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Very Early Screening of Wood Quality for Radiata Pine: Pushing the Envelope

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Abstract

For many years, breeding of *Pinus radiata* for structural wood relied on improving basic density assessed at age 7 or 8 years old, with little progress. Current efforts have moved to acoustic screening for stiffness at similar age. Breeding cycles are still too long. An alternative is to screen out the worst trees even earlier: shorter breeding cycles should outweigh the lower accuracy due to early selection. Besides genetic effects, there is also evidence that wood stiffness is affected by wind, particularly for stands with low stocking and trees in forest margins.

A glasshouse experiment was setup for early selection considering two factors: tree position and clone. Tree positions were straight (control), leaning (30° from the vertical) and rocked (15 minutes every hour, simulating 10 km h^{-1} wind). Four clones were used covering a range of wood stiffness and replication was 12 plants per treatment. The response variables at 8 months were squared acoustic velocity (v^2, surrogate of stiffness), basic density, collar diameter, diameter asymmetry and compression wood.

There were significant differences of v^2 for treatments and clones. Straight trees had the higher v^2 (2.15 km^2 s^{-2}), followed by leaning trees (1.95 km^2 s^{-2}) and rocked trees (1.74 km^2 s^{-2}). The 19% v^2 reduction from straight to rocking trees is consistent with observations on the effect of forest margins. Clonal means ranged from 1.53 to 2.11 km^2 s^{-2}. Basic density showed significant differences between treatments but not for clones, with higher values for leaning trees (408.0 kg m^{-3}), followed by rocked trees (370.2 kg m^{-3}) and straight trees (358.3 kg m^{-3}). There was zero correlation between v^2 and basic density. Straight and rocked trees formed little compression wood in thin arcs at random within the cross-section. Leaning trees formed continuous compression wood on the underside of the leaning stem. We discuss the implications for tree improvement.

Keywords: *Pinus radiata*, wood stiffness, compression wood, early selection, tree breeding.

Introduction

Pinus radiata—the most important plantation conifer in the Southern Hemisphere—is a general-purpose species, used for fibre, structural and appearance wood production. In New Zealand most of the production is targeted for structural use, with a minimum stiffness threshold of 7 GPa. After reducing rotation age in the 1990s, most of New Zealand's crop did not qualify as structural. This situation prompted to change the standards, so that 92% rather than only 47% of the wood is now considered of framing quality (Gaunt 1998).

Silviculture and tree breeding are techniques that could improve the proportion of structural quality wood. For example, Laserre et al. (2005) pointed out that stiffness was considerably worse in low stocked stands. This situation extends to other genera as well (e.g., Warren et al. 2008). There is also an effect of position within the stand, where trees in the margins show lower stiffness (Bascuñán et al. 2004), hinting at the role of wind on the expression of wood quality.

There is huge between-tree genetic variation for wood quality to be exploited by tree breeding. Breeders make a distinction between traits targeted for improvement (objective traits; e.g. commercial volume) and the characteristics assessed in genetic trials (selection criteria; e.g. stem dbh). The closer the assessment of selection criteria is to objective traits—both in time and in trait definition—the higher the accuracy of selection. For example, dbh at age 15 provides more accurate predictions for stem volume at rotation end than dbh does at age 5. However, there is a trade off between delaying tree selection (increasing accuracy) and extending generation interval (reducing NPV of the breeding program).

The current 'rule of thumb' is to select trees at around 7 or 8 years old, looking for the largest, densest or stiffest trees. Therefore, it is based on the belief that any improvement has similar value and that more of the good is even better (Apiolaza 2008). This project evaluates the feasibility of an alternative approach, screening out the worst trees at a very early age (less than 4 years old) aiming to only achieve the quality threshold for corewood. We consider that outerwood is already good enough, benefiting only marginally from improvement.

We have chosen to test very early selection using only the extremes of the distribution for stiffness. The rationale behind this choice is that if we cannot find differences between these extremes there is no point in spending resources with a broader—and less differentiated—genetic base.

