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AVOIDING SURPRISES: FAST MASS SCREENING FOR UNWANTED EFFECTS

Abstract. The two principal challenges in processing many eucalypts are the distortion/warping of timber during sawing and the subsequent difficulties in drying the timber without significant degrade. Incorporating wood quality traits associated with these challenges in breeding is considered to be a demanding task. In this paper, simple approaches for mass screening for growth stresses, shrinkage, collapse and drying rates have been proposed. Sawing of log or stem along the length through the pith and measuring the outward bending of two half rounds form a quick and reliable method for screening trees with low growth stresses. A mathematical model was developed that relates the longitudinal growth stress and bending in half rounds. Methods for assessment of shrinkage avoiding preparation of precise sized specimens and initial measurements, drying rates from small dimension quarter sawn boards, drying deformations using discs have been proposed.

1. INTRODUCTION

Quality requirements for solid wood products are generally related to issues such as density, strength, stiffness, shrinkage, stability, distortion, tension wood, spiral grain, and aesthetic features such as colour and appearance. Most *Eucalyptus* species have moderate to high basic density, superior strength, stiffness and hardness.

Critical quality issues relate mainly to high magnitude of growth stresses, excessive shrinkage and collapse during drying, and slow drying. End-splitting, warp and brittle heart, consequences of growth stresses, have a very marked impact on volume recovery of wood of acceptable quality in a sawmill and on the costs of processing. Drying difficulties and shrinkage related problems pose serious technical challenges for processors. With short-rotation, small-diameter logs these problems can become more acute. These undesirable features have cast a shadow over the true potential of eucalypts for solid wood products.

It is well recognized that many wood traits like basic density, fibre length and microfibril angle, that determine wood properties, are under genetic control. Also, growth stresses and shrinkage have been reported to have a moderate to high heritability (Pelletier *et al.* 2008, Greaves *et al.* 2004, Murphy *et al.* 2005, Henson *et al.* 2004). The genetic influence on these properties provides an opportunity to screen eucalypts drawn from highly variable unimproved (wild) populations for unwanted effects. Breeding eucalypts with superior wood quality traits would help mitigate the problems associated with solid wood from small-diameter short-rotation crops.

Most of the breeding objectives developed for eucalypts have related to pulp and paper production (Raymond and Apiolaza, 2004). However, developing improved breeding values for solid wood products are even more challenging. Progress has been inhibited by the need to include a diverse range of solid wood quality traits, the need to measure these within large populations and the cost of such a demanding effort. The characterization of large scale populations quickly and cost effectively requires a suite of new simple, efficient and reliable tools and techniques.

This paper presents a comprehensive approach for assessing wood quality traits particularly growth stress, shrinkage and deformation, and drying rates in a large number of samples quickly and reliable. The approach is of particular relevance for early selection of superior quality breeding material or for isolating individuals with unwanted traits to be discarded from breeding.

2. MEASUREMENT OF GROWTH STRESSES

There is no technique for measuring growth stresses directly. Instead they are estimated indirectly by measuring strain (ε) on the wood surface after releasing the growth stress (σ) by cutting the fibres all around the point of strain measurement. These strains are generally termed growth strains and multiplying them by the elastic modulus (E) of wood provides an estimate of growth stresses, $\sigma = \varepsilon.E$. Generally growth strains are considered to be a direct indicator of growth stress in a tree as stress is proportional to strain within the elastic limits.

An important stimulus to growth stress research has been development of tools and techniques for growth strain measurements. Comprehensive reviews of various methods for measuring growth strains in trees and logs have been provided by many researchers (Archer 1986, Kubler 1987, Yang and Waugh 2001, Raymond *et al*. 2002, Yoshida and Okuyama 2002)

The strain gauge and dial gauge methods are the two most popular methods for strain measurement in standing trees. The strain gauge method requires gluing a wire strain gauge to the wood surface and cutting fibres either all around the strain gauge to completely release the stresses or at least above and below the strain gauge. The strains due to stress relaxation are directly measured from the strain indicator. When stress are released by cutting fibres above and below the gauge, the strain values depends on the distance between the edge of the slot and gauge, width of the slot and the slot depth (Yoshida and Okuyama 2002). The width of the slot should be about 1.5 times the distance between the strain gauge and nearest edge of the slot (Saurat and Gueneau, 1976).

