

VARIATION OF INTERNAL CHECKS RELATED TO ANATOMICAL STRUCTURE AND DENSITY IN *EUCALYPTUS NITENS* WOOD

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Abstract. The occurrence of internal checks and their relationship with anatomical structure and basic density in three clones of *Eucalyptus nitens* plantation trees grown in the eighth region of Chile were studied. Two trees per clone were sampled. The number, radial location, and length of internal checks were determined in samples oven-dried at temperatures increasing from 50 to 100°C. Wood anatomical features including vessel frequency and diameter and annual growth ring width were measured by image analysis. Results show that internal checks were greater for clones with lower basic density. Internal check frequency decreased with height in the tree and increased from pith to bark. A low wood basic density was related to greater ring width and vessel frequency, which contributed to the development of internal checks.

Keywords: Internal checks, vessel frequency, growth rings width, basic density.

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INTRODUCTION

Eucalyptus nitens is an introduced species in Chile. The 167,899 ha of plantations of this species are expected to produce about 5.6 Mm³/yr by 2025. A large part of this future resource is privately owned by small- and medium-sized companies (INFOR 2011). The wood obtained from this species presents some limitations for solid wood products manufacturing. Drying is particularly difficult because of the tendency of this wood to develop internal checks within the annual growth rings (Leandro et al 2008) and collapse during the process (Ananías et al 2009).

Leandro et al (2008) mentioned that the development of internal checks in *E. nitens* is determined by radial position and height in the tree. They reported a higher frequency of internal checks at the base of the tree where low wood basic density, thin cell walls, a higher proportion of vessels, and a lower proportion of fibers are found. Regarding the variation in the radial direction, a greater frequency of internal checks was found in the earlywood of the last six growth rings of the internal heartwood. However, a lower frequency of internal checks was found in the earlywood of the external growth rings located close to the bark corresponding to a higher basic density and higher latewood proportion. Conversely, Shelbourne et al (2002) and Blackburn et al (2010) reported no clear relationship between basic density and internal check frequency in the growth rings of *E. nitens*. However, McKenzie et al (2003) reported a weak relationship between low basic density and high frequency of internal checks for *E. nitens*.

Regarding the anatomical structure of *E. nitens*, it was found that vessel frequency decreased from pith to bark (McKimm and Ilic 1987; Lausberg et al 1995; Leandro 2010). Results obtained by Leandro (2010) showed that average vessel frequency decreased from 10 per mm² close to the pith to 7 per mm² close to the bark. For 15-yr-old *E. nitens* trees, Lausberg et al (1995) reported vessel frequencies of 5 per mm² at a cambial age of 5 yr and 4 per mm² at a cambial age of 10 yr. Leandro (2010) also reported that the radial and

tangential lumen diameters increased from 181 and 109 μm, respectively, close to the pith to 276 and 161 μm, respectively, close to the bark. These results agree with those reported by McKimm and Ilic (1987) regarding the radial variation of vessel diameter.

Leandro (2010) found radial and tangential average fiber cell wall thicknesses of 2.6 and 2.4 μm, respectively. This shows the small difference between fiber cell wall thicknesses in both directions. Leandro (2010) also reported average fiber lumen diameters of 14 and 11 μm in the radial and tangential directions, respectively, combined with a heterogeneous anatomical structure.

Growth ring width decreases from pith to bark. Earlywood width decreases from pith to bark, but latewood width remains almost constant. It was also observed that overall, earlywood and latewood basic density increased from pith to bark. From these results, it was concluded that growth ring width (or earlywood width) mainly determines wood average basic density, although decrease in vessel frequency from pith to bark can also play a significant role. On that basis, one can infer that the large difference in basic density between earlywood (400 kg/m³) and latewood (900 kg/m³) favors the development of internal checks in the growth rings and collapse in *E. nitens* (Leandro et al 2008).

Leandro (2010) mentions that basic density increased from 451 kg/m³ close to the pith to 535 kg/m³ close to the bark. For *E. nitens* grown in New Zealand, lower wood basic density values varying from 407-412 kg/m³ were found for 8- and 11-yr-old trees, respectively (McKinley et al 2002). Results reported by Evans et al (2004) and Leandro et al (2008) show that *E. nitens* wood basic density increased with height in the tree.

