wheatbelt to reduce salinity effects while providing a commercial crop.

The current major areas of maritime pine are Gnangara, Pinjar and Yanchep plantations, about 35 km north of Perth, with a combined area of about 20 000 ha. All plantings since 1972 have been improved or pedigree stock resulting from an intensive tree-breeding program initiated by the then Forests Department. The areas will be thinned and clear-felled progressively over the next 20 years and the area converted to a State park.

Maritime pine industrial wood is used by Wesfi Ltd for medium density fibreboard (MDF) production in Kewdale, and by Pinetec Pty Ltd, who mill mainly pallet timber. There is a current proposal for a Japanese and a local company to use part of the maritime pine resource to manufacture laminated veneer lumber (LVL) for either structural or non-structural purposes. Most of the product would be exported.

Efficient utilisation requires detailed information on the wood properties of the species, particularly the pedigreed resource planted since 1972, because thinnings from these compartments are providing an increasing resource to Wesfi and Pinetec and would be used in LVL production. Wood density is an important predictor of strength properties, and an initial survey was to obtain a better understanding of wood density variation with age of maritime pine.

The initial survey was based on systematic sampling at breast height (1.3 m) of trees in areas planted with pedigreed pine each year from 1972 to 1980 (P72 to P80), with comparisons made with unimproved material from P69 to P71. Some younger (P81 to P87) and older (P51 and P57) material was also included. The data from this survey confirmed the trend of decreasing basic density with decreasing age in the juvenile and adjacent wood. Wesfi were concerned about this trend (and that of decreasing density with increasing height in the tree), particularly as it affected the basic density of trees from P82 to P87: they requested additional sampling.

A subsequent survey with destructive sampling was required to quantify the basic density variation with increasing height in the tree, with a single compartment selected as being representative of a specific planting year (P72 to P87).

Another Wesfi concern was the lower density of veneers produced from P82 logs sent to Japan for LVL trials, compared with the density data from the initial survey. Further core samples were collected from the P82 to P87 areas, and taken from immediately adjacent to plots sampled for the LVL logs for Japan. In the wood density assessments, sampling was carried out a minimum of 20 m from the edge of the stand, so sample trees provided data representative of that particular resource. However, when sampling of the resource was required for the LVL pilot trial, the specification included a minimum diameter limit that could only be achieved by sampling the open-grown edge trees. The Department of Conservation and Land Management (CALM) postulated that the lower density resulted from edge trees being sampled in these young plantations to make the minimum diameter specification, and that lower basic density subsequently measured in LVL produced from edge trees was not representative of that age stand. It was necessary to quantify the basic density differences between edge trees within the compartment, and the next sampling was done in three specific stands (P80, P82, and P84).

The systematic sampling of maritime pine planted in these plantations showed a consistent increasing trend with age in unextracted basic density of cores. Koch (1972) indicated that resin continued to be produced in the southern pines of the United States (e.g. *P. elliottii var elliottii, P. taeda*) after the initial heartwood formation, and it was postulated that this situation also occurred in Western Australian-grown maritime pine. Resin content increases wood density, but has negligible effect on strength. A small pilot study used paired cores from 1957 (P57) and 1984 (P84) plantings, with unextracted basic density of one core compared with basic density of the other core after the resin was extracted at the Western Australian Chemistry Centre.

The major objective of the comprehensive survey and studies was to assess wood basic density of Western Australian-grown maritime pine of a wide range of ages as an indication of its potential uses. The effects of increasing height in the tree on wood density, the differences between edge and internal trees in the compartment, and the comparative resin content in juvenile wood of P57 and P84 trees were also assessed.

METHODS

Survey of basic density at breast height

The sampling pattern used to assess basic density variation in the pedigreed resource was based on the area established annually from 1972 to 1987 (P72 to P87). A smaller sample of unimproved resource (P51, P57, P69, P70 and P71) was included for comparative purposes. The number of plots sampled was proportional to the area planted, and stratification was done based on silvicultural and site variations. A bark-to-pith core at breast height was taken from each of four trees in the selected plot, and basic density of each 35 mm section measured. The location of five temporary plots (each with four trees) was nominated by a CALM forester with intensive knowledge of Gnangara, Pinjar and Yanchep plantations (Table 1).

Each tree had a core sample removed at breast height, using a 'Trecor'® Wood Corer with a 'Tanaka'® petrol motor drill. The position was modified if within 15 cm of a whorl of branches. After the diameter at breast height over bark was measured, a mark was made on the corer to ensure that the core being drilled went past the pith in each tree. Only one radial core was used from each tree, to reduce the damage to the stem. The corer was sharpened at the start of the survey, and proved very effective in producing a clean uniform core with good definition of the growth rings. Immediately after removal the cores were wrapped in a marked plastic bag to minimize moisture loss. A pilot trial had shown that overnight moisture loss in the core could be compensated for with a 20-minute soaking in water before cutting the core into sections and measuring green volume.

The procedure in the laboratory was to break off the bark at the cambium, cut the core to length through the pith with a Stanley knife, and then measure and record the length from pith to cambium. The core was divided into 35 mm sections, commencing at the pith. This length is based on the radius of the residual 70 mm diameter cylinder left after peeling veneers, and is not directly related to number of growth rings. Each 35 mm section was cut with the knife, and any residual length less than 5 mm included with the previous section because of the difficulty in obtaining an accurate density estimate when earlywood/latewood proportions are affected. Year, tree and height in tree were marked on the core section with a 'Lumochrom' pencil, which provides a waterproof marking.