The dial gauge method measures the change in the distance separating two axially-aligned reference pins that are first hammered into stem wood. After drilling either a single hole between the two pins or two holes, above and below the reference pins, the distance between the two pins is re-measured.

Of the two methods the strain gauge method is probably more reliable, consistent and suitable for *in-situ* measurement of growth strain in standing trees and logs (Yoshida and Okuyama 2002).

Neither method is practical for large scale screening of very young trees – therein lies an opportunity for a new approach.

3. GROWTH STRESSES AND THE BENDING IN TWO HALF ROUNDS

One of the major consequences of growth stresses in trees is the warping in timber during sawing, an outcome that matters the most. The extent of warping depends on
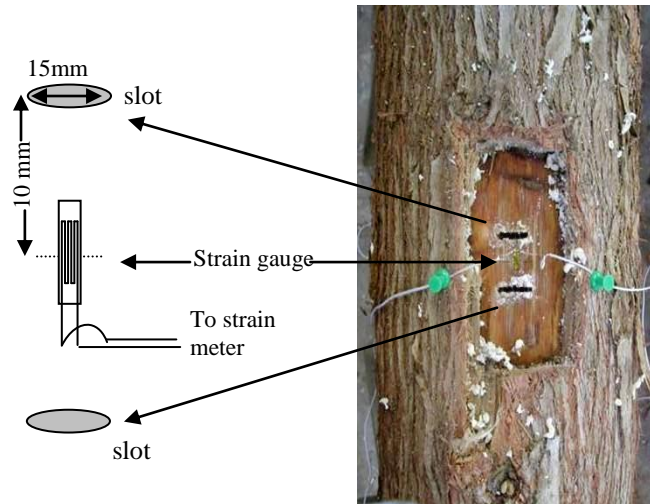
Figure 1. To measure growth strain, it is necessary to open a bark window and glue a small wire strain gauge, typically 5 mm long, to the woody tissue. The tensile strain in the outer-wood fibres is then released by cutting (drilling) slots immediately above and below the gauge. The strain is measure by recording the minute change in the electrical resistance of the wires that comprise the strain gauge when they change in length.

the gradient in the growth stresses from pith to bark. According to Kubler (1987), for a given growth strain at the periphery, small-diameter logs show steeper growth stress gradients across the diameter. Therefore, sawn boards from a small-diameter log show greater distortion than sawn from a large-diameter log with the same peripheral strain. This tendency to warp can be visualised by sawing logs along the pith to produce two half-round posts: the two half-rounds bend outward and the severity of this bending should be associated with the magnitude of the growth stresses in that particular stem. Though this phenomenon was well known, until now the exact nature of the relationship between the longitudinal growth stress at the cambium and the outward bending had not been studied. Here, the outward bending was assessed by measuring the opening at the log ends as shown in Figure 2.
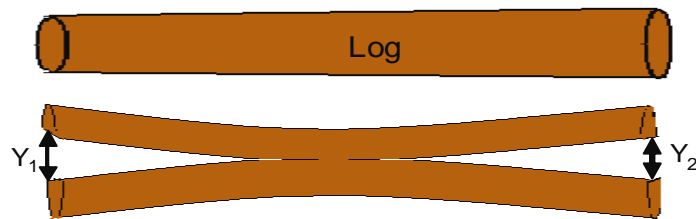

Figure 2. The two half-rounds where cut from a stem open outwards: the severity of the effect is a function of the growth stresses locked in the standing tree.

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This outward bending can be expressed mathematically in terms of surface growth strain and log dimensions viz. log length, log taper and log diameter.

Based on the bending moment of a tapered cantilever beam of a semi-circular cross-section, a theoretical model equation (Eq. 1) was developed to predict the magnitude of the outward opening in log.

