WOOD BASIC DENSITY AND MOISTURE CONTENT OF YOUNG EUCALYPTUS REGNANS GROWN IN NEW ZEALAND

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ABSTRACT

Wood of 66 **Eucalyptus regnans** F. Muell. trees aged 4 to 17 years, from the North and the South Islands of New Zealand, was sampled for basic density and moisture content. Four bole positions (base, 1.4 m, half height, and three-quarters height) were sampled. Average basic density and moisture content values were 395 kg/m^3 and 174% (North Island) and 398 kg/m^3 and 164% (South Island) respectively. Basic density increased up the tree from 1.4 m to three-quarters height, but moisture content showed the opposite trend. Using regression analysis, the plot mean weighted basic density and moisture content could be estimated within 2% using the 1.4-m disc alone. Basic density generally increased from the pith outward at all sample positions. Trees more than 13 years old had greater basic density and lower moisture content values than younger trees.

INTRODUCTION

Eucalyptus regnans has been planted sporadically and on a small scale in New Zealand for over 100 years. Most plantings have been for windbreaks, local wood supplies, and aesthetic reasons. It is a fast-growing species well suited to the cool, moist, temperate climate and pumice soils of the central North Island.

Since the early 1960s *E. regnans* has been planted by N.Z. Forest Products Limited to provide short fibre for use in the manufacture of fine writing and printing papers. The usual rotations are between 15 and 18 years. The current planting programme involves 800 ha/year and to date over 4000 ha have been established (G. Fry, pers. comm.). Recently interest has been expressed by industry and by the Government in the potential for using various eucalypts (including *E. regnans)* for energy and chemical feedstocks to relieve New Zealand's dependence on imported oil. There is thus a need for detailed information on wood properties for determining dry matter production, pulp and energy yields, and volume conversions.

Most data on the physical properties of New Zealand-grown eucalypt wood have been from trees between 15 and 70 years old. Harris & Young (1980) reported that 70-year-old naturally regenerated *E. regnans* at Waitati in the South Island had a basic density averaging 496 kg/m^3, which compares with Australian values of 410–580 kg/m^3 (Dadswell 1972) and 580–800 kg/m^3 (FAO 1981) for trees of similar age or older. Hillis & Brown (1978) reported lower values for younger material. Harris & Young (1980) found that 40-year-old trees from Mahinapua (South Island) had an average basic density of 426 kg/m^3. J. Leonard and W. Cunningham (pers. comm.) recorded mean basic density values of 421 kg/m^3 for 20-year-old plantation-grown trees in the central North Island and 391 kg/m^3 for trees between 10 and 17 years old. Likewise, 14-year-old trees in the same region had a mean basic density of 393 kg/m^3 (Hannah *et al.* 1977). It is apparent that the age at which wood is formed has a marked effect on wood basic density, with wood of lower density coming from young trees. Younger trees have correspondingly higher average wood moisture content which directly affects drying and fibre yields. Young trees also have favourable interfibre bonding properties and produce paper with high surface smoothness. No New Zealand data have previously been published on basic density or moisture content for trees less than 10 years old, which may be near the optimal rotation age for intensively cultured stands grown for energy feedstocks. Variations in basic density and moisture content of plantation-grown *E. regnans* between 4 and 17 years old, from both the North Island and the South Island, are reported here.

MATERIALS AND METHODS

Six plantations of *E. regnans* aged 4, 7, 8, 10, 13, and 17 years, on lands of N.Z. Forest Products Limited near Kinleith, were chosen for study. Three additional stands aged 5, 8, and 13 years were selected near Reefton and Lake Ahaura on the West Coast of the South Island. All stands were fully stocked, unthinned, and growing on good quality sites. A 20 × 20-m sample plot was randomly located in each stand and 5 to 10 trees were selected to cover the range in diameters in the stand. Between November 1980 and June 1981 a total of 66 trees were felled and their heights measured. Four discs, each 10 cm thick, were cut from each bole at the base, 1.4 m, one-half, and three-quarters total height and their diameters recorded. The discs were then immediately sealed in plastic bags for transport to the Forest Research Institute at Rotorua where they were placed in cold storage prior to laboratory processing.