Previous studies on *E. nitens* grown in Chile show significant differences in vessel diameter, vessel frequency, and basic density obtained at different radial positions and for different trees from a given clone (Leandro et al 2008; Leandro 2010; Valenzuela et al 2012). However, knowledge gaps remain on the relationship between

anatomical characteristics of *E. nitens* wood and development of internal checks within the growth rings and on variation of these characteristics with height in the tree. Understanding of internal check development in *E. nitens* is fundamental to improve the drying process of this species and develop solid wood products from it.

The objectives of this study were to determine if the development of internal checks within early-wood of *Eucalyptus nitens* can be related to clone of origin, wood anatomical properties, and wood basic density.

MATERIALS AND METHODS

Materials

The wood used in this study was obtained from 12-yr-old *Eucalyptus nitens* trees from the site “Las Mellizas” of the Rucamanque farm in the

vicinity of Huépil, eighth region, Chile. Two trees from each of three different clones were cut for the study for a total of six trees. Three disks were sampled at four heights in the trees: 0, 3, 6, and 9 m from the stump (Fig 1).

Methods

Sample preparation. A stick including the pith and oriented in the north–south direction was cut from each disk. This stick was cross-cut in two equal parts: north and south. The south part was used for this study. Basic density (d_b , oven-dry mass/saturated volume) was determined by the gravimetric method according to the Chilean standard NCh 172/6 (INN 1986).

Internal checks induced from drying. The sticks obtained from the first disk were used to determine the presence of internal checks following drying in a convection oven according to a

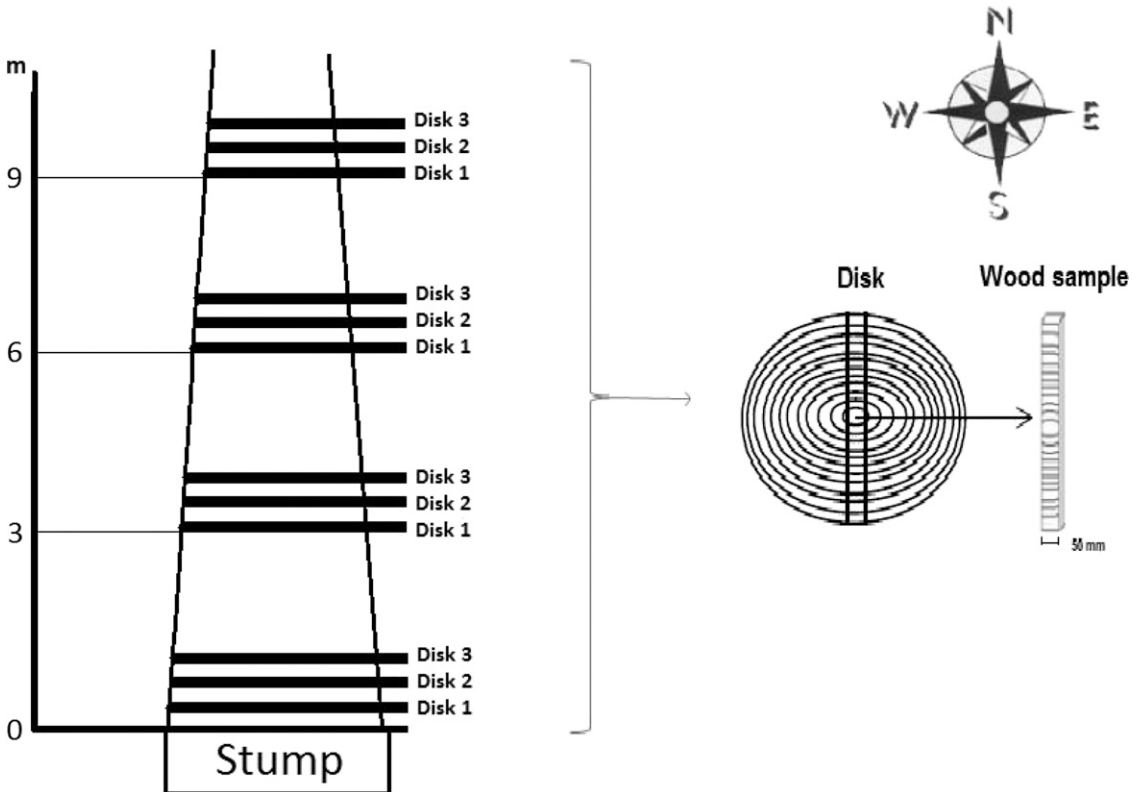


Figure 1. Wood samples selection.

procedure developed by Leandro et al (2008). Drying started at 50°C and was increased to 70°C until constant weight. Temperature was then increased to 100°C until a constant oven-dried weight was reached. Number of internal checks within each growth ring was then counted from pith to bark.

