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Wood properties of southern gidgee (*Acacia pruinocarpa*) from different sites in the Pilbara and goldfields regions of Western Australia

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SUMMARY

The CALM**Science** Division and CALM Timber Technology undertook a joint study to investigate the basic wood properties of initial moisture content, density, fibre saturation point and shrinkage of southern gidgee (*Acacia pruinocarpa* Tindale) trees from three geographic regions within the arid zone of Western Australia.

The low initial moisture contents observed for southern gidgee (24 to 35 per cent) from the three areas is a product of the dry environment in which the species grows, and the high density of its wood. The mean basic density, air-dry density and green density for all sites were 926 kg m^{-3}, 1083 kg m^{-3} and 1203 kg m^{-3} respectively.

The estimated fibre saturation point was 21.2 per cent, lower than that of most other species. The mean tangential, radial and longitudinal shrinkages from green to 12 per cent moisture content for this study were 2.5 per cent, 1.68 per cent and 0.12 per cent respectively. The tangential:radial:longitudinal shrinkage ratio for southern gidgee at 12 per cent moisture content was therefore 21:14:1, compared with the general ratio of 100:50:1. This result could be attributed to the presence of wavy grain and the difficulty in achieving perfectly backsawn or quartersawn samples.

Southern gidgee has an attractive dark ebony colour and very dense wood, giving the species the potential for value-adding into furniture, craftwood and musical instruments.

INTRODUCTION

In its natural environment southern gidgee (*Acacia pruinocarpa* Tindale) grows to a tall dominant tree 12 m high, with a large spreading crown and rough, deep fissured bark which folds into the wood of the trunk and branches (Mitchell and Wilcox 1994). Trees generally occur on rocky hills and on hard mulga (*A. aneura* Muell ex Benth) plains in shallow loamy soils over rock or a hardpan. Larger trees are often found in moisture gaining sites. Southern gidgee has a wide distribution through the central and northern desert areas of Western Australia (WA), beginning about 50 km east of Carnarvon, and extending east into the Northern Territory (Pronk 1997).

The common name of *gidgee* is also applied to a similar looking, but unrelated species (*A. cambagei* R.T. Baker) which grows in the dry inland areas of Queensland and New South Wales. The wood properties of *A. cambagei* are described in Bootle (1983).

Southern gidgee has wide distribution and a large size, considering it grows in an arid environment. Its attractive dark ebony coloured wood with its high density give the species potential for value-adding into furniture and craftwood. This report discusses a joint trial undertaken by the CALM**Science** Division and CALM Timber Technology to investigate the basic wood properties of density, shrinkage, initial moisture content and fibre saturation point of trees from three geographic regions of WA.

METHODS

The southern gidgee trees were sampled from areas ranging from three sites in the Pilbara through to two sites each in the North Eastern and North Western Goldfields (Table 1). The trees were felled, docked to 2.6 m log lengths, and delivered to CALM Timber Technology at Harvey within three to four weeks of harvesting, then stored under water spray. Some were delivered to the Herbarium initially, where they were kept moist until transport to Harvey was available. Generally, the time recommended between felling and stockpiling logs from regrowth jarrah (*Eucalyptus marginata*) and karri (*E. diversicolor*) is less than one week, but the long distances involved in this study resulted in the delay between felling and stockpiling. After stockpiling, the logs were sawn and specimens prepared for assessing the following basic wood properties:

- initial moisture content
- green density, air dry density and basic density
- fibre saturation point (f.s.p.)
- tangential, radial and longitudinal shrinkage

TABLE 1
Site details of southern gidgee logs collected for wood properties assessments.

GEOGRAPHIC REGION	SITE	VOUCHER No.	No. OF TREES SAMPLED	DATE COLLECTED	LATITUDE	LONGITUDE	LOCATION DESCRIPTION
Pilbara	Savory Creek	S. van Leeuwen 3380	1	15 Oct 1997	28° 48' 39" S	120° 24' 40" E	3.2 km SW of Burranbar Pool, 17.3 km E of Mundiwindi, 26 km ENE of Cundlebar, 9.2 km W of Kimberley Well
	Hamersley	S. van Leeuwen 3384	1	15 Oct 1997	23° 12' 44" S	119° 28' 11" E	7.2 km SE of Pamelia Hill, 15.7 km SE of Rhodes Ridge, 32.4 km ENE of Giles Point
	Fortescue Valley	S. van Leeuwen 3386	1	15 Oct 1997	22° 03' 51" S	118° 15' 44" E	Mulga Downs Station, 8.6 km WNW of Windemurra Well, 21 km NNW of Wittenoom, 22.4 km E of Pigeon Camp Well
North Eastern Goldfields	Lake Carnegie	N.A.	3	25 Nov 1997	25° 50' S	122° 33' E	Gunbarrel Highway (south side), about 305 km E of Wiluna
	Yakabindie Station	N.A.	1	30 July 1997	27° 27' S	120° 34' E	Yakabindie Nickel Mine site
North Western Goldfields	Mt Magnet-East	T. M^{c}Kenzie	1	Sept 1997	28° 06' S	117° 50' E	20 km east of Mt Magnet
	Mt Magnet-North East	T. M^{c}Kenzie	1	Sept 1997	28° 06' S	117° 50' E	15 km NNE of Mt Magnet