Basic density is the oven dry mass divided by the green volume. The volume was estimated using the displacement method. A clamp stand was placed beside a set of electronic scales with a beaker of water. The scales were tared to read zero, and a length of sharpened wire inserted at right angles into the core section, which was then submerged below the surface of the water. The reading on the scales is an accurate estimate of the displacement of water and therefore of core volume.

The cores were then dried using the oven-dried method, which requires drying at 103°C to constant weight, when all moisture has been removed from the sample. The

TABLE 1

Planting years (P51 = planted in 1951) and compartments sampled for wood density survey of maritime pine (*Pinus pinaster*) in Gnangara, Pinjar and Yanchep plantations.

STRATUM	COMPARTMENT	TRIAL No.	No. of PLOTS
NON-PEDIGREED			
P51	Gnangara 13,18,127	-	3
P57	Gnangara 46,49,52	-	3
P69	Yanchep 1,2: Pinjar 1,2: Gnangara 20,23	-	6
P70	Yanchep 1,2,8,9	-	4
P71	Pinjar 4	-	2
PEDIGREED			
P72	Pinjar 3,6,7,8	-	5
P73	Yanchep 13,15,16,20	-	5
P74	Gnangara 28,29,30,31	-	5
P75	Pinjar 2,3,5,6,11,12,13,15	-	10
P76	Pinjar 21,28,29,30,31,33,34,35,36	-	10
P77	Pinjar 25,26,27,41,42,45,46,47	-	10
P78	Pinjar 39,40,48	-	5
P79	Pinjar 6,7,9,10	-	5
P80	Pinjar 9,20,22	-	5
P81	Pinjar C 12, 13,15	-	5
P82	Pinjar C 14,18	-	5+5
P83	Yanchep C 1,2,3	-	5+5
P84	Pinjar 4,5,10,16,17	-	5+5
P85	Pinjar H 6,9,15	-	5+5
P86	Pinjar 8,13	-	5+5
P87	Yanchep 11B,13, 14A	-	5+5
RESEARCH (TREE BREEDING)			No. OF TREES
P65	Gnangara 7	YS1	2
P66	Gnangara 7, Yanchep 46A	YS3, 07	4
P67	Yanchep 37A,46A	YS12	6
P68	Gnangara 13, Yanchep 60	YS11B,12, 13B	6
P69	Yanchep 60, Gnangara 109A	YS19,20	8
P72	Pinjar 2	YS43	4

measurements were done on unextracted cores that contained varying amounts of resin, because extraction facilities were not available without incurring considerable costs.

The mean basic density values and standard deviations were calculated, excluding a few results where resin content was unacceptably higher than average. Standard deviation was not calculated for fewer than five samples.

The supplementary sample taken following the request by Wesfi was four trees per plot from each of the five plots in each year P82 to P87, in the same compartments as the original samples. The additional sampling increased sample size from 20 to 40 trees in those years of planting. The supplementary sampling is shown with details of the initial survey for the P82 to P87 planting years in Table 1.

Effect of height in tree on basic density

In a survey with destructive sampling to quantify variation in basic density with increasing height up the stem one of the original compartments (P72 to P87) was randomly selected and trees adjacent to those in the first sample selected (Table 2). Five trees were sampled from each compartment, and felling was required to allow coring in the upper sections of the stem, at breast height, 3 m, 6 m and 9 m. The whole core was used for the survey of effect of height in tree on basic density, without cutting into 35 mm long sections. The cores were handled similarly to samples from the previous survey to obtain basic density estimates. This survey was necessarily destructive to enable coring at 3 m intervals up the tree, and the trees were felled.

TABLE 2

Compartments sampled for survey of basic density at different heights in maritime pine trees in Pinjar and Yanchep plantations.

PLANTING YEAR	COMPARTMENT
P72[a]	Pinjar 3
P73	Yanchep 20
P74	Gnangara 22
P75	Pinjar 17
P76	Pinjar 30
P77	Pinjar 27
P78	Pinjar 40
P79	Pinjar 6
P80	Pinjar 22
P81	Pinjar C 23
P82	Pinjar C 14
P83	Yanchep C 4
P84	Pinjar 5
P85	Pinjar H 9
P86	Pinjar 8
P87	Yanchep 11B

[a] P72 = planted in 1972

Basic density of edge trees

To compare basic density of edge and interior trees, sample trees were selected randomly from immediately adjacent to the P80, P82 and P84 areas harvested for LVL trials in Japan. Five trees were selected from the edge of the stand, five from 10 m from the edge, and five from 30 m from the edge, in each of the three age classes.

A 12 mm diameter core was drilled at breast height with a 'Trecor'® borer, as described previously. The method for measuring basic density in 35 mm sections of each core, commencing at the pith, was also described. Mean unextracted basic density was calculated for each 35 mm segment in each treatment. Weighted mean basic density for the cross-section was estimated for the 105 mm radius (i.e. 210 mm diameter) in both edge and internal logs, with density data from each 35 mm section and using the difference in the area of circles of 35 mm, 70 mm and 105 mm radius.

