

## VARIATIONS IN HEARTWOOD PROPORTION AND BASIC DENSITY BETWEEN PROVENANCES OF *EUCALYPTUS GRANDIS* IN KENYA

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**LANGAT, D. K. & KARIUKI, J. G. 2004. Variations in heartwood proportion and basic density between provenances of *Eucalyptus grandis* in Kenya.** *Eucalyptus grandis* is one of the exotic tree species that have received wide attention in Kenya because of its fast growth and multiple uses. In 1980, a provenance trial was established in Elburgon, Kenya to assess its growth performance. The wood quality variation between these provenances is not known. Trees from each of the 18 provenances were selected at 16 years of age to investigate variations in heartwood proportion and basic density. The study indicated large variations between provenances for the two properties assessed. The average heartwood proportion ranged from 29.5 to 61.5%. Heartwood proportion decreased with height with maximum at 1.3 m and minimum at 12.0 m. The average basic density ranged from 490.4 to 592.7 kg m<sup>-3</sup>. Basic density decreased between 1.3 and 4.0 m height and thereafter increased slightly for most provenances except for south of Tyalgum, northern New South Wales and south of Murwillumbah whose density increased with sampling height.

Key words: Elburgon – wood properties – growth performance – sampling heights – provenance trials

**LANGAT, D. K. & KARIUKI, J. G. 2004. Variasi perkadaran teras kayu dan ketumpatan asas antara provenans *Eucalyptus grandis* di Kenya.** *Eucalyptus grandis* merupakan salah satu spesies dagang yang banyak diberi perhatian di Kenya disebabkan pertumbuhannya yang cepat dan penggunaannya yang pelbagai. Pada tahun 1980, ujian provenans dimulakan di Elburgon, Kenya untuk menilai prestasi pertumbuhan spesies ini. Variasi kualiti kayu antara provenans tersebut tidak diketahui. Pokok berumur 16 tahun daripada 18 provenans dipilih untuk mengkaji perkadaran teras kayu dan ketumpatan asas. Kajian menunjukkan variasi yang besar antara provenans untuk kedua-dua ciri yang dikaji. Purata perkadaran teras kayu berjulat antara 29.5% hingga 61.5%. Perkadaran teras kayu berkurang dengan ketinggian pokok dengan nilai maksimum dicatat pada ketinggian 1.3 m dan nilai minimum pada ketinggian 12.0 m. Purata ketumpatan asas berjulat antara 490.4 kg m<sup>-3</sup> hingga 592.7 kg m<sup>-3</sup>. Ketumpatan asas berkurangan antara ketinggian 1.3 m hingga 4.0 m dan kemudian bertambah bagi kebanyakan provenans kecuali selatan Tygalum di utara New South Wales dan selatan Murwillumbah yang menunjukkan ketumpatan yang bertambah dengan ketinggian pokok.

### Introduction

*Eucalyptus grandis* is one of the fast growing exotic species planted in Kenya. It is popularly used for afforestation because of its ease in nursery care, good for n

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and multipurpose uses. In 1980, a *E. grandis* international provenance trial was established at Elburgon, under the auspices of the International Union of Forestry Research Organizations (IUFRO) as part of national and international efforts in assessing growth performances in various ecological zones. Results of growth performance between 16 Australian provenances and two local landraces at nine years indicated no significant variation in growth (Oballa & Giathi 1997). However, local landraces ranked low compared with the Australian provenances.

The most important wood properties that influence wood quality for most end-uses are collapse, seasoning, density, and proportion of heartwood and sapwood. Density is a function of the proportion of cell wall material and is a direct indicator for most strength properties of wood (Hillis 1984). Density in combination with moisture content influences the splitting and collapse properties (Chafe 1985). A strong correlation also exists between density and natural resistance (Eldridge *et al.* 1984).

The proportion of heartwood affects most physical and chemical properties of wood and has been found to be heritable (Zobel & Talbert 1984). To increase gain through genetic improvement, it is important to determine the amount of variation in properties that influence wood quality. Currently, there is no information on the wood properties of the introduced *E. grandis* provenances in Kenya. The purpose of this study was to analyse variations in heartwood proportion and basic wood density between the provenances of *E. grandis*.

## Materials and methods

### *Source of materials*

The wood samples were obtained from a 16-year-old provenance trial situated at Ndoswa forest in Elburgon (longitude 35° 52' E, latitude 0° 21' S and altitude 2378 m) (Table 1). The trial was established in 1980 in a completely randomised block design with five replicates and 2.5 × 2.5 m escapements. The trial site had an old crop of *E. saligna*, which was clear-felled as well as agricultural crops planted one year before the establishment of the trial. The trial was managed under the Taungya system for two years (Farmers are allowed to plant agricultural crops on forest lands for two or three years before canopy closure. Weeding by farmers protect the seedlings from competition). The site experiences bimodal rainfall patterns with peaks in April and August, and experiences dry period between October and March. The mean annual temperature is 17 °C. The soils are sandy loam and low in humus content.