Note: Samples are coded by Site name and Voucher number (when given).

Specimen Preparation

Backsawn specimens (28 x 28 mm) were cut from the outer heartwood of randomly selected log lengths. The logs were broken down on a *Forestor 150* horizontal bandsaw, and the flitches sawn into 28 x 28 mm backsawn lengths, using either a *Jonsereds* vertical bandsaw or a *Wadkin* band resaw. These lengths were then dressed on all sides to 25 x 25 mm cross-section to remove saw marks and produce even surfaces to improve measuring accuracy with vernier calipers. Specimens 200 mm long were then docked. Owing to the twisted log shape, it was difficult to achieve straight grained pieces, which consequently affected longitudinal shrinkage measurements and therefore some specimens were rejected in data analysis.

Initial Moisture Content

The initial moisture content (I.M.C.) of a piece of timber is defined as the mass of water contained in that timber expressed as a percentage of the oven-dry mass.

$$\text{I.M.C. (\%)} \ \frac{\text{Green mass} - \text{Oven-dry mass}}{\text{Oven-dry mass}} \times 100$$

(AFRDI 1997).

Data on initial moisture content assist in selecting an economical drying schedule for a particular timber species. Previous assessments of specialty timbers from the WA Goldfields have indicated values lower than those for jarrah and karri (Brennan and Newby 1992).

A section was cut from the end of each 25 x 25 mm length and oven-dried to determine moisture content, as described in AS/NZS1080.1:1997 (Standards Australia 1997). If the green mass could not be measured immediately after cutting, then the specimens were block-stacked and wrapped in plastic to reduce moisture loss.

Fibre Saturation Point

Fibre saturation point (f.s.p.) is the moisture content at which the cell cavities have lost their free water while the cell walls are still saturated. It is usually in the range of

25 to 30 per cent moisture content for most species (Campbell 1997). It is important to know f.s.p. because wood properties of a piece of timber change below that moisture content. For example, as water moves out from between the fibrils of the cell wall and the fibrils move closer together and shrinkage of the cell wall occurs, then shrinkage of the whole piece commences. Removing the free water from the cell cavity also allows easier penetration of chemical preservatives, fire retardants and other additives. Thermal, acoustical and electrical properties also change as the moisture content falls below f.s.p. It is critical to know the f.s.p. when drying timber, particularly if drying at temperatures above 100° C, because cell collapse and internal checking can develop if the cells still contain free water.

Kelsey (1956) used the 'shrinkage intersection point' as an estimate of f.s.p. She defined the shrinkage intersection point as the moisture content at which the extended linear portion of the shrinkage-moisture content curve intersects the line of zero shrinkage. Shrinkage curves were produced for southern gidgee specimens from each site by plotting mean moisture content and mean shrinkage (tangential and radial), using the following method.

The mass of each 25 x 25 x 200 mm specimen was then recorded, and the subsequent mass over the assessment period as the timber dried compared with that initial mass (measured at the time of assessing initial moisture content) to estimate moisture content at each measurement time. At the end of the assessment the mean predicted moisture content was below 8 per cent, and the specimens were then oven-dried.

The oven-dry mass and weekly weighing for each southern gidgee specimen allowed the determination of moisture content at each assessment. The oven-dry mass for each specimen was used to calculate initial moisture content and basic density, and to produce shrinkage curves and estimate f.s.p. From shrinkage curves, shrinkage intersection points were estimated for specimens from each site. Using the data between 5 per cent and 25 per cent moisture content, linear regressions were calculated and the intersection point on the y-axis (MC%) used to estimate f.s.p. To construct a shrinkage curve with most species, at least one data point should be above 25 per cent moisture content, i.e. above f.s.p. This generally allows an elbow to develop in the curve and the regression line can be projected onto the y-axis. In some cases the mean moisture content of some specimens was below 25 per cent M.C. and f.s.p. could not be accurately estimated.