$$Y_0 = \frac{1.74\sigma_s l^2 R_a^3}{E \times R_2^2 (R_1 - R_2)^2} \left[\frac{1}{6} + \frac{R_2^3}{3R_1^3} - \frac{R_2^2}{2R_1^2} \right] \tag{1}$$

where Y_o is the average opening at either ends of the log (mm), R_a is the average radius of the log, R_1 and R_2 are the large-end and the small-end log radii respectively, E is the average elastic modulus of the log, and σ_s is the surface growth stress. The surface growth stress is obtained from the surface growth strain, ε_l, and elasticity modulus of outerwood, K, using following equation (Eq. 2),

$$\sigma_s = K\varepsilon_l \tag{2}$$

so allowing equation (1) to be re-written as:

$$Y_0 = \frac{1.74K\varepsilon_l l^2 R_a^3}{ER_2^2 (R_1 - R_2)^2} \left[\frac{1}{6} + \frac{R_2^3}{3R_1^3} - \frac{R_2^2}{2R_1^2} \right] \tag{3}$$

The actual and theoretical openings were compared using a sample of 126 logs of 10-yr-old *Eucalyptus nitens*. Longitudinal growth strains were measured at approximately mid-length on two opposite sides of each log, using the strain gauge method. KYOWA 120 ohm wire-strain gauges with a gauge factor of 2.05 were used for strain measurements. Subsequently, logs were sawn into two half rounds along the length in the plane perpendicular to the sides of strain measurement. Immediately after sawing, the two halves were re-assembled to reconstruct the log and opening-up at both ends of the logs was measured. The model predicted opening was in a close agreement with the observed opening (Figure 3). This implies that the model equation can effectively be used to predict the magnitude of distortion in logs on sawing knowing the growth strain and *vice-versa*.

Traditionally the measurement of surface growth strain can be helpful in assessing the extent of distortion in wood on sawing and in adopting appropriate processing strategies. However, the measurement process is time consuming, and uneconomic for large-scale operations.

In contrast, the measurement of the outward bending of the two half rounds on sawing a log along the pith together with log dimensions provides a quick and reliable approach for screening or selecting young eucalypt trees that have low growth strain – the surface growth stresses can be subsequently estimated from equation (3). The main advantage of this approach is that it can be applied to very small diameter (~20 mm) segments. This makes the technique suitable for rapid

screening during the early stages of selective propagation in tree-breeding programmes.

More pragmatically, the focus on identifying directly those trees that do not split open on sawing seems more appropriate, rather than indirectly from the measurement of growth strain. Potentially, this approach could be applied rapidly in the field. The method is simple, practical and efficient.
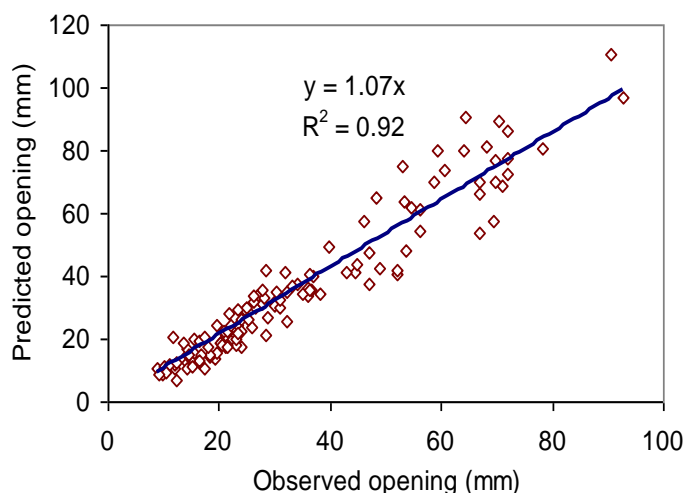

Figure 3. A comparison between the observed and estimated opening where logs are sawn into two half rounds.

3. SHRINKAGE ASSESSMENT

Technologists have an insuperable challenge in sorting/ranking trees for their intrinsic drying characteristics. Traditionally one might value all the lumber cut from a tree and estimate the cost of degrade – warp, collapse etc. To incorporate such traits in breeding objectives was always considered to be impractical. Standard methods of measurement of shrinkage require preparation of samples with predefined sizes and precise measurements of their dimensions. This would turn into an enormously time consuming and challenging task when dealing with a large number of samples.

An alternative approach is proposed here for bulk screening wood resources for their shrinkage properties. In this approach, samples having specific ring orientations are cut from a disc in the green conditions, as shown in Figure 4. This approach does not require careful preparation of samples with specific dimensions. Small pins are inserted at a predefined distances using specially designed templates, avoiding the initial measurements. The samples are then dried and the distance between the pins is measured to evaluate shrinkage. The process is easy, quick and reliable.