### *Field sampling*

Four trees of unforked bole and free from defects were randomly selected from each of the five blocks for each provenance. For each tree sampled, 25-mm thick discs were extracted at four sampling heights (1.3, 4.0, 8.0 and 12.0 m). The cross-wise diameter, sampling height and provenance number were recorded for each disc.

**Table 1** Details of *Eucalyptus grandis* provenances planted at Ndoswa, Elburgon forest

Provenance No.	CSIRO seedlot No.	Provenance location	Latitude S	Longitude E	Altitude (m)
1	S12380	East of Mareeba Northern Queensland	17° 03'	145° 36'	740
3	12426	SFR 700 Gillis Highway Northern Queensland	17° 13'	145° 42'	730
6	12381	Wondela area Northern Queensland	17° 25'	145° 27'	1010
7	12409	Ravenshoe area Northern Queensland	17° 42'	145° 28'	940
8	12382	Tully Falls area Northern Queensland	17° 49'	145° 31'	800
9	12461	West of Paluma Northern Queensland	19° 00'	146° 00'	900
11	10693	North East of Gympie Southern Queensland	26° 07'	152° 42'	76
12	10694	South East of Gympie Southern Queensland	26° 18'	152° 46'	75
13	10695	Kenilworth Southern Queensland	26° 40'	152° 33'	530
14	10696	Bellthorpe Southern Queensland	26° 52'	153° 42'	460
15	11243	South of Tyalgum Northern N.S.W	28° 27'	153° 12'	100
16	11244	South of Murwillumbah Northern NSW	28° 33'	153° 23'	300
17	11681	North of Woolgoolga Northern NSW	29° 32'	153° 12'	30
18	7823	North of Coffs Harbour Northern NSW	30° 10'	153° 08'	18
19	7810	North of Buladelah Northern NSW	32° 20'	152° 13'	120
21	–	Seed orchard, Sabie, South Africa	–	–	–
22	MA74	Muguga arboretum Plot 74	1° 13'	36° 38'	2040
23	MP	Muguga estate plantation Cpt 2G	1° 13'	36° 38'	2040

CSIRO = Commonwealth Scientific and Industrial Research Organization, Australia

SFR = State Forest Reserve

NSW = New South Wales

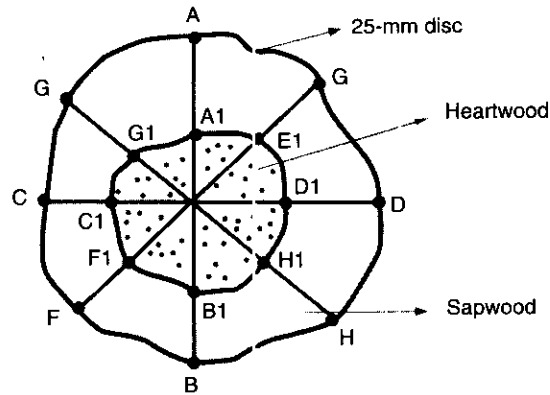
*Determination of heartwood proportion*

The heartwood proportion for each disc was determined by taking measurements depicting the heartwood's outline. Four heartwood diameter measurements and the corresponding diameters for the total cross-section of the disc were taken, A<sub>1</sub>B<sub>1</sub>, C<sub>1</sub>D<sub>1</sub>, E<sub>1</sub>F<sub>1</sub>, G<sub>1</sub>H<sub>1</sub> and AB, CD, EF, GH respectively (Figure 1). The heartwood percentage was then calculated as follows:

$$\text{Heartwood proportion (\%)} = \frac{DHW^2}{DD^2} \times 100$$

where

*DHW* = heartwood diameter*DD* = disc under bark diameter

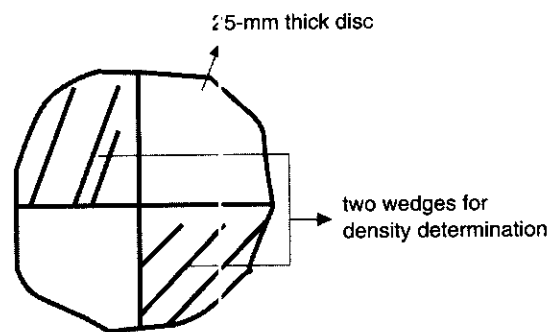


**Figure 1** Axial lines drawn across disc surface used for linear measurements for determination of heartwood per cent

### *Determination of basic density*

Two diametrically opposite wedges (specimens) of approximately the same size were cut from each of the 25-mm disc such that each wedge extended from the pith to the bark (Figure 2). The weight of each wedge was taken to the nearest 0.1 g. Volume of each wedge was obtained to the nearest 0.1 cm<sup>3</sup> using the water displacement method. The specimens were then oven dried at 103 °C until constant weights were achieved. Samples were considered to be at constant weight when the variation between subsequent weights was less than 0.5%. Basic density for each specimen was computed using the following formula:

$$\text{Basic density} = \frac{\text{Oven dry mass of wood}}{\text{Volume of wood}} \quad (\text{kg m}^{-3})$$



**Figure 2** Extraction of wood for determination of basic density

### Data analysis

Data analysis was carried out following the design as a completely randomised experiment with provenance, sampling height and their interactions as the sources of variation. The heartwood per cent and mean density values were subjected to analysis of variance using SPSS 1994.

## Results and discussion

### Heartwood

Table 2 shows significant differences ( $p < 0.05$ ) between the provenances of *E. grandis* for heartwood proportion at all sampling heights. There was also a general reduction in heartwood proportion with increasing height. This is consistent with what has been reported for most *Eucalyptus* species (Hillis 1987). Formation of the heartwood starts at the base and tends to taper from the level of formation towards the crown (Hillis 1987).

A two-way interaction analysis (provenance  $\times$  sampling height) was highly significant ( $p < 0.05$ ). This indicates that the seed source contributes to variation in heartwood proportion across sampling heights. The average heartwood proportion ranged from 29.5 to 61.5% (Table 3).

Ranking of provenances using unweighted heartwood percentage mean values (Table 3) showed that the SFR 700 Gillis Highway northern Queensland provenance had the highest proportion of heartwood (61.5%), followed by North Coffs Harbour (58.4%), West of Paluma (56.1%) and Tully Falls area (54.4%). The local collection from Muguga arboretum plot 74 had 47.5%. The provenance with the least heartwood per cent was Kenilworths, south Queensland with an overall mean of 29.5%.

### Basic density

There were significant differences ( $p < 0.05$ ) between provenances in basic density at all sampling heights (Table 2). The basic density for most provenances generally decreased between 1.3 and 4 m with the exception of six provenances

**Table 2** Analysis of variance for heartwood proportion and basic density of *Eucalyptus grandis* grown in Elburgon, Kenya

Source of variation	Heartwood proportion			Basic density		
	DF	MS	F	DF	MS	F
Provenance	17	0.12	45.22*	17	13059.13	16.21*
Sampling height	3	0.23	84.38*	3	4125.00	5.12*
Provenance $\times$ sampling height	51	0.20	19.77*	51	1603.18	1.99*
Residual	360	0.03		80	805.50	

\* = significant at the 0.05 probability level

**Table 3** Mean heartwood per cent at four different heights for *Eucalyptus grandis* provenances grown in Ilburgon, Kenya

Provenance	Height (m)				Overall mean
	1.3	4.0	8.0	12.0	
SFR 700 Gillis Highway northern Queensland	59.4	70.7	51.8	64.2	61.5
North of Coffs Harbour NSW	57.7	61.9	55.9	58.1	58.4
West of Paluma Queensland	63.4	59.4	52.6	49.1	56.1
Tully Falls area Queensland	55.9	55.5	56.8	49.7	54.4
Bellthorpe southern Queensland	56.7	53.5	54.7	50.2	53.8
South-east of Gympie southern Queensland	53.4	54.5	53.8	49.3	52.8
North of Buladelah NNSW	48.6	56.4	51.5	51.0	51.9
North-east of Gympie southern Queensland	57.4	50.4	59.4	37.5	51.2
Wondela area Queensland	57.5	54.1	48.3	44.4	51.0
Herberton area Queensland	54.6	62.8	54.0	28.0	49.9
South of Murwillumbah NNSW	49.5	49.1	42.5	52.9	48.4
North of Woolgoolga NNSW	51.0	45.6	51.3	44.4	48.1
Muguga arboretum Plot 74	49.5	54.0	51.2	35.5	47.5
East of Mareba northern Queensland	55.6	40.7	45.2	41.2	45.7
Ravenshoe area Queensland	51.9	50.2	45.9	33.5	45.4
Seed orchard, Sabie, South Africa	53.5	48.4	41.6	31.4	43.7
South of Tyalgum NNSW	51.5	48.5	33.5	36.7	42.6
Kenilworths southern Queensland	40.5	30.8	24.0	22.7	29.5

NNSW = Northern New South Wales

(Ravenshoe area Queensland, south of Murwillumbah NNSW, Wondela area, Tully falls area Queensland, north of Woolgoolga NNSW and south of Tyalgum NNSW).