Density (green, air-dry and basic density)

The density of a piece of wood (or any substance) is defined as its mass divided by its volume, usually expressed in kilograms per cubic metre (kg m^{-3}). Three methods of estimating density were used in this trial. They were:

Green density (G.D.) is the ratio of the mass of green or unseasoned wood to green volume. This density is useful when determining log transport costs by relating tonnes to cubic metres, the basis of weight-scaling. However, the moisture content of the logs varies during the year, and green density will vary.

Air-dry density (A.D.D.) is the mass of a piece of wood divided by its volume after seasoning (generally to 12 per cent moisture content). This condition relates to wood in use and is the usual figure used when comparing densities of different species in practical situations.

Basic density (B.D.) is the oven-dry mass divided by green volume. This measure has the advantage that moisture content variations during the year are avoided.

Samples for assessing green and basic density were taken from green boards and from dry boards for estimating air-dry density. Air-dried densities were calculated when the specimen moisture contents were approximately 12 per cent. Because measurements were conducted weekly, it was difficult to assess the specimens when their moisture contents were exactly 12 per cent.

Shrinkage

The shrinkage of a piece of wood is expressed as a percentage of its green dimensions (i.e. when the moisture content is above fibre saturation point).

$$\text{Shrinkage (\%)} = \frac{\text{green dimension} - \text{dry dimension}}{\text{green dimension}} \times 100$$

To obtain accurate shrinkage measurements, the 25 x 25 x 200 mm specimens were measured for tangential (parallel to the growth rings), radial (perpendicular to the growth rings) and longitudinal shrinkage before drying in a controlled humidity chamber. The specimens were re-measured weekly at the same position until the moisture content was below 8 per cent. The equilibrium moisture content (e.m.c.) in the humidity chamber was set at 2 per cent lower than the mean moisture content of the specimens to allow them to dry and shrink before the next assessment.

All data collected for moisture content, density and shrinkage for each site were entered onto an *Excel* spreadsheet.

RESULTS AND DISCUSSION

Density

The green density, moisture content, basic density and air-dry density data for each site assessed for this study are given in Table 2. Note the low values for average initial moisture content, some being below the normal fibre saturation point (f.s.p.). The low initial moisture contents measured (ranging from 24.4 to 35.1 per cent) from the seven sites reflect the arid and semi-arid dry environments in which the trees grow, and the high wood density of southern gidgee.

The mean green density, basic density and air-dry density for all sites were 1205 kg m^{-3}, 925 kg m^{-3} and 1085 kg m^{-3} respectively. The high density of southern gidgee is owing to thick cell walls and small cavities that result in less space available for free water. All sites have

TABLE 2

Moisture content, green, basic and air-dry density of southern gidgee specimens from different sites in the Goldfields and Pilbara Regions.

SITE	No. SAMPLES	INITIAL MOISTURE CONTENT (%)		GREEN DENSITY (kg m^{-3})		BASIC DENSITY (kg m^{-3})		AIR-DRY DENSITY (kg m^{-3})	
		MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
Savory Creek	25	24.4	1.5	1175	55	945	50	1095	55
Hamersley Range	19	35.1	3.3	1230	55	910	45	1065	55
Fortescue Valley	23	29.7	4.3	1155	30	890	30	1045	30
Lake Carnegie	18	32.3	4.2	1210	50	915	45	1070	55
Mt. Magnet – East	25	31.6	4.6	1200	55	915	45	1065	50
Mt. Magnet – North East	21	28.4	6.6	1180	30	920	60	1070	70
Yakabindie Station	28	30.2	5.8	1260	60	970	45	1150	55
All Sites	**159**	**30.2**		**1205**		**925**		**1085**	

long term dry conditions with harsh growing conditions. Kalgoorlie has a mean January maximum temperature of 33.6°C and a low mean rainfall of 260 mm per year (Bureau of Meteorology 1988) which are typical of the conditions for sites assessed.

The logs assessed from Savory Creek, Hamersley and Fortescue were from three different trees, producing nine logs. Four logs were assessed from Lake Carnegie, coming from three different trees. The sampling position within these trees will affect the density results for these sites and the comparisons between sites.