Effect of age on resin content

Sample trees for basic density comparisons were selected randomly from P57 and P84 areas used in the previous assessments. Five trees were randomly selected from each of two different areas in each planting year, to give ten trees in each treatment.

Two 12 mm diameter cores were drilled at breast height with a 'Trecor' borer, as described previously, taking paired cores in the same vertical plane and 30 mm apart. One core had basic density measured unextracted, and the other after resin extraction. Resin extraction was done by the Western Australian Chemistry Centre over 48 hours, using a Soxhlet apparatus and acetone : ethanol : toluene in a 4:1:1 ratio.

Cores were divided into 35 mm sections commencing at the pith, and the basic density assessment done. Resin-extracted cores were soaked for 24 hours before measurement to replace moisture removed during the resin extraction. Mean basic density was calculated for each 35 mm segment in each treatment, and the percentage resin content was estimated by dividing unextracted basic density by extracted basic density.

RESULTS AND DISCUSSION

Survey of basic density at breast height

The mean unextracted basic density and standard deviation of the 35 mm sections in each planting year are given in Table 3.

The 35 mm sections were based on the likelihood of some maritime pine resource being peeled and then used for LVL manufacture. The residual core after peeling on modern equipment is about 70 mm diameter, and therefore peeled veneer would be produced from the wood outside that diameter. That is, the basic density of the second and subsequent 35 mm sections indicates the likely wood density of veneers from that resource.

Table 3 shows definite trends with the mean unextracted basic density increasing with increasing distance from the pith, and decreasing from the older-aged to the younger plantations. Juvenile wood or crown-formed wood produced in the first ten years has lower density than mature wood, but the resin production associated with formation and development of heartwood with increasing age will reduce that difference, owing to the weight of the resinous deposits laid down in the heartwood (Koch 1972). The standard deviation values in the first 35 mm sections tended to be higher than those in the second and subsequent sections, and reflected the variation in resin production in that first section. Inspection showed no obvious variation in ring width or earlywood to latewood proportions that would result in large wood density differences. In screening candidate trees for tree-breeding purposes, it would be an advantage to extract resin to give more accurate comparisons.

As might be expected, the oldest sample trees (P51) had very high resin content. In one tree resin flowed freely from near the pith as the core was being extracted. Drilling was very difficult with the corer binding continually. The trees became progressively easier to drill with decreasing plantation age.

One industry requirement was a minimum air-dry density of 550 kg m^{-3} for veneers for LVL production, to ensure that stiffness of the product would meet US requirements for structural material, according to a consultant to local industry who carried out LVL trials in 1995. Air-dry density of maritime pine is approximately 1.22 times greater than basic density, based on air-dry density having 12 per cent greater mass than basic density, but only 92 per cent of the volume, using shrinkage data from Kingston and Risdon (1961). Consequently, any unextracted basic density greater than 450 kg m^{-3} should be

TABLE 3.

Basic density (kg m^{-3}) at breast height of pedigreed maritime pine compared with that of older unimproved trees (35 mm sections).

STRATUM	PLANTATION	No. PLOTS	CORE LENGTHS (mm)	MEAN BASIC DENSITY (standard deviation in parentheses)					
UNIMPROVED				0–35mm	35–70mm	70–105mm	105–140mm	140–175mm	175–210mm
P51	Gnangara	3	160–210	502 (31)	562 (37)	564 (29)	547 (29)	565 (50)	534 (53)
P57	Gnangara	3	93–180	502 (55)	497 (40)	516 (50)	501 (48)	497 (-)	
P69	Yanchep, Pinjar, Gnangara	2 each	82–160	489 (46)	485 (37)	523 (57)	538 (50)	574 (-)	
P70	Yanchep D, E	4	82–130	482 (43)	491 (32)	527 (39)	545 (47)		
P71	Pinjar	2	92–140	508 (56)	469 (40)	514 (37)	537 (47)		
PEDIGREE									
P72	Pinjar	5	83–135	521 (63)	511 (36)	525 (41)	513 (29)		
P73	Yanchep C	5	105–150	471 (47)	503 (35)	540 (30)	551 (34)		
P74	Gnangara	5	100–155	461 (35)	469 (29)	502 (28)	520 (40)	515 (-)	
P75	Pinjar	10	85–140	466 (40)	478 (35)	503 (38)	491 (31)		
P76	Pinjar	10	90–140	473 (56)	461 (39)	508 (43)	496 (42)		
P77	Pinjar	10	80–140	449 (38)	464 (41)	508 (49)	504 (62)		
P78	Pinjar	5	85–130	460 (35)	468 (39)	506 (44)	498 (52)		
P79	Pinjar	5	86–135	466 (54)	459 (25)	496 (34)	487 (29)		
P80	Pinjar	5	70–125	464 (57)	466 (46)	490 (39)	488 (59)		
P81	Pinjar	5	75–110	433 (35)	440 (37)	466 (31)			
P82	Pinjar	5+5[b]	80–110	449 (43)	456 (37)	490 (49)			
P83	Yanchep H	5+5	68–110	432 (39)	448 (36)	476 (43)			
P84	Yanchep H	5+5	53–105	411 (29)	453 (38)	494 (49)			
P85	Yanchep H	5+5	65–105	416 (29)	451 (39)	463 (48)			
P86	Yanchep H	5+5	60–90	393 (27)	434 (38)	462 (40)			
P87	Yanchep H	5+5	60–100	388 (26)	438 (28)	442 (49)			
RESEARCH									
P65–P72	Yanchep, Pinjar, Gnangara	30 trees	110–215	481 (41)	501 (41)	503 (34)	527 (35)	530 (47)	503 (34)

[a] P51 = planted in 1951
[b] Including supplementary sampling

satisfactory for structural material, but lining and other products could have lower density.