The northern (east of Mareba northern Queensland) and southern Queensland (north-east Gympie southern Queensland, south-east Gympie southern Queensland and Kenilworths southern Queensland) provenances had similar trends in basic density variation. All had slight decrease between 1.3 and 4.0 m except for north-east Gympie south Queensland and south-east Gympie where the decrease was substantial; thereafter, all showed moderate increase or decrease with increasing height depending on individual provenances (Table 4). This trend is similar to that reported by Purnel (1988) for *E. nitens* provenances in Transvaal, South Africa. The average basic density ranged from 490.4 to 592.7 kg m<sup>-3</sup>.

Ranking of provenances using unweighted basic density means (Table 4) showed that SFR 700 Gillies Highway of northern Queensland had the highest mean basic density (592.7 kg m<sup>-3</sup>), followed by north-east Gympie (589.3 kg m<sup>-3</sup>) and Ravenshoe area provenances (582.6 kg m<sup>-3</sup>). The South African Sabie provenance ranked twelfth, while the local collection from Muguga arboretum ranked tenth (544 kg m<sup>-3</sup>). The provenance with the least density was south Tyalgum NNSW provenance (490.4 kg m<sup>-3</sup>).

Earlier experiments assessing growth performance of *E. grandis* had recommended Buladelah, Tully Falls, Paluma, Ravenshoe and Gympie provenances as potential good seed sources (Oballa & Giathi 1997). The results from this study indicated that the recommended provenances had average basic densities ranging from 500.1 kg m<sup>-3</sup> to 589.3 kg m<sup>-3</sup> and heartwood proportion from 45.4 to 56.1 %. Although Gillis Highway northern Queensland provenance

**Table 4** Mean basic density ( $\text{kg m}^{-3}$ ) at four different heights for *Eucalyptus grandis* provenances grown in Elburgon, Kenya

Provenance	Height (m)				Overall mean
	1.3	4.0	8.0	12.0	
SFR 700 Gillis Highway northern Queensland	594.4	592.0	578.0	606.5	592.7
North-east of Gympie southern Queensland	618.0	565.5	577.0	596.5	589.3
Ravenshoe area Queensland	559.5	584.0	564.0	633.0	582.6
Herberton area Queensland	559.5	554.0	564.0	623.0	575.1
South of Murwillumbah NNSW	537.5	557.5	574.0	589.0	564.5
North of Buladelah NNSW	617.0	513.5	551.0	566.0	561.9
West of Paluma Queensland	602.0	583.5	532.0	528.0	561.4
Bellthorpe Southern Queensland	597.0	522.5	557.0	567.0	560.9
South-east of Gympie southern Queensland	612.5	525.0	536.0	526.0	549.9
Muguga arboretum Plot 74	557.0	508.5	552.5	558.0	544.0
Wondela area Queensland	548.5	551.5	555.0	512.5	541.9
Seed orchard, Sabie, South Africa	552.5	502.0	530.0	540.5	531.3
North of Coffs Harbour NSW	530.5	509.0	520.0	548.5	527.0
Kenilworths southern Queensland	525.5	496.0	530.0	542.5	523.5
East of Mareba northern Queensland	495.5	467.0	528.5	520.5	502.8
Tully Falls area Queensland	489.5	503.5	499.0	508.5	500.1
North of Woolgoolga NNSW	495.0	509.0	404.0	578.0	496.5
South of Tyalgum NNSW	489.5	546.0	465.5	460.5	490.4

SFR = State Forest Reserve

NNSW = northern New South Wales

had higher basic density and is probably suited for timber and pulp production, its higher heartwood content (61.5%) and poor growth in the area make it unsuitable as a source of pulpwood material.

### Conclusions

This study indicated that heartwood proportion and basic density varied between provenances and this variation was greatly influenced by sampling height. Mean basic density of provenances studied ranged from 490.4 to 592.7  $\text{kg m}^{-3}$ . These provenances are most likely suitable for pulp production since they are within the recommended range of 500 to 650  $\text{kg m}^{-3}$ . Heartwood proportion ranged from 29.5 to 61.5%. Based on the results of growth performance (Oballa & Giathi 1997) and this study, it is recommended that for future expansion of *Eucalyptus* plantations the seed source should come from Buladelah, Tully Falls, Paluma, Ravenshoe and Gympie provenances or from their established progeny trials.

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