TRENDS ON EUCALYPTUS WOOD DENSITY IN SITES WITH DIFFERENT WATER AVAILABILITY

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Abstract
We present the trends in basic wood density response from six different eucalyptus genotypes (*Eucalyptus globulus* (EG), *E. nitens × globulus* (ENG), *E. nitens* (EN), *E. camaldulensis × globulus* (ECG), and E. *badjensis* (EB)) growing under contrasting water availability. This study was based on a field experiment that considered two forest sites with contrasting water availability conditions, with water irrigation and water irrigation exclusion, in south-central Chile, in the Biobío region. The basic wood density was measured indirectly by a non-destructive tool (drill-resistograph PD-400 IML model) and compared with laboratory methods based on the ratio between the dry weight of wood divided by the green volume of the same wood (SCAN-CM 43-95). The tool operates based on the drilling resistance of a needle into the tree. The power consumption of the drilling device is registered electronically and a bark-to-bark amplitude profile at drilling depth is produced, showing the density variation of earlywood and latewood. EUCAHYDRO project, which investigates the sensitivity of different eucalyptus genotypes to environmental stresses, and their productivity responses in different water availability associated with new climate change scenarios, provided the data for this study.

Keywords
wood density, water availability, environmental stress

Introduction

Planted forests increasingly contribute to the lsupply of wood, fiber, fuel, and non-timber forest products. Simultaneously, they provide environmental services such as land degradation reduction and CO_2 capture for mitigating climate change (Battaglia et al. 1999; Payn et al. 2015; Waring et al. 2020).

The increasing temperature, CO^2 and O_3 concentrations, ultraviolet radiation and changes in precipitation patterns promote changes in trees' physiology and wood attributes for different end-use (Ashton 2012). Thus, in doing tree breeding for growth and wood quality, it is important to exploring

the performance of the genetic material growing under effects of climatic change, significantly when trees are growing with limiting water availability conditions. A canonic wood property suitable to assess the wood quality for many applications is the wood density. Wood density is the canonical attribute to evaluate wood's physical and mechanical properties and an indicator of tree growth rate in both softwoods and hardwoods (King et al. 2016). Traditional methods to assess wood density are mostly destructive and expensive, limiting the number of samples that can be processed (Raymond 2002). However, non-destructive sampling techniques and innovative assessment methodologies lead to a large increase in the numbers of trees and traits possible to evaluate (Schimleck et al. 2020). A device named Resistograph can assess the wood density of standing trees in seconds, and one the graphic output consists of a resistogram that presents a succession of peaks and valleys, showing the variations in the effort for penetrating tree wood. Thus, the total energy need to penetrate the sample is intimately related to the wood material (Rinn et al. 1996; Pellerin 2002; Kloppenburg 2018; Schimleck et al. 2020).

Increasingly, the resistographic technology is being implemented in breeding programs (Chauhan et al. 2013; Potts et al. 2014). Thus, one of its applications is to assess progeny trials and determining the patterns of variation, degree of genetic control, and economic importance of many wood traits, leading to the inclusion of wood properties in many eucalypt-breeding programs (Downes et al. 2018).

Materials and Methods

Sites conditions. This study was based on an experiment that considered two forest sites conditions with contrasting water availability conditions with and without irrigation. The trail is located 9.6 Km south of Yumbel, Biobío region, central south Chile (37° 8′0.01″S, 72°27′34.70″W) Table 1 presents a summary of the site's information for North and South trials.

Table 1. Summary of climatic and soil information of the experiment.

Attributes	Trial in the South site
Previous land use	*Pinus radiata* D. Don harvested, where the stumps were removed and the remaining residues were crushed and then incorporated by harrowing.
Soils	Young soils, deep and coarse volcanic black sands of andesitic and basaltic volcanic origin deposited by rivers in flat areas. Soils of Arenales soil series (CIREN,1999) Slope < 3%
Temperature	Mean annual: 13.8 °C Minimum: 7.6 °C in July Maximum: 20.5 °C in January
Precipitation	Total precipitation per growing season: Year 2014: 1252 mm year^{-1} Year 2015: 1102 mm year−1

Genetic material and experiment design. The experiment used 30 *Eucalyptus* genotypes, top-ranked by the tree genetic programs of two forest companies, CMPC and ARAUCO. The genotypes were planted in a randomized complete factorial block design with 3 replicates for each of two irrigation treatments, low and high. The genetic material planted consisted of 17 cuttings and 2 seedlings of *Eucalyptus globulus* (EG), 6 cuttings of *E. nitens × globulus* hybrids (ENG or *E. gloni),* 2 seedlings of *E. nitens* (EN), and single cuttings of *E. camaldulensis × globulus* (ECG or *E. camglo*), and *E. badjensis* (EB) Plants were established at a 3 × 2 m spacing (1666 trees/ha).