In the laboratory, diametrically opposed sectors were marked on each disc and, from these, samples were prepared proportional to increasing volumes from the pith outward. For the 17-year-old samples, annual growth layers in groups of five were marked off from the pith outwards on discs containing at least 10 annual rings and each five-ring group was prepared as a separate sample. Volume and weight were measured for each sample block in the green and oven-dry conditions. From these values, moisture content (%) and basic density (kg/m^3) were calculated for each disc. In this study basic density is defined as the mass of oven-dry wood per unit volume measured in the green condition. Weighted basic density and moisture content values were then calculated for stem sections and entire stems using stem green volumes as the weighting factor.

The results may be expected to be affected by seed source (M. D. Wilcox, pers. comm.) but it has not been possible to positively identify this information for all the trees examined.

RESULTS AND DISCUSSION

Mean diameters and ranges for the 51 North Island and 15 South Island trees are shown in Table 1. Overall mean diameter for all 66 trees (average age 9 years) was 18.3 cm with a range of 5.0–37.3 cm. Mean stand diameter increased with age but was also affected by site and stocking differences. At a given age, trees from the North Island had significantly larger diameters, heights, and volumes than South Island trees.

Weighted basic density and moisture content values are also summarised in Table 1. Both parameters were quite variable among trees and stands, but mean values were not significantly different between the North and South Islands. Mean basic density and moisture content for North Island trees were 395 kg/m^3 (range 326–449 kg/m^3) and 174% (range 137–220%), respectively. South Island trees had a mean basic density of 398 kg/m^3 (range 343–430 kg/m^3) and a mean moisture content of 164% (range 134–201%). Mean density values for both regions were similar to those for 10- to 20-year-old trees on N.Z. Forest Products Limited lands in the central North Island (J. Leonard and W. Cunningham, pers. comm.). No published moisture content values are available for New Zealand-grown *E. regnans,* but our values are higher than those reported for 23-year-old trees in Australia (Marysville, Victoria) which ranged from 118% for sapwood to 135% for heartwood (Hillis & Brown 1978). The highest mean density and lowest moisture content values were observed in the 17-year-old trees. There is a marked change in these wood properties after age 13, with basic density increasing substantially and moisture content decreasing.

TABLE 1—Mean and range of diameter, and mean and standard error of weighted wood basic density and moisture content for nine stands of **E. regnans** based on 66 trees

Stand age	Diameter at 1.4 m (cm)		Basic density (kg/m^3)		Moisture content (%)	
	Plot mean	Range	Weighted plot mean	S.E.	Weighted plot mean	S.E.
North Island						
4	10.7	5.0–16.0	394	± 7	176	± 4
7	17.3	10.1–26.4	376	± 6	188	± 4
8	14.9	7.9–22.0	400	± 7	168	± 4
10	24.8	9.4–35.5	382	± 5	181	± 4
13	21.5	9.8–37.3	390	± 8	177	± 4
17	23.8	8.1–36.0	428	± 9	152	± 4
Average	18.8		395		174	
South Island						
5	8.6	6.5–11.0	413	± 8	159	± 5
8	11.5	8.7–16.4	385	± 16	177	± 9
13	16.7	13.1–20.1	397	± 6	157	± 8
Average	12.3		398		164	

Basic density values were variable but consistently increased from 1.4 m to the three-quarter height position (Fig. 1). This trend has been found in samples from older trees in New Zealand and is typical for other members of the ash group of eucalypts (Harris & Young 1980). Studies with eucalypts in Australia have shown similar but

