RADIATA MANAGEMENT TECHNICAL NOTE Site Productivity

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How Stem Slenderness of Juvenile Radiata Pine is Affected by Site and Genotype and Relation to Wood Stiffness

Summary

Wood stiffness, one of the most important wood properties, is known to vary widely among radiata pine genotypes and between different planting sites. It is known to be related in some way to stem slenderness. A good understanding of the relationships between wood stiffness, stem slenderness, genotype and site characteristics would assist the development of a reliable prediction model for radiata pine wood stiffness across the country.

Task 1.5 of the PEEF programme is concerned with development of site-specific management solutions through the study of site:genotype matching for better wood quality of radiata pine. Another goal is the development of a better understanding of site and genotypic variation in wood stiffness and stem slenderness.

This study set out to investigate the magnitude of clonal and site effects on stem slenderness in 40 radiata pine clones at nine sites. Trees were measured at age 4 years, and site factors (climate and soil characteristics) were examined. The relationship between clonal means for stem slenderness and wood stiffness was also determined for 15 clones selected for a range of stem slenderness and grown at two contrasting sites for 5.5 years.

Clonal and site differences in stem slenderness were found to be substantial, and the magnitude of their interacting effects was large. Soil cation exchange capacity (a measure of soil “fertility”) had a negative correlation with stem slenderness and explained 76% of the site variation. Mean annual temperature explained 33%. The other site factors investigated had a negligible effect.

At two sites where wood stiffness was measured, clonal difference in wood stiffness was found to be greater than the difference due to site. Overall clonal wood stiffness was greater at Rolleston than at Kaingaroa.

The nature of the relationship between clonal stem slenderness and wood stiffness suggests that stem slenderness could be used as an indicator of wood stiffness. It is also likely that wood stiffness could be increased by matching specific clones to appropriate sites. It will be necessary to investigate the characteristics of more sites and clones if these suggestions are to be developed into reliable site management tools.

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Introduction

Advances in tree breeding and silvicultural practice have resulted in improved growth rates of plantation conifers and therefore in shorter rotation lengths. Faster-growing trees have a larger proportion of juvenile wood[1] which has lower strength and stiffness properties than mature wood, and therefore a lower economic value. In the past, managers have focussed on total merchantable volume, but attention is now turning towards techniques that enhance tree growth and desirable wood properties[2] concurrently.

Wood stiffness is one of the most important wood properties. Large genetic differences in wood stiffness of radiata pine at tree age 6 years or younger have been found to have medium to high heritability [3,4] but the effects of site and genotype on wood stiffness are variable and poorly understood. Relationships between wood stiffness and tree attributes such as height and diameter are also obscure.

Recently, stem slenderness (height:DBH ratio) was found to be associated with 49-71% of the variance in wood stiffness [2,5,6]. More work is required to find out how genotype and site influence this relationship between wood stiffness and stem slenderness.

The aims of this study were to:

- detect the magnitude of clone and site effects on stem slenderness and wood stiffness; and
- determine the relationship between stem slenderness and wood stiffness in specific clonal material.

Materials and Methods

Trial Locations and Site Characteristics

Results from ten trials containing a number of clones of radiata pine were used in this study. Site locations and

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characteristics are listed in Table 1. Soil properties determined for each site were pH; total carbon (C); total nitrogen (N); C/N ratio; total phosphorus (P); Olsen P; exchangeable calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na); and cation exchange capacity (CEC).

Table 1. Site locations and characteristics.

Site	Elevation (m.a.s.l)	Annual rainfall (mm)	Mean annual temp. (^{o}C)	Soil type
Aniseed Valley	321	1356	11.7	Dun silt loam
Mahia	145	1248	13.7	Mahia fine sandy loam
Balmoral	315	864	10.4	Balmoral stony sandy loam
Forest Creek	740	1008	7.9	Cass silt loam
Berwick	381	924	8.3	Waipori silt loam
Lawrence	262	816	9.0	Waitahuna silt loam
West Coast 1 (TWC1)	192	2688	10.8	Okarito peaty silt loam
West Coast 2 (TWC2)	183	2700	10.9	Okarito peaty silt loam
Rolleston	47	684	11.5	Lismore stony silt loam
Kaingaroa*	630	1548	10.1	Kaingaroa sand

* The Kaingaroa site contained third rotation trees. All other sites supported first or second rotation stands.