Materials and Methods

A glasshouse experiment in Christchurch, New Zealand, considered two factors: tree position and clones. Tree positions were straight (control), leaning (30° from the vertical using a wooden stake) and rocking (intermittently, 24 cycles/minute reaching an inclination of 22°, for 15 minutes in every hour) to simulate 10 km h^{-1} wind. Rocking was performed using a purpose-built machine (see Fig. 1). There were four clones (A, F, K and W) covering a range of wood stiffness and replication was 12 plants per treatment. The response variables were squared acoustic velocity (v^2), basic density (kg m^{-3}), collar diameter (mm), diameter asymmetry (ratio of the diameter on the direction of rocking or leaning divided by the diameter perpendicular to that direction) and compression wood (%).

Figure 1: Rocking machine simulates the movement of trees under wind of 10 km h^{-1}.

Growth data were collected in a monthly basis, but only the results of the latest assessment (at 8 months of age) are presented in this paper. Wood quality traits were assessed at the same time. We analysed the data using a two-way factorial design (for tree position and clone) allowing for the interaction between the factors, with the model:

$$y_{ijk} = \mu + P_i + C_j + P_i \times C_j + e_{ijk}$$

where y_{ijk} is a response variable, μ is the overall mean, P_i is the effect of the i^{th} tree position, C_j is the effect of the j^{th} clone and e_{ijk} is the residual for the k^{th} plant under the i^{th} tree position and j^{th} clone. Residuals followed an identical and independent normal distribution with variance σ_e^2.

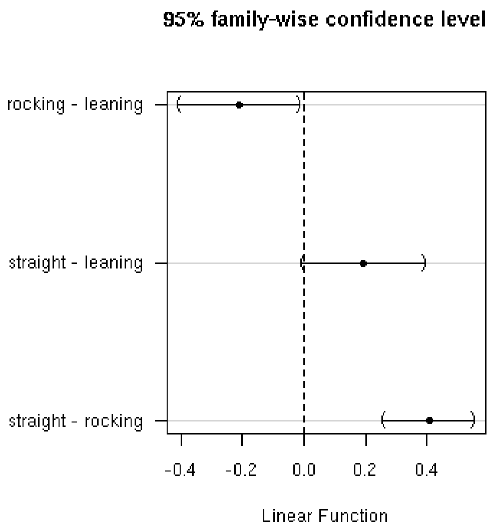
The relationships between continuous variables (e.g. tree height on diameter) were modelled using regressions with dummy variables, to test for common intercepts and slopes.

Results and Discussion

Wood Quality Traits

There were significant differences of v^2 for treatments and clones, but their interaction was not significant (Fig. 2). Straight trees had the highest v^2 (2.15 km^2 s^{-2}), followed by leaning trees (1.95 km^2 s^{-2}) and rocked trees (1.74 km^2 s^{-2}). The 19% v^2 reduction from straight to rocking trees is consistent with observations on the effect of forest margins (Bascuñan *et al.* 2004). Clonal means ranged from 1.53 to 2.11 $km^2 s^{-2}$.

Mature trees of clone F are known for their low wood stiffness. This trait is also expressed in juvenile trees, with ramets showing v^2 significantly lower than for other clones (see comparisons involving F in Fig. 2 right). The discriminating ability of very early screening extends to other clones as well, although with lower accuracy. The ranking for wood stiffness at age 7—from highest to lowest—for these clones is K, W, A and F (Charles Sorensson, personal communication). The ranking at eight months is W, K, A, F; which means that the same trees would have been selected and discarded for breeding purposes.