Basic density determination. A 12 mm increment borer was used to obtain samples from trees at 1.3 m height to determine basic wood density according to the Tappi Standard Method T258 om-94. The basic wood density (ρk) is the ratio of oven dry weight by the green volume, expressed in weight per unit volume. First, the green volume of wood (Vmax) was measured using the water displacement method (Olesen 1971). Then, the wood samples were dried in an oven at 105ºC until their moisture content (MC) reached 0% ($m0$), and the weight was measured using a laboratory balance.

Resistograph evaluation. Trees samples were drilled bark-to-bark at BH using the IML Resistograph PD400 (Instrumenta Mechanik Labor GmbH, Germany). This device has a micro-drilling needle 1.5 mm in diameter (3 mm for the drill bit head) and a maximum drilling depth of 40 cm. In addition, the tool provides a graphic representation (called resistogram). The total energy consumed in the penetration is closely related to the material density. Resistance profiles stored in the electronic unit were downloaded using the PD-Tools Pro software provided with the Resistograph.

Statistical analysis.

To facilitate the comparison between groups with different treatments, a test of means and variance was performed. The results of wood basic density dispersion of the results for each treatment are shown in a boxplot analysis.

Results

Wood basic density

In the field test, we found that there are differences between the basic wood density obtained from the increment dowel sample between eucalyptus species growing with irrigation and without irrigation conditions. For all the species *E. globulus, E. nitens, E. nitens x globulus and E. badjensis* we found that the basic wood density is higher under without irrigation condition. Contrarily can be observed that only for the *E. camaldulensis x globulus* species it was found that the basic wood density is lower under with irrigation condition (figure 1).

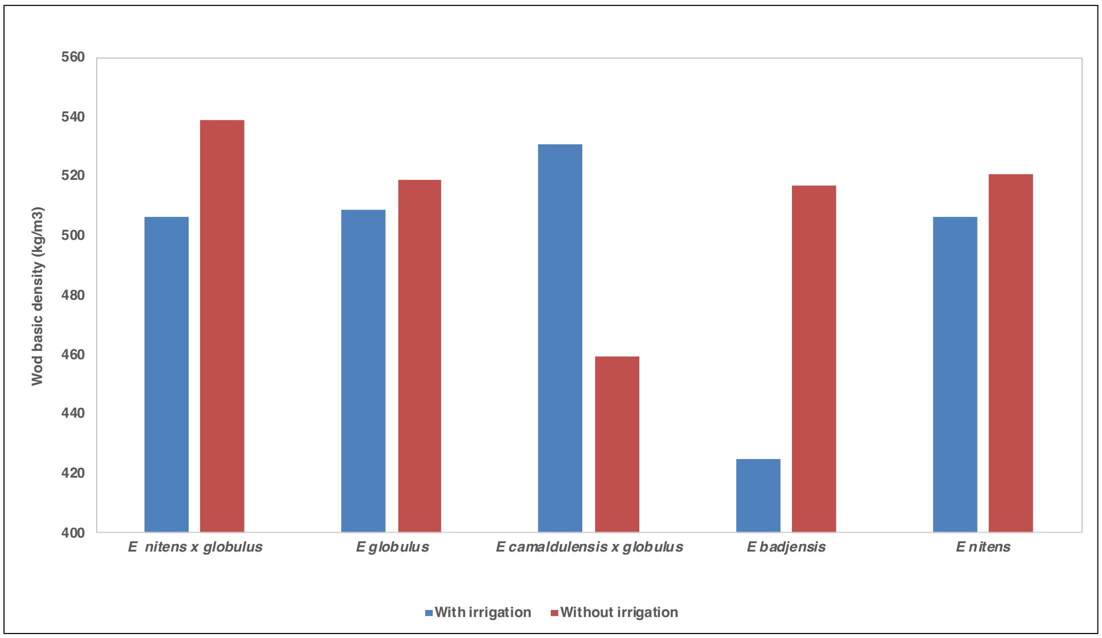


Figure 1. Wood density variation between species per sites with and without irrigation

The results of wood basic density dispersion for each treatment with and without irrigation for *Eucalyptus* spp. are shown in a boxplot analysis (figure 2).