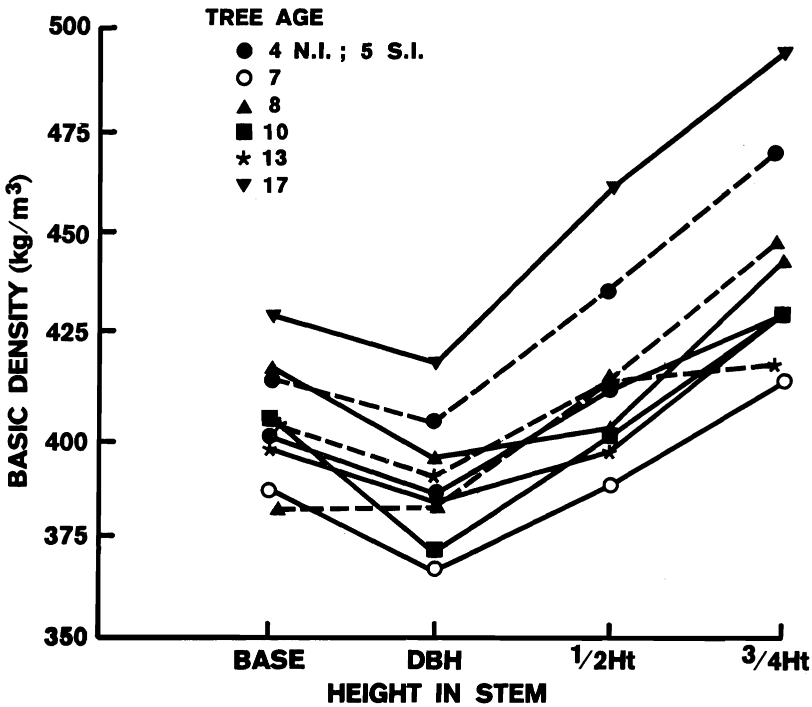

FIG. 1—Variation in mean wood density with stem height for **E. regnans** trees from the North Island (—) and the South Island (- - -) of New Zealand.

less dramatic trends. For example, Higgs (1969) reported density increased near the top of the clear bole for 34- to 44-year-old trees. Similarly, Dargavel (1968) found denser wood near the top of the lower half of the trees he sampled. For our trees there was a decline in density from the tree base to 1.4 m with the lowest values occurring at 1.4 m. The percentage increase in basic density from the tree base to three-quarter height averaged 6.76% for North Island trees aged 4 to 13 while the percentage increase for the 17-year-old trees was 14.6%. Not only was the mean density of the 17-year-old trees higher, but also the percentage increase with height was more than twice that of the 4- to 13-year-old trees. The average percentage increase for the South Island trees was 11.4% with the greatest increase (17.6%) occurring in the 8-year-old trees from Due North Creek (Inangahua East State Forest 130). Trends in moisture content for all stands were similar but reversed (Fig. 2). The only exception was the slight increase from one-half to three-quarter height for the 13-year-old Lake Ahaura (Hochstetter State Forest 26) trees. The percentage decrease in moisture content with height was greater than the corresponding increase in basic density, averaging 11.6% for North

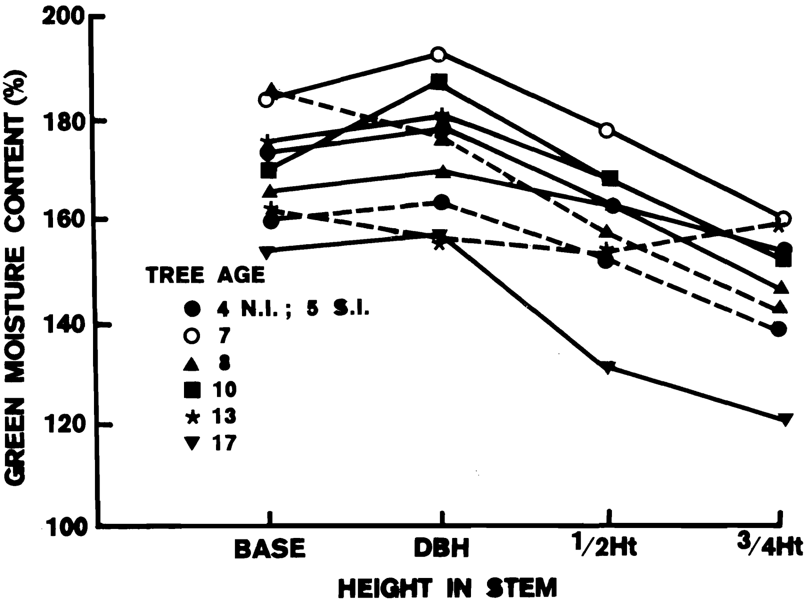

FIG. 2—Variation in mean wood moisture content with stem height for **E. regnans** trees from the North Island (—) and the South Island (- - -) of New Zealand.

Island trees aged 4 to 13 years and 21.4% for the 17-year-old trees. South Island trees showed more variation and the largest percentage decrease with height: Slab Hut (Tawhai State Forest 194, 5 years old) – 16.9%; Due North Creek (8 years old) – 30.7%; and Lake Ahaura (13 years old) – 1.8%. The plot mean weighted basic density and moisture content can be estimated within 2% using the 1.4-m disc alone.

For individual trees, mean tree density and mean tree moisture contents (m.c.) may be estimated from values at 1.4 m by the formulae

$$\text{tree density} = 0.958\ (\text{density at } 1.4\,\text{m}) + 24 \quad \text{S.E.} = 5.0$$

$$\text{tree m.c.} = 0.913\ (\text{m.c. at } 1.4\,\text{m}) + 12 \quad \text{S.E.} = 3.1$$

There was no significant improvement produced in the regression by adding diameter at 1.4 m or total height as a second variable, nor was there any significant difference in the relationships of these values between North and South Islands.