The pedigreed material planted from P76 to P95 came from the Mullaloo seed orchard, and consequently the same genetic material was planted (Hopkins and Butcher 1994). Some culling over the years had removed some of the poorer parents, including those with lower than average basic density. Silvicultural systems have not changed, and the range of sites over Gnangara, Pinjar and Yanchep plantations is similar.

Comparison of matched routine and pedigreed trees growing adjacent to each other in a P73 stand showed that basic density in both treatments was similar, although the pedigreed trees had produced about 30 per cent greater volume (Hill 1999). The cores taken from seven different heights in the tree (1.3 m, 2.4 m, 4.8 m, 7.2 m, 9.6 m, 12.0 m and 14.4 m) were measured in five ring sections (0-5, 6-10, 11-15, 15+) allowing the comparison.

This basic density survey in Gnangara, Pinjar and Yanchep, which compared pedigreed material from P72 to P87 showed definite trends of increasing unextracted density with increasing age, using breast height samples (Fig. 1). The trend was most pronounced in the first 35 mm core sections, and can be explained by the resin content increasing with time. A similar trend in the southern pines of the United States (e.g. *P. elliottii var elliottii, P. taeda*) was reported by Koch (1972).

Effect of height in tree on basic density

An additional survey confirmed the uniform trend of decreasing average basic density with increasing height in the tree (Table 4).

Mean basic densities and standard deviations of cores from each height in each of five trees from each planting year are given in the Table, showing definite trends with the mean basic density decreasing with increasing height in the trees, and decreasing with decreasing age. Juvenile wood or crown-formed wood produced in the first ten years has lower density than mature wood, and the mean density of the cross-section will increase with increasing age. Inspection showed no obvious variation in ring width or earlywood to latewood proportions that would result in wood density differences. The trees became progressively easier to drill with decreasing plantation age.

The data in Table 4 show the expected trends, with occasional anomalies in those trends because of the smaller sample size (of five trees) than that used when sampling at breast height only. However, with 80 trees sampled overall, and generally four cores per tree, the survey provides considerable information. The trends in basic density with increasing height in the tree are shown in Figure 2.

Basic density of edge trees

There was apparently low basic density of younger samples in the batches of logs from P72 to P84 which were sent to Japan for an LVL trial. When sampling additional trees adjacent to the areas logged, it appeared likely that the low densities of logs from the younger stands (P80, P82 and P84) compared with the data from the comprehensive survey, was the result of felling edge trees to achieve the minimum log diameter requirement for LVL production. Edge trees grow faster and generally have lower wood density than trees inside the compartment, and it was necessary to quantify the differences.

The results of this study, showing mean basic density and standard deviations of edge trees compared with internal trees in P80, P82 and P84 stands, with values given for each 35 mm section are presented in Table 5.

Edge vs internal trees

The data in Table 5 and the weighted mean values show that the mean basic density of the edge trees is less than that of the internal trees. The exception is the 0–35 mm core section, where the results are similar because in the first few years of growth there are no competition effects. Once crown competition commences, the edge trees have more light, water and nutrients available. They consequently grow considerably faster but with lower wood density than dominant internal trees.

The 35–70 mm and 70–105 mm sections show an increasing difference in basic density between edge and internal trees, because different aged rings are involved, e.g. sections from 35–70 mm in edge trees contain more juvenile wood than the same sections from internal trees. As age increases, the edge trees have wider growth rings than internal trees, and the lower density values indicate lower percentage latewood. The greatest differences were found in the 70–105 mm sections, with mean basic density varying from 30 kg m^{-3} in P80 to 64 kg m^{-3} in P82 stands.

The estimates of weighted mean basic density to 105 mm radius (210 mm diameter) under bark, based on the areas of each 35 mm in the cross-section were as follows:

P80 - Edge trees 467 kg m^{-3}	Internal trees 497 kg m^{-3}
P82 - Edge trees 443 kg m^{-3}	Internal trees 481 kg m^{-3}
P84 - Edge trees 459 kg m^{-3}	Internal trees 487 kg m^{-3}.

The differences between weighted mean basic density of edge and internal trees were therefore 30 kg m^{-3} for P80, 38 kg m^{-3} for P82, and 28 kg m^{-3} for P84. This variation between edge and internal tree density would explain the apparent anomaly when the LVL trial produced material of lower density than found in the initial survey.

Overall, the study reached the major objective of quantifying the differences in mean basic density and weighted density of edge compared with internal trees, showing that edge trees were of lower wood density.