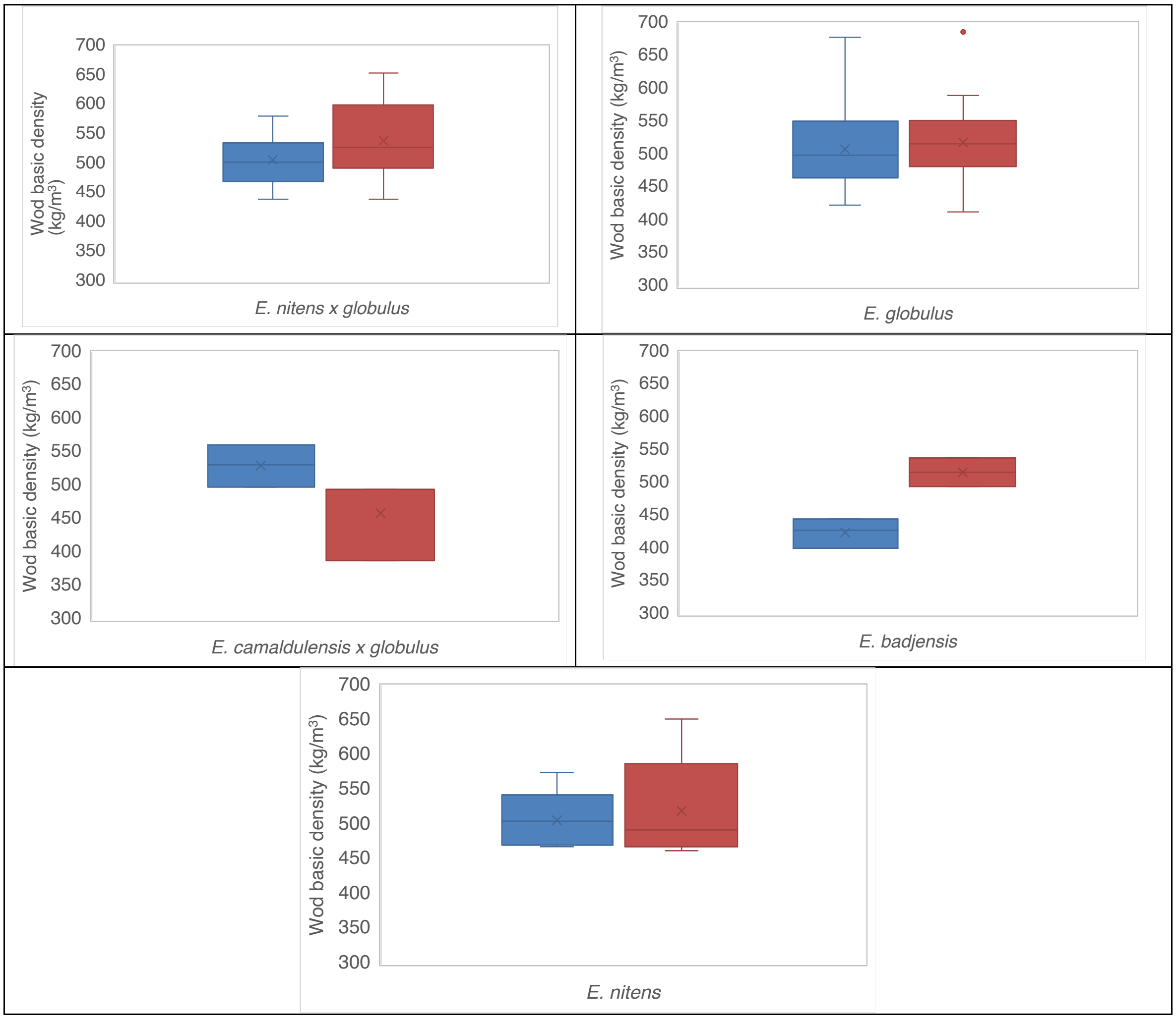
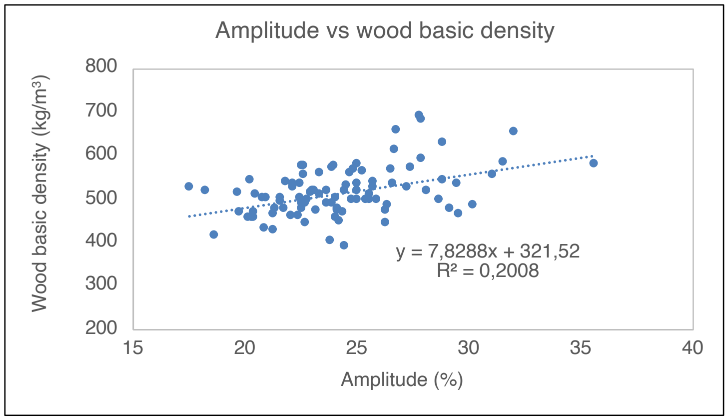