For 17-year-old trees the greatest increase in radial variation across the stem from the pith outwards was in the basal disc, with progressively smaller increases in the 1.4 m and one-half height discs respectively (Fig. 3). Although density generally increased from the pith outwards, the change was not as dramatic as with older trees such as the 70-year-old trees sampled by Harris & Young (1980). Our samples were young and had a limited number of growth segments, making estimates of radial variation in density more difficult. However, it is likely that these trends will continue and become more pronounced with age.

The increase in density from the pith outwards and with height even in very young trees is significant for utilisation and dry weight yields if short rotations are envisaged.

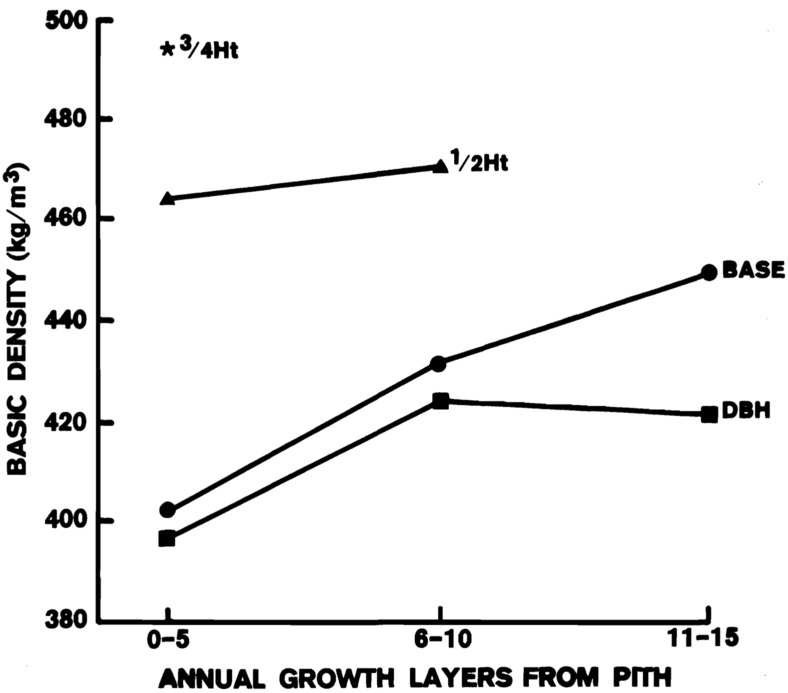

FIG. 3—Radial variation in mean wood density at different stem heights for 17-year-old **E. regnans.**

Additionally the increase in density and decrease in moisture content beyond 13 years is important and may help in identifying the optimum rotation age with respect to wood properties and planned end uses. In trees up to 13 years old, wood from the upper bole portions with the highest density and lowest moisture content is most suitable for pulping and energy. Beyond age 13, the entire tree becomes more suitable which suggests rotations at least this long. Such wood property information, combined with biomass and energy yields which we are currently investigating, will enable managers to plan the use of the *E. regnans* plantation resource in New Zealand to better advantage.

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REFERENCES

DADSWELL, H. E. 1972: The anatomy of eucalypt woods. **CSIRO Division of Applied Chemistry Technical Paper No. 66.**

DARGAVEL, J. B. 1968: Variations in the basic density of mountain ash. **Australian Forest Research 3(3):** 25–30.

FAO 1981: "Eucalypts For Planting". Food and Agricultural Organization of the United Nations, Forestry and Forest Products Studies, Rome. 669 p.

HANNAH, B. C.; FERGUS, B. J.; JONES, R. N. 1977: Kraft pulping and bleaching studies on young exotic hardwood species. **Appita 30(6):** 483–7.

HARRIS, J. M.; YOUNG, G. D. 1980: Wood properties of some New Zealand grown eucalypts. Paper presented at ANZIF Conference, Rotorua, May 12–16.

HIGGS, M. L. 1969: Genetic and environmental factors influencing commercially important wood properties of **Eucalyptus grandis** F.V.M. Ph.D. Thesis, Australian National University, Canberra.

HILLIS, W. E.; BROWN, A. G. (Eds) 1978: "Eucalypts For Wood Production". CSIRO, Canberra. 434 p.