The content of cell wall material in wood and thus density varies not only between species but also within species and individual trees. Wood density is affected by factors such as proportions of heartwood and sapwood, rate of growth and the proportion of earlywood to latewood (particularly in conifers). Young trees have a significant volume of juvenile wood in their central core, which is of lower density than mature wood of the same species, and considerable variation in density occurs both between and within trees. Average density increases with cambial age or distance from the pith (Brennan 1997).

Green density is the density of the wood at the time the living tree is felled. It varies considerably with the season, weather conditions, and the age of the tree (Bootle 1983). The seven sites included in this study were sampled at different times of the year under different weather conditions, which affected green density. Yakabindie, which produced different results from all other groups, was sampled in July. All other samples were collected between September and November, and seasonal variation in green density may explain the significant differences in green density. Genetic differences owing to long distances between some sites may contribute some of the variation in green density.

The Yakabindie sample had the highest value for each of the three density measurements, i.e. green, basic and air-dry density. All three density values for Yakabindie were within the range of densities quoted for mulga, a species with similar wood characteristics (Bootle 1983; Brennan and Newby 1992).

Brennan (1997) reported similar densities to the mean results of the present study for raspberry jam (*A. acuminata)* and mulga (*A. aneura*), other *Acacia* species from the Wheatbelt and Goldfields Regions of WA. Bootle (1983) reported green density values of about 1300 kg m^{-3} for two *Acacia* species referred to as gidgee (i.e. *A. cambagei* and *A. georginae*), and air-dry density of about 1250 kg m^{-3} for *A. cambagei*: values slightly higher than those reported in this study.

Special attention is required when milling, drying and processing southern gidgee, as the timber has potential for high value end uses, for example furniture, craftwood and components for musical instruments. High-density timbers normally require high-speed planers and sharp tools with slow feed speeds. Drying of high density timbers with a minimum of degrade is difficult because movement of water through the dense cell structure is slow. High equipment costs, maintenance costs and the slow drying times result in higher processing costs than those of lower density timbers which are softer and faster to dry while equipment requires less maintenance.

Shrinkage

Fibre saturation point estimates were made by generating a regression line from the shrinkage curves of moisture content and shrinkage between 5 and 25 per cent, and taking the 'y' intercept as the f.s.p. prediction: f.s.p. estimates are shown in Table 3.

Fibre saturation point estimates from the longitudinal shrinkage curves were consistently lower than estimates from the tangential and radial shrinkage curves. Estimated f.s.p. for southern gidgee [because changes in dimensions are very small compared with tangential and radial, and less reliable] for reliable data (i.e. excluding longitudinal) was 21.2 per cent for tangential shrinkage curves and 20.4 per cent for radial shrinkage curves. In comparison, the f.s.p. for most species lies between 25 and 30 per cent (AFRDI 1997), but the estimate in the present study is similar to the 21.7 per cent estimate for gidgee made by Siemon and Kealley (1999).

The mean shrinkage data for tangential, radial and longitudinal shrinkage at a moisture content of 12 per cent and at final moisture content (between 7.5 and 9.0 per cent M.C.) are shown in Table 4.

The mean tangential, radial and longitudinal shrinkage for all sites from green to 12 per cent is 2.5 per cent (SD 0.8), 1.7 per cent (SD 0.4) and 0.1 per cent (SD 0.1) respectively. This gives a tangential:radial:longitudinal shrinkage ratio for southern gidgee of 21:14:1. For all sites from green to final moisture content (Table 4) shrinkages

TABLE 3

Fibre saturation point predicted from tangential (tang), radial and longitudinal (long) shrinkage curves.

	F.S.P. ESTIMATES			INITIAL MC%		
SITE	TANG	RADIAL	LONG	MEAN	STD DEV	RANGE OF MC% FOR F.S.P. ESTIMATES
Yakabindie	21.93	21.53	19	30.21	5.77	21.7–7.5
Savory Creek	21.1	19.7	16.5	24.4	1.45	24.4–8.5
Hamersley	21.2	20.42	15.08	35.1	3.26	20.9–9.0
Fortescue	21.92	21.51	12.04	29.7	4.3	20.3–8.6
Lake Carnegie	21.35	20.24	15.79	32.3	4.24	22.3–8.9
Mt Magnet – East	21.04	20.15	13.35	31.6	4.58	22.2–8.7
Mt Magnet – North East	19.73	19.15	17.78	28.4	6.64	21.1–9.0
Mean all sites	**21.2**	**20.4**	**15.6**	**30.2**	**4.32**	

TABLE 4

Tangential, radial and longitudinal shrinkage measurements of southern gidgee for sites assessed.