Anatomical characteristics. The second disk was used to determine the anatomical characteristics of wood: vessel frequency and diameter using the image analysis software WinCell Pro Version 2011 (Regent Instruments, Quebec City, Canada). Growth ring width was measured on the third disk using the image analysis software WinDendro Version 2009.

Sample cubes of 20 × 20 × 20 mm were cut from pith to bark in the south stick obtained from the first disk at each height of each tree for the determination of vessel frequency and diameter. Care was taken to sample the cubes in the same growth ring sequence in each stick. Thin transverse slices were obtained from each cube according to the protocols described by Chaffey (2002). The procedure can be described by the following steps: 1) the annual rings to sample were identified in the stick; 2) the sample cubes were cut and soaked in water for 36 h; 3) 35- μm -thick slices were obtained using a Microm Model HM325 microtome (Fisher Scientific); and 4) the thin wood slices were stained in safranin and mounted on a glass slide and cover glass using Canada balsam. The thin slices were analyzed using WinCell software equipped with a Lumenera (Ottawa, Ontario, Canada) Infinity digital camera mounted on an optical microscope Zeiss axiolab (Carl Zeiss, Inc., Jena, Germany).

Vessel frequency and diameter were measured using the 20 \times objective of the microscope. A sampling surface of 0.785 mm² was established randomly in the earlywood of each growth ring from pith to bark, and the number of vessels present was determined. The diameter of four vessels randomly selected within the sampling surface in each growth ring was measured in the radial and tangential directions.

Statistical Analysis

Vessel diameter and frequency were analyzed statistically. Normality of the data and homoscedasticity were tested by the Kolmogorov-Smirnov and Bartlett tests, respectively. Analysis of variance (ANOVA) was performed using a random-effects model to test the effect of clone, radial position, and height on the variables studied. A significance level of 0.01 was used. A Duncan multiple range test was performed to compare means a posteriori. Multiple regressions and Pearson correlation were also performed to explore the relationships among the variables studied. The software Statgraphics Plus Version 5.1 (StatPoint Technologies, Inc., Warrenton, VA) was used for statistical analysis.

RESULTS AND DISCUSSION

Typical internal checks in *E. nitens* observed in this study are shown in Fig 2. The checks are located in the earlywood, have a lenticular shape, and are oriented in the radial direction.

The number of internal checks as a function of height in the tree for the three clones studied is given in Fig 3. ANOVA showed a significantly

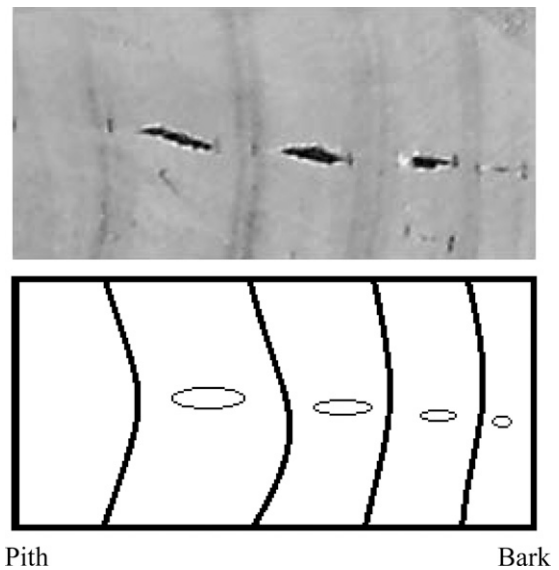


Figure 2. Internal checks in *Eucalyptus nitens*.