Figure 2. Boxplot analysis for species of *Eucalyptus* in different conditions: blue with irrigation and red: without irrigation.

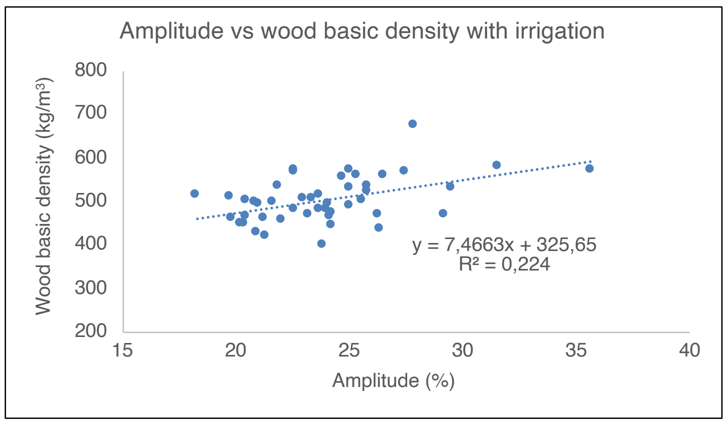
Correlation resistograph and wood basic density

For the prediction of basic wood density using the indirect and non-destructive resistography method based in amplitude, we found that there is no exist high correlation between the pooled data between the with and without irrigation conditions for all eucalyptus species. Only increase correlations slightly using the separate conditions (figure 3).

A



B



C

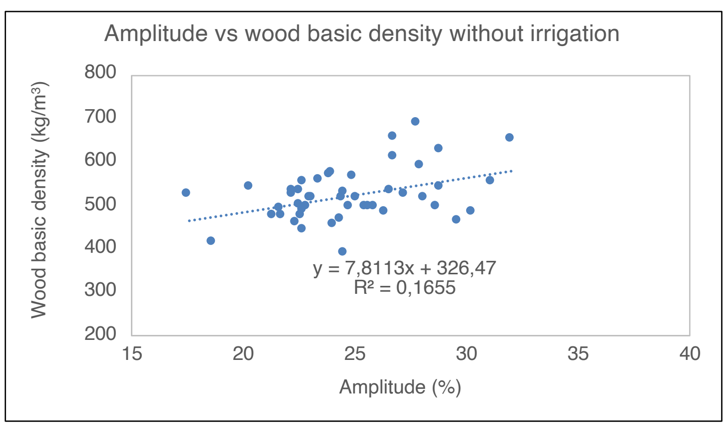


Figure 3. Correlation between amplitude resistograph and wood basic density A: all species of eucalyptus in both conditions, B) all species of Eucalyptus with irrigation and C) all species of *Eucalyptus* without irrigation

On the other hand, using preliminary data separated by eucalyptus species, we found better correlations between amplitude and basic wood density that could allow a better prediction of it (figure 4).