Figure 4. Four samples can be cut from each disc. Shrinkage is measured along their lengths, respectively in the radial and tangential directions.

Simultaneously, distortion of the tangentially orientated samples provides a visual assessment of warp tendency in wood during drying while distortion in radial samples provides information about collapse. Mass screening of populations for reduced drying degrade should be possible based on these deformations and the shrinkage measurements.

Figure 5. Differences in radial and tangential shrinkage can be assessed by leaving thin discs to dry.

In another approach, air-dried or oven-dried discs can be ranked empirically based on the number of checks, check-width, and disc split width (Figure 5). Such ranking is largely influenced by differences in radial and tangential shrinkage, and collapse.

4. DRYING RATE

Most eucalypt take an inordinately long time to dry if excessive degrade is to be avoided. Moisture transport processes and transport rates within the wood – and drying degrade – depend on many poorly characterised factors such as the initial moisture content, density, permeability, ray structure, growth rate *etc*. Enormous variations in inherent wood properties within unimproved (wild) populations lead to the postulate that there must be an equivalent enormous variability in drying behaviour. Conventional drying studies of lumber would be too massive and laborious for large-scale determination of drying rates of wood from different trees/families. In a simpler approach, a quarter-sawn board taken from a small billet were used to assess the drying rate. The free-standing boards were dried in an environmentally controlled room at a constant temperature and weighed at regular intervals (Figure 6).

Figure 6. Drying of quarter-sawn boards

5. OVERALL ASSESSMENT

All these approaches have been used to study variability in wood quality traits for 50 families of 9-yr-old *Eucalyptus dunnii* growing at Bombee, New South Wales, Australia, felling four to five trees per family (Chauhan, unpublished). Summary statistics for the various wood characteristics irrespective of their family and provenance are shown in Table 1. The signicance of Table 1 lies in the high coefficients of variation for easily measurable wood quality attributes that might be considered worth incorporating into selection at a much earlier age.

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Table 1. Summary statistics for *Eucalyptus dunnii.*

Variable	Mean	SD	N	Min	Max	CV (%)
Green density (kg/m^3)	1099	30.94	179	973.2	1212	2.82
Moisture content (%)	115.1	13.06	179	86.25	149.5	11.35
Basic density (Kg/m^3)	512.9	38.63	179	429.9	650.5	7.53
HW proportion (%)	58.11	6.37	178	40.37	72.25	10.96
Ratio SW/HW	0.74	0.21	178	0.38	1.48	27.78
Director velocity (km/s)	3.69	0.19	181	3.19	4.21	5.25
Log opening (mm)	39.77	8.21	181	19.19	73.99	20.64
Calculated Strain ($\mu\varepsilon$)	826.7	147	181	381.7	1326	17.78
Calculated stress (MPa)	12.46	2.8	181	5.59	22.82	22.49
Disc opening/periphery	3.91	1.47	179	0	7.21	37.54
Maximum check width (mm)	7.29	3.63	179	0	21.09	49.77
Disc Scoring	11.21	3.8	179	0	24.69	33.91
Mean radial shrinkage (%)	3.08	0.59	180	1.76	5.22	19.07
Mean tangential shrinkage (%)	11.66	2.14	179	6.12	20.89	18.35
Drying rate first 100 hrs (g/hr)	1.72	0.35	181	0.86	3.07	20.17
Drying rate 100-300 hrs (g/hr)	0.42	0.09	181	0.19	0.68	21.69

Based on the average values of different wood quality variables for each family, 10 families were identifed by Forests, New South Wales, as having the best mix of characteristics with low growth stresses, less drying degrades and faster drying rates.

5. CONCLUSIONS

The wood quality attributes desired for solid wood production are somewhat at variance with desirable pulpwood characteristics. Thus different breeding objectives need to be developed for the production of saw logs of eucalypts. The two principal challenges in solid wood processing of many eucalypts are the distortion/warping of timber during sawing and the difficulties in drying the timber without significant degrade. The work reported here demonstrates that desired wood quality traits can be measured directly and without undue effort. This raises the prospect of very early selection of elite breeding populations.

6. ACKNOWLEDGEMENTS

Forests, New South Wales, Australia for providing an opportunity to carry out screening trial with *Eucalytpus dunnii*.

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8. AFFILIATIONS

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