SHRINKAGE FROM GREEN TO 12 % MOISTURE CONTENT

SITE	n	TANGENTIAL (%)		RADIAL (%)		LONGITUDINAL (%)		MEAN MC(%)
		MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	
Savory Creek	24	2.44	0.76	1.57	0.25	0.08	0.05	11.3
Hamersley	19	2.54	0.52	1.63	0.25	0.22	0.09	11.7
Fortescue	23	2.85	0.66	1.76	0.35	0.06	0.06	11.9
Lake Carnegie	18	2.4	0.95	1.57	0.23	0.11	0.07	11.9
Mt. Magnet – East	25	2.42	0.71	1.37	0.46	0.09	0.07	11.8
Mt Magnet – North East	21	1.91	0.48	1.44	0.29	0.12	0.07	11.9
Yakabindie	28	2.83	0.90	2.27	0.37	0.16	0.12	12.5

SHRINKAGE FROM GREEN TO FINAL MOISTURE CONTENT

SITE	n	TANGENTIAL (%)		RADIAL (%)		LONGITUDINAL (%)		FINAL MC(%)
		MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	
Savory Creek	24	3.56	0.91	2.45	0.32	0.12	0.05	8.5
Hamersley	19	3.38	1.04	2.26	0.33	0.12	0.07	9.0
Fortescue	23	3.94	0.99	2.62	0.38	0.07	0.06	8.6
Lake Carnegie	18	3.26	1.15	2.30	0.37	0.12	0.10	8.9
Mt. Magnet – East	25	3.54	0.90	2.31	0.43	0.12	0.09	8.7
Mt Magnet – North East	21	2.95	0.53	2.23	0.36	1.20	0.13	9.0
Yakabindie	28	4.72	1.28	3.92	0.50	0.31	0.22	7.5

were 3.7 per cent (SD 1.1), 2.6 per cent (SD 0.7) and 0.2 per cent (SD 0.3) respectively, giving a ratio of 20:14:1. Published data on shrinkage is normally given as the shrinkage between green and 12 per cent MC, a figure representative of seasoned timber in dwellings. The mean tangential and radial shrinkage for all sites from green to 12 per cent MC (2.5 per cent and 1.7 per cent respectively) were less than the 2.9 per cent and 2.3 per cent respectively quoted by Siemon and Kealley (1999). The high standard deviations observed in the shrinkage measurements, particularly in longitudinal shrinkage, are owing to wavy grain and/or measuring inaccuracies, with the latter a likely source of variation when measuring the very small changes observed in longitudinal shrinkage.

The tangential:radial:longitudinal ratio of 21:14:1 was significantly different from the generally quoted ratio of 100:50:1. Shrinkage of wood as it dries is caused by the fibrils moving closer together rather than the fibrils actually shrinking. The greatest shrinkage occurs at right angles to the direction in which the fibres lie. Most cells have the fibrils running spirally and close to parallel to the length of the cell. There is little shrinkage in the length of the cell and greater shrinkage at right angles to the length of the cell in the radial and tangential directions, and longitudinal shrinkage is much less than either tangential or radial shrinkage. Radial shrinkage is less than tangential shrinkage because the medullary rays reduce shrinkage in the radial direction.

The amount of shrinkage in a piece of timber is affected by the direction of the grain in that piece. Although we tried to select specimens where the growth rings were parallel to the face, southern gidgee has a very twisted wavy grain making it difficult to select perfect samples. Within a 25 x 25 x 200 mm specimen the grain can change direction, which causes distortion during drying to 12 per cent or final MC and greater than expected longitudinal shrinkage. An increase in the longitudinal shrinkage reduces the ratio of tangential:radial:longitudinal shrinkage.

Southern gidgee's wide distribution and arborescent growth form with large stem diameter for a semi-arid environment, combined with the attractive dark ebony colour and high density of the wood, gives this species the potential for value-adding into furniture, craftwood and in musical instruments. The nature of a scattered resource over vast areas and the difficulty in finding suitable logs from a tree with poor form means that southern gidgee would only have potential for a small scale specialty timber industry.

Considerable interest has been shown in using Goldfields timbers for manufacturing flutes and woodwind instruments (Kealley 1989). The acoustic properties of southern gidgee should be tested for its possible use in the manufacture of musical instruments, because mulga has given satisfactory results in flutes. Desert Timber Products in Kalgoorlie is currently using southern gidgee for guitar components. Future research on southern gidgee may include assessment of sawmilling recoveries, timber drying, processing and an evaluation of its acoustic properties.

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