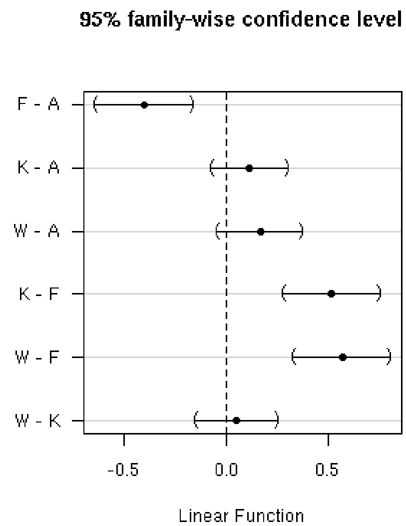


Figure 2: Multiple comparisons shown as differences for average squared velocity and their confidence intervals between tree positions (left) and clones (right). Notice that clones W and F were not replicated under leaning. Intervals that include 0 are not significantly different.

Basic density was included in *P. radiata* breeding programs in the early 1990s, when it was considered as the canonical wood quality trait. There is a strong positive linear relationship between wood stiffness and basic density when ignoring age. Nevertheless, the relationship breaks down for young trees (Chauhan and Walker 2006). In this experiment basic density showed significant differences between treatments but not for clones, with higher values for tilted trees (408.0 kg m^{-3}), followed by rocked trees (370.2 kg m^{-3}) and straight trees (358.3 kg m^{-3}). There was zero correlation between v^2 and basic density, even when taking into account the different tree positions (Fig. 3). There was no significant relationship between basic density and collar diameter either.

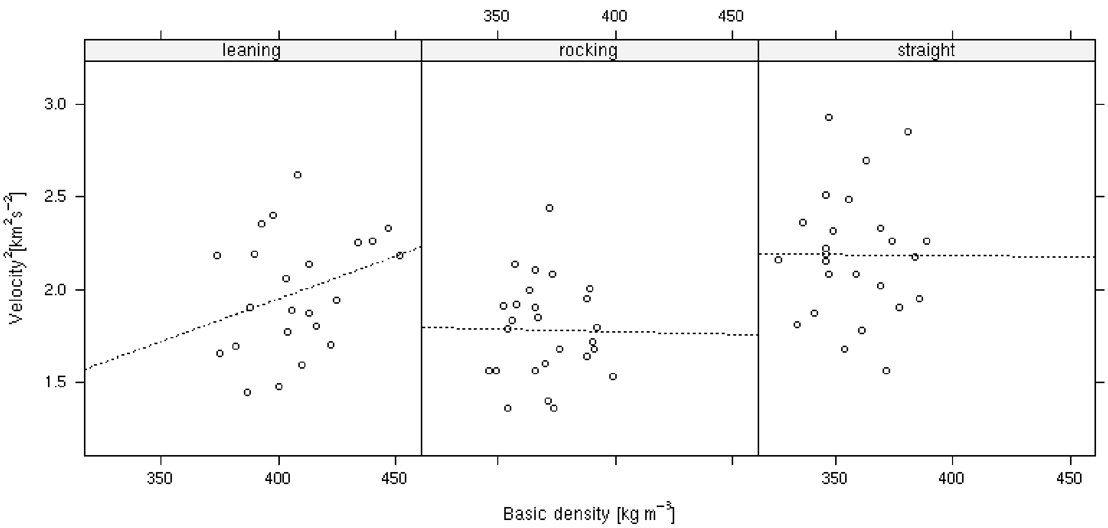


Figure 3: Relationship between v^2 and basic density for each tree position. None of the relationships is statistically significant, although there is a positive trend for leaning trees.

Straight and rocked trees formed little compression wood in thin arcs at random within the cross-section (Fig. 4a). Tilted trees formed continuous compression wood on the underside of the leaning stem (Fig. 4b).