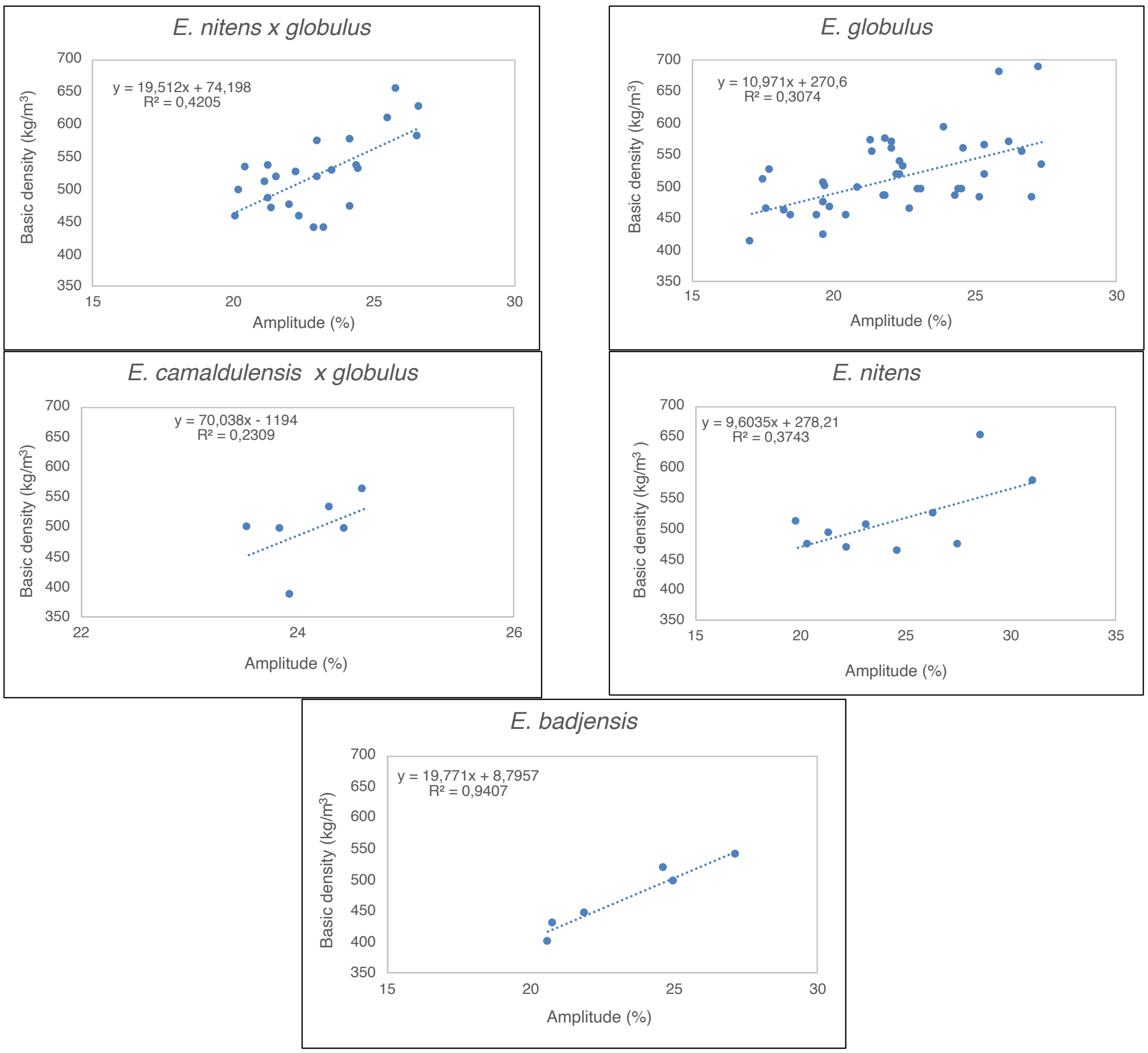


Figure 4. Correlation between amplitude resistograph and wood basic density for all species of Eucalyptus in both conditions

Conclusion

- ***Irrigation have significant effect in wood basic density property of eucalyptus species.***
- ***Lack or decrease of irrigation causes an increase in wood basic density in most eucalyptus species.***
- ***Resistography is a potential tool for nondestructive prediction of wood basic density in eucalyptus species.***

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