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The effects of genotype and spacing on *Pinus radiata* [D. Don] corewood stiffness in an 11-year old experiment

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Abstract

The influence of initial stand density and genetic population on corewood dynamic stiffness of 11-year-old *Pinus radiata* [D. Don] was investigated at a field trial in Canterbury, New Zealand. Corewood dynamic stiffness was determined on standing trees using the stress wave method over the lower stem (0.2–2.0 m) of 182 trees, from an experiment which included three contrasting genetic populations (GF1, GF27 and clonal) grown at 833 and 2500 stems ha^{-1}.

Stiffness was significantly influenced by planting density ($P < 0.001$), and genetic population ($P < 0.01$). Planting density had the largest influence on stiffness, with values in the high-density plots exceeding values in the low-density plots by on average 1.7 GPa or 34%. Gains in stiffness attributable to genetic population averaged 0.8 GPa or 15%. Stiffness was not significantly influenced by the interaction between planting density and genetic population.

There was a significant ($P < 0.01$) negative relationship between tree diameter at breast height (DBH) and stiffness, for all genetic populations, which explained 57%, 56% and 14% of the variation in stiffness for the clones, GF27 and GF1, respectively. Although correction for variation in DBH reduced variation in stiffness, residual variation in stiffness between planting densities and genetic population were still significant after the effect of DBH had been removed. These findings highlight the importance of planting density in regulating stiffness, and strongly suggest that effects of planting density and genetic population on stiffness are independent.

Keywords: *Pinus radiata*; Genetic population; Planting density; Stiffness; Genetic population and planting density interaction; Stress wave method; Dynamic modulus of elasticity

1. Introduction

Two of the most important decisions made during the establishment of a forest plantation are the selection of appropriate genetic material and a suitable

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spacing. Linking these management decisions to the desired end products requires information on how genetics and silviculture influence both internal and external characteristics of trees within the stand, for a particular site. While considerable research has focused on how genetic population and initial stand density influence the external characteristics of growth and form (Fries, 1984; Wilcox and Carson, 1989; Carson et al., 1999; Land et al., 2004), considerably less information is available on the influence of these factors on internal wood characteristics.

New Zealand has a very advanced breeding program for *Pinus radiata* (Dorey, 2001), which has over the last 50 years significantly improved many characteristics of this widely planted fast growing conifer (Shelbourne, 1997). During the first generations of the breeding program efforts were focused on improving external characteristics of *P. radiata* such as stem and branch form, vigour and disease resistance. The method used to classify genetic quality of these first generation *P. radiata* seedlots is the growth and form (GF) rating system, introduced in 1987 by Forest Research (Vincent, 1987). The system estimates growth and form of a particular seedlot relative to unimproved seed, expressed as a GF number. While the breeding program has bought about a marked narrowing of the genetic base it is possible for two relatively unrelated seedlots to have similar GF rating.

Although the greater level of improvement in growth and form indicated by higher GF numbers has been found in genetic gain trials little is known about concomitant alterations to key wood quality characteristics within these seedlots. Subsequent selections which have been more focused on wood properties such as wood density, and more lately strength, stiffness and stability (Cremer et al., 1982; Matheson et al., 1997; Sorensson et al., 1997; Jayawickrama, 2001; Kumar et al., 2002), are designated by GF Plus numbers which provide more detailed information about wood property traits in addition to growth. Recently geneticists have begun to use clonal treestock, which should maximise the uniformity of log and wood quality when monoclonal stands are established (Sorensson et al., 1997).

Over the last three decades gains in growth and form obtained through advances in tree breeding (Dickson and Walker, 1997), improved establishment techniques and changing silvicultural practice have resulted in a decline in the average rotation length from more than 35 years (Chapman, 1949; Macalister, 1997) to 27 years (New Zealand Forest Owners Association, 2004) and lower average planting density from 1800 to 960 stems ha^{-1} (Tombleson and Carson, 1991). As a result of these changes the proportion of low value corewood present within the harvested crop has increased. Although definitions of corewood can be subjective, it has often been defined as the innermost 10 growth rings (Cown, 1992), where wood properties are changing most rapidly (Walker and Nakada, 1999). Corewood is generally characterised by low density, thin cell walls, short tracheids with large lumens, high grain angle, and high microfibril angle, with the result that it has low strength and stiffness, and poor dimensional stability compared to outerwood (Harris and Cown, 1991).

The growing awareness that *P. radiata* corewood from most plantations is of low stiffness and poor quality has spurred research on determining how best to balance growth rates with optimisation of corewood properties. Stiffness and stability are now accepted as top priorities for breeding solid wood (Jayawickrama, 2001). Various studies on the behaviour of different *P. radiata* genetic material have been published, concluding that wood properties are often under elevated or at least moderate genetic control. Whole-tree clonal heritability of stiffness was estimated around 0.77, which is high (Shelbourne, 1997). Given this high heritability, clonal forestry may have the potential to markedly enhance the stiffness and structural end-product conversion of fast-grown *P. radiata* (Sorensson et al., 2004).

For *P. radiata* changes in stand density may provide an alternative means of enhancing corewood stiffness. The major visible effects of wider spacing are greater rates of early diameter growth and longer retention of a deep living crown with increased knot diameter, as suppression of branch growth is delayed. Although studies describing the influence of spacing on wood quality are more sparse, previous research has found an increase in stiffness as stand density increases for *Cryptomeria japonica* [D. Don] (Wang and Ko, 1998; Chuang and Wang, 2001), *Tsuga heterophylla* [Rafinesque], *Picea sitchensis* [Bongard] (Wang et al., 2001) and *Picea mariana* [Miller] (Zhang et al., 2002). Also of considerable interest to both