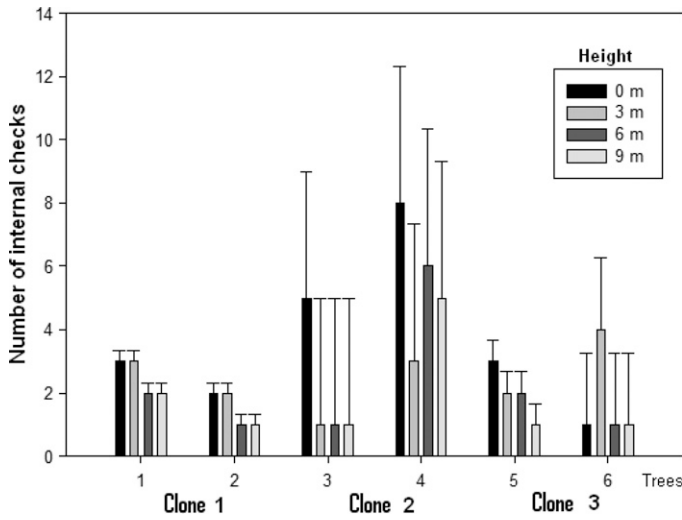


Figure 3. Internal checks in *E. nitens* clones; variation with height in the tree.

higher number of checks in clone 2 than in clone 3 (Table 1) but no significant effect of height in the tree (Fig 3). Nevertheless, the number of checks shows a tendency to decrease with height in the tree. This implies that a higher number of internal checks could be expected in the first log, close to the stump. This tendency agrees with results reported by Shelbourne et al (2002), Leandro et al (2008), and Washusen et al (2009). However, because of the high variability of the number of internal checks measured, a larger sample should be used to confirm this result.

Figure 4 shows the number of internal checks as a function of cambial age and clone. It can be seen that the higher number of internal checks appears in growth rings 1-5. This behavior was

also reported by Shelbourne et al (2002) and Leandro et al (2008).

Growth ring width was greater close to the pith and decreased from pith to bark (Fig 5a). Vessel frequency followed a similar pattern (Fig 5b). ANOVA showed significant differences between clones for average growth ring width and vessel frequency (Table 1).

Table 1 shows that clone 2 had significantly greater vessel frequency and growth ring width than the others. Clone 2 also had the tendency to develop more internal checks. The average basic density of clone 2 was 463 kg/m³, significantly lower than for the other clones. Density also has a tendency to increase with height in the tree, which favors a decrease in the number of internal checks with height (Fig 6). As reported by

Table 1. Analysis of variance of wood properties ($\alpha = 0.01$).

	Clone 1	Clone 2	Clone 3	F	p
Vessel frequency/mm ²	6.2 A	7.37 B	6.18 A	4.82	0.009
Vessel area (mm ²)	76,250.5 A	81,997 A	69,014.5 A	1.82	0.1648
Width ring (mm)	8.96 A	10.49 B	9.78 C	19.74	0.0000
Density (kg/m ³)	503.56 B	463.26 A	497.71 B	29.91	0.0000
Number of internal checks	2.13	3.75	1.88	2.84	0.0808

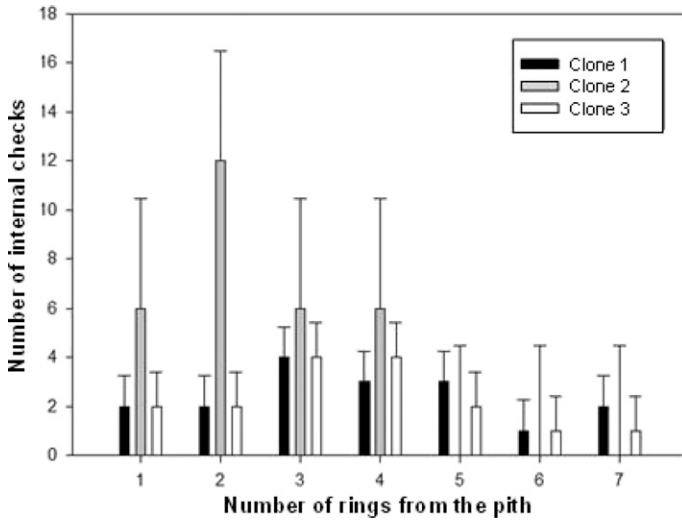


Figure 4. Number of internal checks in *E. nitens* clones; variation with number of rings from the pith.