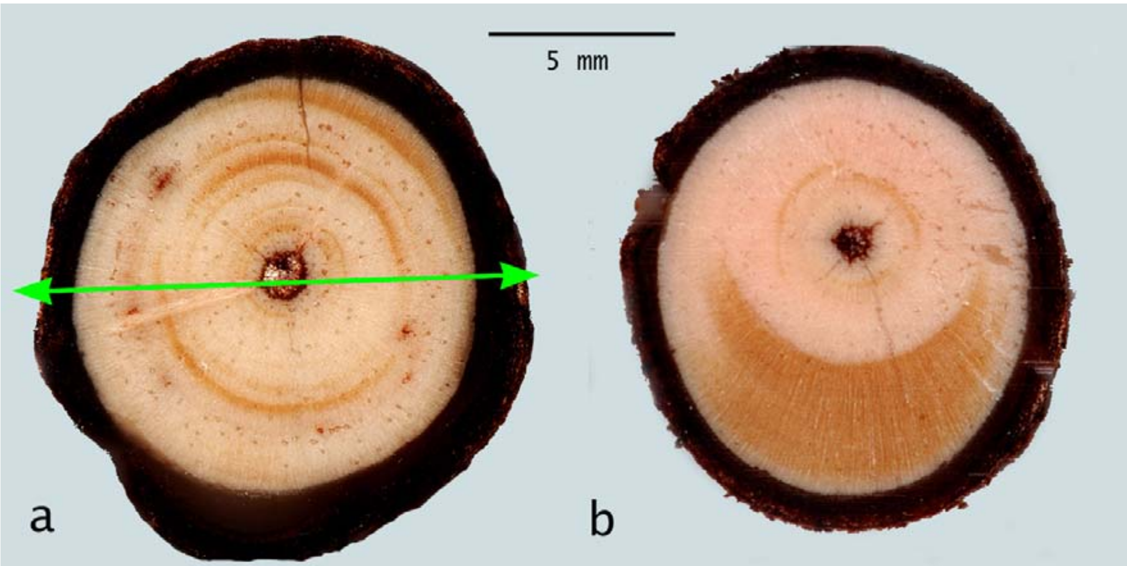


Figure 4: stem cross-sections for rocking tree showing compression wood in thin arcs at random (a) and leaning tree showing a continuous wedge of compression wood on the underside of the stem (b). The green line shows the direction of rocking.

There was a significant effect of leaning on percentage area of compression wood (33%), while the difference between straight (17%) and rocking (13%) trees was not significant. This effect was expected, as it has been reported many times in the literature. There were no significant differences between clones. Much more relevant was the effect of leaning on exacerbating clonal differences for other wood quality traits like density and v^2.

Growth Traits

In the case of tree collar diameter there were no significant effects for either tree position or clone. There was no significant diameter asymmetry (mean ratio 0.98) for rocked trees; however, leaning trees were significantly asymmetric (mean ratio1.11), with markedly wider stems in the direction of leaning. Clones had no effect on diameter asymmetry.

There were no significant differences for tree height between tree positions, although straight trees tended to be taller. However, there were statistically significant differences ($p = 0.03$) between clone W (88.9 cm) and clone A (79.4 cm), and marginally significant ($p = 0.05$) between clone W and clone K (80.5 cm).

As expected, there was a positive relationship between tree height and collar diameter. The regressions shared a common intercept for all tree positions (26.5 ± 14.8); however, the slope is significantly steeper for straight trees (6.6 ± 1.3 versus 3.7 ± 1.1). That is, straight trees are slender. There are indications that 'stem slenderness' influences wood stiffness in older trees (Watt *et al.* 2006).

Implications for Tree Improvement

Breeding can change the mean of a trait by selecting the best trees or by screening out the worst ones; the latter is easier with very young trees. For example, this experiment easily discriminated clone F as a poor performer, confirming older age assessments. However, smaller differences amongst specific clones may prove more difficult to ascertain.

Tree breeders have been hesitant to continue reducing selection age, particularly for wood quality, due to the poor correlation with rotation age performance. Nevertheless, shorter breeding cycles should outweigh the lower accuracy due to early selection.

We hypothesise that trees that show acceptable early wood quality—under conditions that normally induce wood quality problems—will develop acceptable corewood. Leaning trees exacerbates wood quality differences between clones, making early testing more efficient. Unfortunately, mortality in clones F and W did not leave enough material to further explore this result. We are currently expanding this experiment to a broader genetic base to check if the results hold.

We expect that very early phenotypic screening—in combination with molecular tools such as genome wide scanning—will allow breeders to dramatically shorten generation interval to improve corewood quality.

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