Trial Design

- Each trial consisted of four plots.
- Each plot contained three randomly distributed individuals from each of 40 radiata pine clones.
- Of the 40 clones, 20 were derived from fascicle cuttings from control-pollinated families (GF24-31) selected for high volume growth rate and improved stem form.
- The remaining 20 clones were derived from fascicle cuttings from open-pollinated families (GF7) selected for differing Mg-related Upper and Mid-Crown Yellowing symptom scores and diameter growth [7].

All trials were established between 2002 and 2005, with stocking rates of 625-800 trees/ha.

Tree Growth and Wood Stiffness Measurements

Measurements of height and DBH of trees in ten sites were used to calculate stem slenderness for each clone. Wood stiffness, measured as the modulus of elasticity, was determined by using IML electronic hammer on standing trees in the Rolleston and Kaingaroa trials only.

Data Analysis

Relationships between the stem slenderness at age 4 years and mean annual temperature or soil characteristics were examined by correlation analysis.

The correlation between clonal means for stem slenderness and wood stiffness was also determined for 15 selected clones grown at two contrasting sites for 5.5 years.

Clonal data were summarised in boxplots (e.g. Figure 1) to show the median, the 25% and 75% quartiles, and the minimum and maximum values for each site.

Results

Site, clone and site x clone interaction were all found to affect stem slenderness (*p* <0.001). The clonal means of stem slenderness (averaged across nine sites) ranged from 35 to 57 m/m, while the site means of stem slenderness (averaged across 40 clones) ranged from 23 to 49 m/m. Clonal variation was largest at Aniseed Valley and smallest at Mahia (Figure 1).

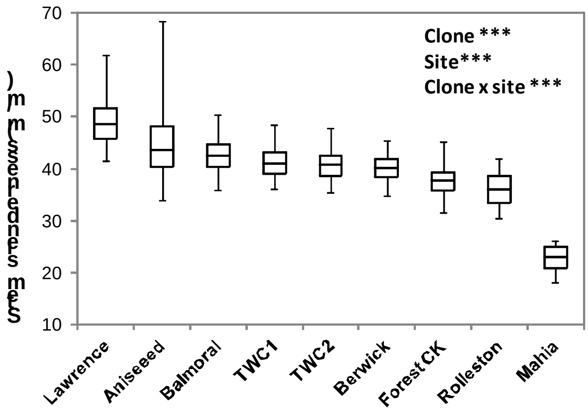

Figure 1. Clonal variability in stem slenderness of 4-year-old radiata pine at nine sites. The rectangle in each boxplot shows the median and the most frequently observed values recorded for all clones at the site. Vertical lines above and below the box represent the largest and smallest values in the sample recorded.

Soil cation exchange capacity (CEC) is a measure of soil fertility. Variation in soil CEC explained 76% of between-site difference in stem slenderness (Figure 2). This negative relationship indicates that when compared to the growth pattern for infertile sites, more DBH growth is promoted than height growth at fertile sites, which reduced tree slenderness.

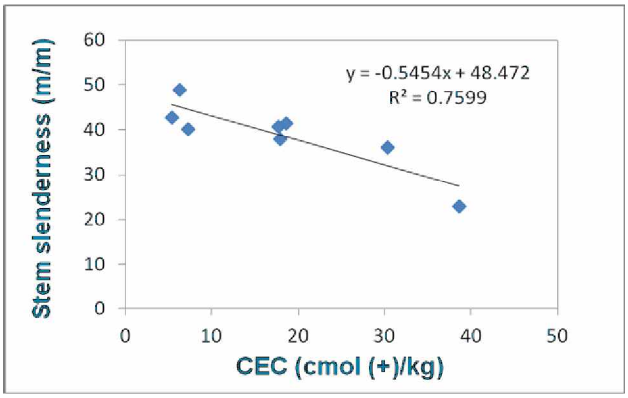

Figure 2. The relationship between site means of soil CEC and stem slenderness (excluding Aniseed site, which has an abnormally high soil CEC).

Mean annual temperature explained 33% of site differences in slenderness, while other climatic and soil factors explained little.