Age effects

Table 5 shows the general trend of decreasing mean basic density with decreasing age, similar to the results reported by Hill (1999). There were some minor anomalies with the smaller sample size than that used in the previous intensive studies. For example, mean basic density in the

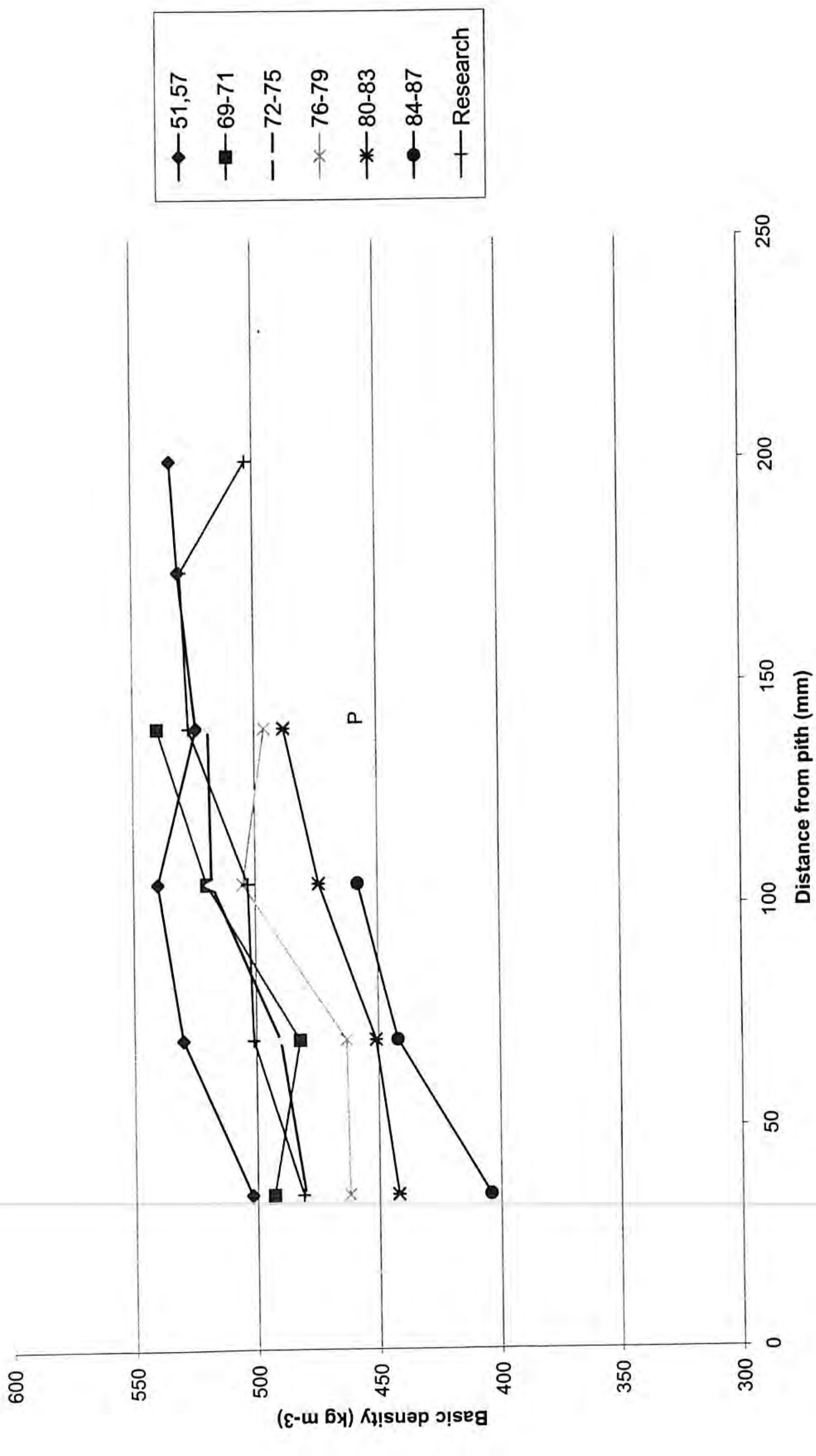

Figure 1. Breast height basic density of maritime pine from Gnangara, Pinjar and Yanchep Plantations by grouped planting years.

TABLE 4

Effects of age and height in tree on wood basic density (kg m^{-3}) of pedigreed maritime pine.

PLANTING YEAR	MEAN BASIC DENSITY (SD in parentheses)			
	1.3 m	3 m	6 m	9 m
P72[a]	477 (29)	452 (29)	440 (42)	418 (-)[b]
P73	484 (24)	460 (35)	450 (41)	439 (44)
P74	499 (16)	468 (33)	464 (19)	432 (4)
P75	468 (30)	466 (21)	439 (17)	415 (28)
P76	489 (18)	473 (28)	455 (32)	422 (29)
P77	457 (20)	445 (18)	433 (21)	408 (17)
P78	469 (23)	456 (11)	443 (22)	421 (-)
P79	479 (31)	433 (36)	446 (37)	433 (42)
P80	474 (24)	430 (28)	423 (15)	419 (-)
P81	438 (19)	430 (28)	423 (15)	398 (-)
P82	470 (15)	463 (24)	442 (26)	
P83	444 (27)	418 (22)	408 (-)	
P84	436 (7)	418 (14)	407 (-)	
P85	419 (24)	411 (21)	412 (-)	
P86	427 (30)	395 (24)	395 (-)	
P87	408 (17)	412 (29)	390 (14)	

[a] P72 = planted in 1972

[b] Standard deviation was not calculated for fewer than five samples.

