Variation of wood stiffness and genetic control within eucalyptus hybrid stems from clonal plantations in Brazil

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The aim of this study was to explore the spatial variations of wood stiffness and its genetic control in *Eucalyptus* stems. The elastic modulus strongly increased from pith to bark. The variations in modulus of elasticity along the stem are less consistent than those in the radial direction. These findings are interesting for sawn timber breeders because it is stiffness that is desirable rather than its constituent traits or density. The genetic control of modulus of elasticity varied up to 0.4 depending of the region of the stem. We found greater genetic control over wood stiffness in two specific zones of the stem of *Eucalyptus*.

Keywords: modulus of elasticity, NIR spectroscopy, clonal test, heritability, *Eucalyptus*

Introduction

A number of wood traits were identified as worthy of attention for *Eucalyptus* tree improvement, including wood density, stiffness and microfibril angle (Raymond, 2002). While most research on Eucalyptus genetics were focused on growth traits and wood density (Greaves et al., 1997, Hamilton and Potts 2008) relatively few studies have investigated the genetic aspects of variation in wood stiffness in *Eucalyptus*. The aim of this study was to explore the variations of the genetic control of wood stiffness in *Eucalyptus* stems.

Material and Methods

Wood discs removed at 0, 25, 50, 75, and 100% of the tree height from 150 *Eucalyptus grandis* x *E. urophylla* hybrids (6-years-old) coming from three nearest but contrasted clonal tests (CT) established in Brazil (19°17' S, 42°23' W, alt 230-500 m) were used. The main difference between sites was their declivity level.

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Clonal test 1 is planted on a flat terrain, the slope of CT 2 and CT 3 is 20 degrees and 40 degrees respectively. Previous calibrations based on near infrared (NIR) spectroscopic data (Hein 2011) were used for estimating modulus of elasticity (E) on radial positions of 750 wood discsm and broad-sense heritability of elastic modulus. The NIR-estimated E values were analyzed independently (univariate analysis) to estimate the variance components by using an individual mixed linear model as y = μ + Clone + Site + ClonexSite + å where ì is the mean value, Clone is the random effect, Site is the fixed effect, Clone×Site is random interaction effect and å is the residual. The variances associated to random and fixed effects were estimated by restricted maximum likelihood (REML) analysis by using computer routines written in the R statistical programming language (R Development Core Team 2008). As the variances were assumed to be independent, the total phenotypic variance was calculated as $\sigma^2_p = \sigma^2_g + \sigma^2_{gxe} + \sigma^2_e$, where σ^2_p is the phenotypic variance, σ^2_g is the clonal variance, σ^2_{gxe} is the clone by site interaction variance and σ^2_e is the environmental (error) variance. The broad-sense heritabilities were estimated as $H^2 = \sigma^2_g / (\sigma^2_g + \sigma^2_{gxe} + \sigma^2_e)$.

Results and Discussion

The spatial variation of modulus of elasticity along the *Eucalyptus* trees at three contrasting sites are presented in Figure 1A. The variations in modulus of elasticity along the stem are less consistent than those in the radial direction, especially in the bottom. The E strongly increased from pith to bark at the base (~6,300 MPa), at 25% of height (~6,900 MPa), at 50% of height (~5,600 MPa) and at 75% of height (~3,900 MPa). The stiffness at the base and at 25% of height increased in the same magnitude (~6,500 MPa) towards the bark, but the absolute E values at 25% of height were, on average, 2,500 MPa higher. These findings are interesting for sawn timber breeders because stiffness is more desirable rather than its constituent traits or density.

The pith to cambium variations in wood stiffness was lower in trees from the clonal test 1 (terrain slope 0°) and higher in trees from clonal test 2 (terrain slope 20°). The higher pith to bark variation at the base was found in trees from the clonal test 1, where there was no inclination.

Broad-sense heritability estimates for modulus of elasticity strongly varied within the stem (Figure 1B). Null heritability was found in the sapwood of the base while H^2 of 0.36 was estimated in the outer heartwood at 75% of height. Figure 1 shows that genetic control over stiffness is larger in two regions of the stem: (i) in

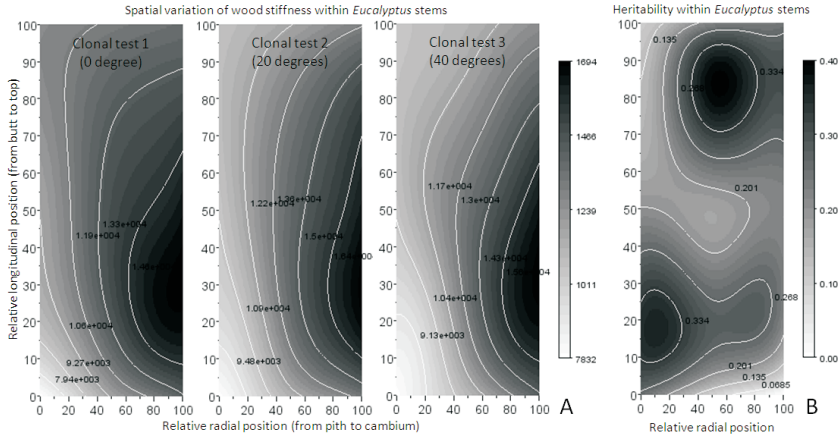

Figure 1. Spatial variation of modulus of elasticity (MPa) in clonal tests 1, 2 and 3 (A) and of heritability estimates within in *Eucalyptus urophylla* x *Eucalyptus grandis* clones (B).

the inner heartwood region (0-25% of relative radial position) of the lower zones of the tree (10-30% of the relative longitudinal position) (dark and round spot at the bottom of the chart) and (ii) at the top of the tree, a zone localized at 40-80% of relative radial position and at 70-90% of the relative longitudinal position (dark and round spot at the top of the chart). No clear patterns of radial variation were established for H^2 estimates of modulus of elasticity along the stems of *Eucalyptus*.

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