Data from the two sites at which wood stiffness was determined (Kaingaroa and Rolleston) showed:

- Significant differences between sites and between clones in both wood stiffness and stem slenderness (Table 2). Clonal differences in stem slenderness and wood stiffness were larger than the difference due to site (Table 2).
- Significant site x clone interaction for stem slenderness and wood stiffness, i.e. values obtained for individual clones differed according to the site at which the trees were planted (Figure 3).

Table 2. Means of stem slenderness and wood stiffness. Values within columns followed by different letters differ at $p < 0.05$.

	Slenderness (m/m)	Wood stiffness (GPa)
Site effect		
Rolleston	39.5 a	2.265 a
Kaingaroa	35.7 b	1.804 b
Clone effect		
Highest value	42.2 a	2.550 a
Lowest value	31.2 b	1.654 b

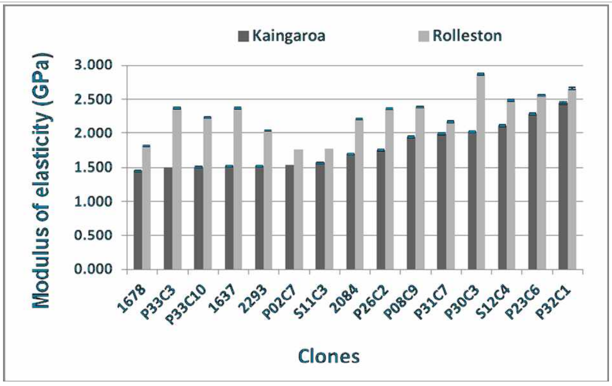

Figure 3. Effect of site and clone on wood stiffness (modulus of elasticity). Values are means ± one standard deviation (s.d.). Where no s.d. is shown the s.d. is smaller than the size of the upper horizontal bar.

- There was a positive correlation (r = 0.77) between clonal stem slenderness and wood stiffness (combined site data). This indicates that a more slender clone had a greater wood stiffness.

Conclusions

- Clones differed considerably in terms of stem slenderness.
- Site characteristics had a marked effect on stem slenderness.
- The magnitude of clone x site interaction was large. This means that the difference between clones was influenced by site characteristics.
- Soil CEC and mean annual temperature were the two site factors that had the greatest effect on stem slenderness. The influence of soil CEC was greater than that of mean annual temperature.
- At Rolleston and Kaingaroa, clonal differences in wood stiffness were larger than the difference due to site characteristics.
- The positive relationship between clonal stem slenderness and wood stiffness suggests that stem slenderness has potential for use as an indicator of wood stiffness.
- It is possible that selection of clones that are appropriate for specific sites will assist management for increased wood stiffness.

- It will be necessary for more sites and clones to be characterised before the genetic relationship between stem slenderness and wood stiffness can be determined.

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References

1. Downes, G. M. et al. 2000. The commercial cambium: understanding the origin of wood property variation. In R. A. Savidge, J. R. Barnett, R. Napier (Eds.), *Cell and Molecular Biology of Wood Formation.* BIOS Sci., Oxford, UK. pp. 325–336.

2. Watt, M. S. et al. 2009. Modelling the influence of site and weed competition on juvenile modulus of elasticity in *Pinus radiata* across broad environmental gradients. *Forest Ecology and Management 258*: 1479-1488.

3. Kumar, S. 2004. Genetic parameter estimates for wood stiffness, strength, internal checking, and resin bleeding for radiata pine. *Canadian Journal of Forest Research 34:* 2601–2610.

4. Dungey, H.S. et al. 2006. Genetics of wood stiffness and its component traits in *Pinus radiata. Canadian Journal of Forest Research 36*: 1165-1178.

5. Watt, M.S. et al. 2006. Modelling the influence of stand structural, edaphic and climatic influences on juvenile *Pinus radiata* dynamic modulus of elasticity. *Forest Ecology and Management 229:* 136-144.

6. Waghorn, M.J., Mason, E.G., and Watt, M.S. 2007. Influence of initial stand density and genotype on longitudinal variation in modulus of elasticity for 17-year-old *Pinus radiata*. *Forest Ecology and Management 252:* 67–72.

7. Beets, P.N. et al. 2004. Genetic and soil factors associated with variation in visual magnesium deficiency symptoms in *Pinus radiata*. *Forest Ecology and Management 189*: 263-279.