70–105 mm section in P84 was similar to the P80 value, and greater than the P82, but fewer than five trees reached this dimension.

Effect of age on resin content

Table 6 shows the mean basic density and standard deviations of extracted and unextracted cores from trees in P57 and P84 stands, with values given for each 35 mm section. The percentage resin is based on extracted density.

Table 6 indicates that mean basic density of older trees continues to increase with increasing age. As expected, the effect was most pronounced in the 0–35 mm core section, with 13.9 per cent resin in P57 compared with 3.7 per cent in cores from P84 trees. The unextracted basic density values in that core section were similar to those shown in Table 3, i.e. 502 kg m^{-3} for P57 and 411 kg m^{-3} for P84.

However, CALM considered that the trend resulted from continuing resin production after the initial heartwood formation. Similar trends have been reported in the southern pines of the United States (Koch 1972), and in South Africa (South African Department of Forestry 1964).

According to Koch (1972), the extraction process removes most of the extractives, which are generally referred to as resins. They may require extraction with a range of chemicals, but Koch quotes alcohol/benzene as removing the greatest amount of extractives. Acetone : ethanol : toluene is now recommended because of the possible carcinogenic effects of benzene, but it is possible that residual amounts of the extractives remained after the Soxhlet extraction.

In commercial use such as LVL or plywood production where pine is used with the normal resin content, it is likely that some volatile components of the resins will be given off during the veneer drying process with drying temperatures probably about 160°C. The highest resin content is in the 70 mm diameter core discarded after peeling. The thin veneers peeled outside this diameter should not be adversely affected by resin content, particularly with the high quality gluelines achievable from modern adhesives and technology.

Table 6 shows the general trend of decreasing mean basic density with decreasing age, similar to the results reported by Hill (2000). There were some minor anomalies with the smaller sample size than that used in the previous intensive studies. Overall, the study indicated that the resin or extractives content continued to increase with increasing age, with the greatest effect found in the 0–35 mm section of the core.

Comparison with other Western Australian wood density data

Table 7 gives other data relating to the wood density of maritime pine grown in Western Australia. The 85 superior trees of maritime pine selected by Perry in Leiria, Portugal, in 1965 were the basis for the Forests