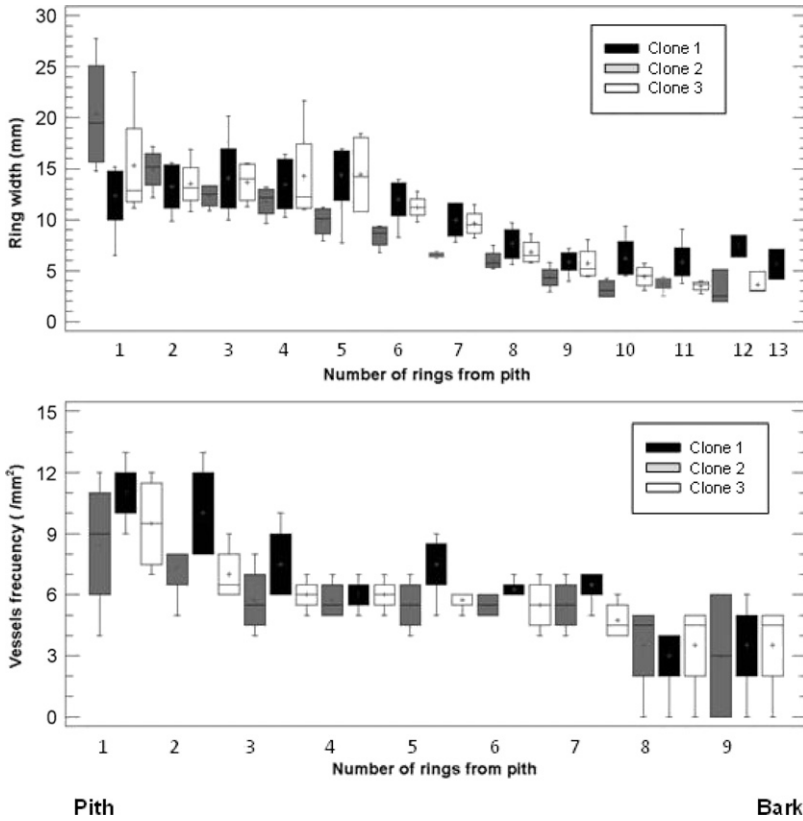


Figure 5. Ring width and vessel frequency of *E. nitens* clones; variation with number of ring from the pith.

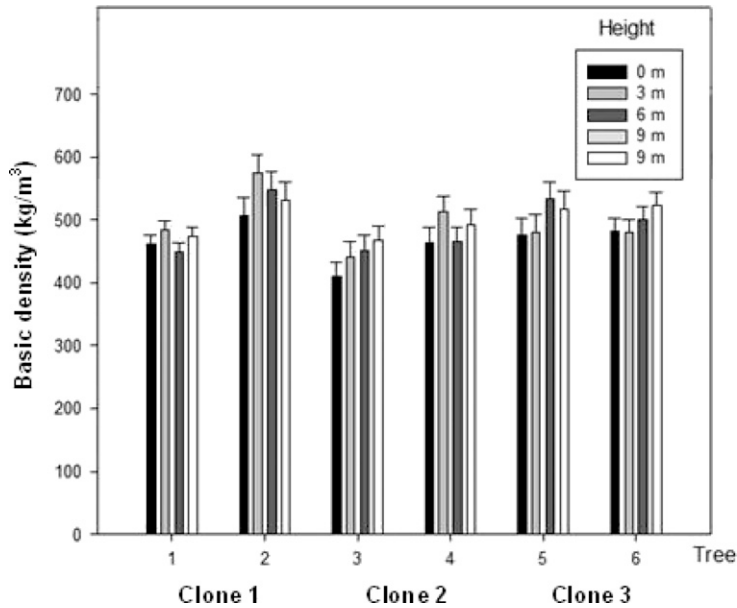


Figure 6. Basic density of *E. nitens* clones.

Leandro et al (2008), a higher vessel frequency involves a decrease in the proportion of fiber cell walls and of density. This explains the higher frequency of internal checks in the growth rings located close to the pith in *E. nitens*.

The Pearson correlation coefficients (*r*) among the frequency of internal checks, basic density, and anatomical characteristics were determined and found to be statistically significant. In particular, the correlation coefficient between internal check frequency and basic density was negatively weak ($r = -0.47$). The correlation coefficient between internal checks and growth ring width was 0.32, vessel frequency was 0.22, and vessel area was 0.12. Wood of lower basic density tended to be associated with greater internal checks. This relationship may be used to compare the performance of *E. nitens* clones for solid wood products.

CONCLUSIONS

Internal checks varied significantly among clones of *Eucalyptus nitens*. The number of internal checks decreased with height and increased from pith to bark. Internal check frequency was

greater when basic density was lower. The results from this study provide information on the performance of *E. nitens* clones for use in solid wood products.

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