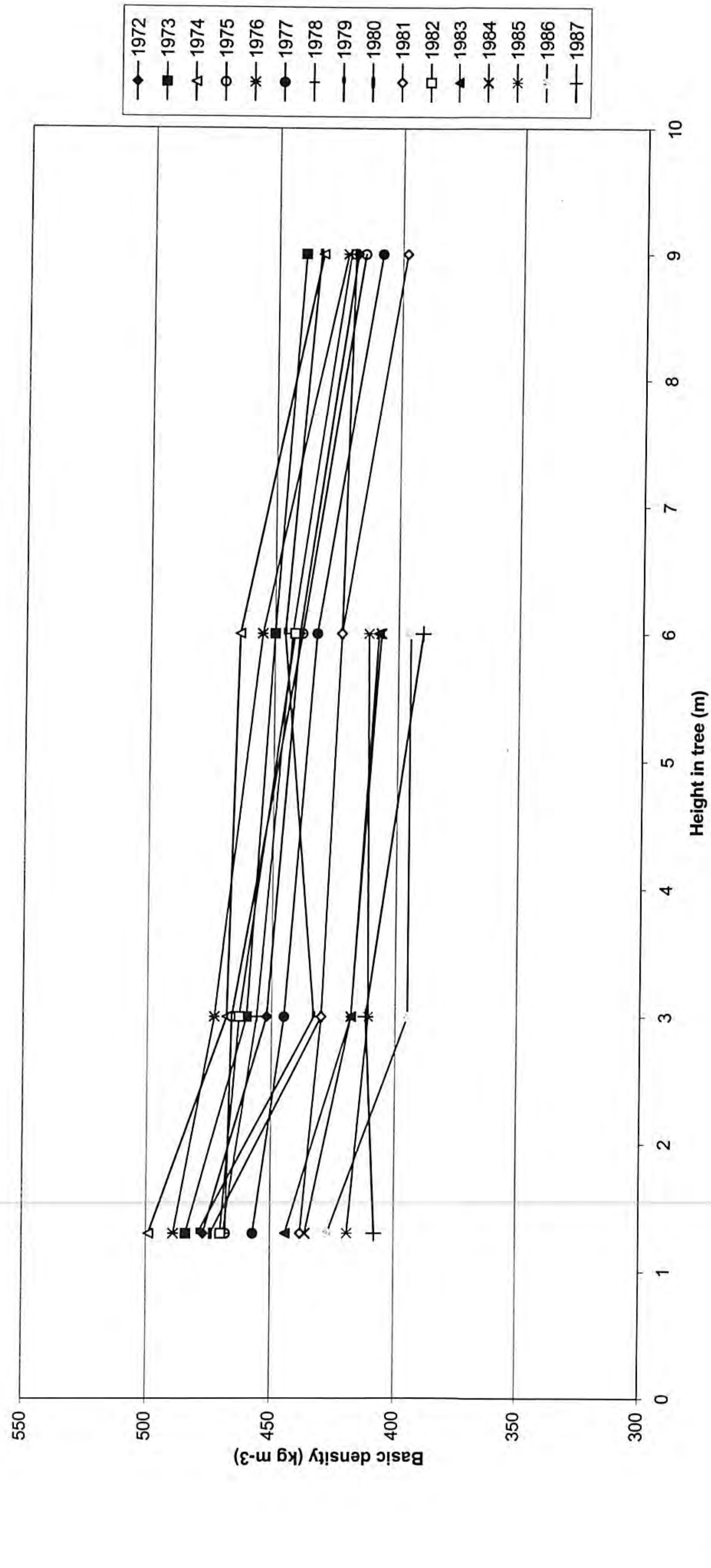

Figure 2. Basic density of maritime pine with increasing height in tree-planting years 1972 to 1987 (P72 to P87).

TABLE 5

Mean basic density (kg m^{-3}) and standard deviations (in parentheses) of edge and internal maritime pine trees (35 mm sections).

YEAR	SAMPLE LOCATION	0–35 mm	35–70 mm	70–105 mm	>105 mm
P80[a]	Edge	441 (71)	448 (48)	483 (29)	520 (-)[b]
	Internal	453 (69)	485 (30)	513 (36)	
P82	Edge	423 (71)	440 (37)	449 (-)	513 (-)
	Internal	415 (31)	450 (47)	513 (-)	
P84	Edge	387 (30)	443 (36)	484 (-)	520 (-)
	Internal	410 (35)	458 (31)	520 (-)	

[a] P80 = planted in 1980
[b] Standard deviation is not given for fewer than five sections.

TABLE 6

Mean basic density (kg m^{-3}) and standard deviations (in parentheses) of unextracted and resin-extracted cores from maritime pine trees (35 mm sections), and estimated resin contents.

YEAR	SAMPLE	0–35 mm	35–70 mm	70–105 mm	>105 mm
P57[a]	Unextracted	517 (68)	512 (45)	554 (32)	566 (-)[b]
	Extracted	454 (48)	485 (39)	534 (43)	576 (-)
	Resin (%)	13.9	5.6	3.7	-
P84	Unextracted	419 (22)	465 (52)	495 (-)	
	Extracted	404 (23)	450 (40)	486 (-)	
	Resin (%)	3.7	3.3	1.9	

[a] P57 = planted in 1957
[b] Standard deviation is not given for fewer than five sections.

Department's intensive tree breeding program. Perry and Hopkins (1967) gave basic density data for each selected tree (age range 30 to 138 years), with a mean of 500 kg m^{-3}. The major traits for improvement in the program were stem straightness and vigour, with consideration also given to branch size and angle.

The CSIRO Division of Forest Products completed a major survey of density and shrinkage of native and exotic species grown in Australia (Kingston and Risdon 1963). They assessed samples of unimproved maritime pine from Western Australia, which had mean air-dry density of 596 kg m^{-3} and basic density of 490 kg m^{-3}.

Nicholls *et al.* (1963) assessed wood properties of the four major provenances of maritime pine, i.e. Leiria, Corsica, Esterel and Landes, and concluded that the Leirian provenance had higher basic density, good fibre length and superior vigour and form compared with the others (Table 7). Mean values were not given, but a graph in the report indicated that a basic density of 500 kg m^{-3} was achieved by ten years.

The tree-breeding program progressed with its concentration on phenotype, and wood density was given minor consideration until a screening of parents for the breeding population for the next generation was done to confirm that juvenile wood (defined as the first eight rings) was of acceptable density (Hopkins and Butcher 1994). They reported mean basic density of 430 kg m^{-3} for juvenile wood (first eight rings) and 480 kg m^{-3} for mature wood (ninth to twelfth rings).

Air-dry density was measured as part of an assessment of the strength properties of Western Australian-grown maritime pine by Siemon (1983), with treatments ranging from P36 to P66. The 16-year-old material reported in the study as 'pedigree', and which came from the Flinn's agroforestry trial near Mundaring, had air-dried density as low at 474 kg m^{-3}. This material was actually unimproved. The mean air-dry density for all samples in the study was 559 kg m^{-3}. A later assessment of Donnybrook Sunkland trial plots and 13 and 14-year-old maritime pine showed a mean air-dry density of 570 kg m^{-3}.

Wespine Industries Pty Ltd carried out a sawmilling trial of maritime pine in which graded recoveries and knot sizes from older resource was compared with those of pedigreed material and unimproved planted in 1971

TABLE 7

Air-dry and basic density (kg m^{-3}) from previous assessments of Western Australian-grown maritime pine.

RESOURCE	SAMPLE SIZE	AIR-DRY DENSITY MEAN	AIR-DRY DENSITY SD	BASIC DENSITY MEAN	BASIC DENSITY SD	REFERENCES
Leirian trees selected by Perry in 1965 (age 30–138)	85			500	33	Perry & Hopkins (1967)
Mature wood from the Sommerville plantation (1960s)				550		Nicholls (1966)
Screening of breeding population (age 8–12)	336			430(Juv)		
				480(Mat)	30	Hopkins and Butcher (1994)
					40	
Wespine sawmilling trial: P71 pedigreed	36	588	37			Meachem[a] (pers.comm)
31-year-old Yanchep plantation	10	569	53			Meachem (pers.comm)
47-year-old Gnangara plantation	10	611	54			Meachem (pers.comm)
WA resource: overall mean		559				Siemon (1983)
" 16-year-old (Agroforestry)	5	474				Siemon (1983)
Donnybrook Sunkland trial plots (13, 14 year old)		570	85			Siemon (1995)
CALM Timber Technology assessment of P73 orchard stock (Yanchep C23): 25 years old	11 (x 7 discs)	557	80	458	55	CTT (1998)
Routine stock	11	550	81	454	63	
CSIRO data	10	596	36	490	28	Kingston & Risdon (1961)

[a] Mr G. Meachem, Wespine Pty Ltd, Moore Rd, Dardanup WA 6236.

(Meachem,[1] personal communication). Air-dry density was also measured, and mean value was 588 kg m^{-3}. Other data collected by Wespine were air-dry density of 569 kg m^{-3} for 31-year-old unimproved and 611 kg m^{-3} for 47-year-old pines.

CALM Timber Technology had completed a wood density assessment of eleven maritime pine trees (P73) of seed orchard origin, which included a comparison with adjacent unimproved trees in the Yanchep trial (Hill 2000). Although there was a significant improvement in stem straightness and increase in vigour (and therefore size) in the pedigreed trees, the air-dry densities and basic densities were similar in the two treatments. Air-dry densities of pedigreed and unimproved trees were 557 kg m^{-3} and 550 kg m^{-3} respectively, and basic densities were 458 kg m^{-3} and 454 kg m^{-3} respectively. The mean ring width of the pedigreed specimens was greater than for unimproved, but obviously the latewood percentage was similar in both, resulting in similar density.

CONCLUSION

The first survey of basic density compared wood of pedigreed maritime pine planted in Yanchep, Pinjar or Gnangara plantations from 1972 to 1987 with some older unimproved material (P51, P57, and P69 to P71). There was a trend of decreasing basic density as stand age decreased, which would be explained by the higher resin contents in the older trees. Further assessments of basic density of pedigreed maritime pine will continue, with plots planted in semi-arid areas scheduled for survey in 2000.

The second survey assessed effect of height in tree on wood basic density of pedigreed maritime pine planted in Pinjar and Yanchep plantations from 1972 to 1987. There was a trend of decreasing basic density as stand age decreased, which would be explained by the higher resin contents in the older trees. The trend of decreasing mean basic density with increasing height in the tree was confirmed.

In commercial use such as LVL or plywood production where pine is used with the normal resin content, it is likely that some volatile components of the resins will be given off during the veneer drying process with drying temperatures probably about 160°C. The highest resin content is in the 70 mm diameter core discarded after peeling. The thin veneers peeled outside this diameter should not be adversely affected by resin content, particularly with the high quality gluelines achievable from modern adhesives and technology.

ACKNOWLEDGEMENTS

The first survey was organized in consultation with Ian Knobel of Wesfi Ltd, and Barry McCombe, a consultant to Wesfi. Clayton Sanders of CALM's Plantation Group nominated sampling areas in the routine plantations, and Trevor Butcher permitted sampling of research trials. Ernie Jordan provided technical assistance in the fieldwork.

In the second survey to assess the effect of height in tree on basic density, Tony Dehnel and Brian Haley provided technical assistance in the fieldwork.

Yumiko Bonnardeaux provided assistance with the fieldwork for the resin content assessment, and David Harris of the WA Chemistry Centre organized the resin extraction from the cores.

REFERENCES

Hill, P. (2000). Wood density of improved compared with unimproved maritime pine (*Pinus pinaster*). *CALMScience* **3** (3), 309–315.

Hopkins, E.R. and Butcher, T.B. (1994). Improvement of *Pinus pinaster* Ait. in Western Australia. *CALMScience* **1**(2), 159–242.

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.

Koch, P. (1972). Utilization of the southern pines. US Department of Agriculture Forest Service, Southern Forest Experiment Station, *Agriculture Handbook* No. 420.

Nicholls, J.W.P. (1968). Selecting Portuguese *Pinus pinaster* for tree improvement in Australia, Part II: Wood quality assessment. Paper presented at Ninth British Commonwealth Forestry Conference.

Nicholls, J.W.P., Dadswell, H.E. and Perry, D.H. (1963). Assessment of wood qualities for tree breeding, II: In *Pinus pinaster* Ait. from Western Australia. *Silvae Genetica* **12**(4), 105–110.

Perry, D.H. and Hopkins, E.R. (1967). Importation of breeding material of *Pinus pinaster* Ait. from Portugal. Forests Department of Western Australia *Bulletin* 75.

Siemon, G.R. (1983). Strength properties of *Pinus pinaster* Ait. in Western Australia. Forests Department of Western Australia *Research Paper* 72.

Siemon, G.R. (1995). Wood density and spiral grain of radiata pine and maritime pine grown in Donnybrook Sunkland trial plots. *CALMScience* **1**(3), 251–257.

South African Department of Forestry (1964). *Annual Report 1963–1964.*

[1] Mr G.Meachem, Wespine Pty Ltd, Moore Road, Dardanup WA