Air-drying of Seven Clones of *Eucalyptus grandis* × *Eucalyptus urophylla* Wood

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Selecting clones with the best genetic material is one goal of eucalyptus breeding programs. Understanding the variations between the wood from different hybrid clones during drying is necessary to process improvement. This study aimed to select eucalyptus clones for lumber production based on their drying defects. From a plantation in Brazil, 42 trees within the seven different clones were used. All trees were 13 years old. The effect of the genetic material on the apparent density of the clones was significant. It was possible to separate the clones into four groups. Even if the wood was from the same genotype, a load of boards made from *Eucalyptus grandis* × *Eucalyptus urophylla* wood exhibited heterogeneity in the drying rate due to factors inherent in the wood, especially the apparent density. The apparent density negatively affected the drying rate of the clones, *i.e.*, approximately 70.5% of the drying rate was explained by the apparent density. Denser pieces exhibited lower drying rates. For a more homogeneous natural drying, it is recommended that the composition of the stacks use pieces with the same apparent density and thus similar initial moisture. The air-drying process is recommended to release any free water from eucalyptus woods.

Keywords: Wood defects; Lumber; Cup; Split

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INTRODUCTION

Tree species within the *Eucalyptus* genus are planted in different continents in response to the needs of the high demand for forest resources, the environmental pressures on the use of native forests, its overall general rapid growth, and a wide range of uses of its renewable material. Recently, interest in the higher value-added wood products of *Eucalyptus* sp. as a source of timber and lumber has increased in Brazil (Teixeira *et al.* 2009).

However, even with its availability, the wood of the main *Eucalyptus* species has technological processing difficulties, such as high growing tensions, non-ideal fiber orientation, and problems arising from the drying process that are responsible for reducing the yield in lumber manufacturing. Another factor that affects the lumber industry is the unavailability of suitable raw material. The logs available are predominantly from short rotation periods (fast-grown species) and small-diameter logs, mainly composed of juvenile wood (Washusen 2013).

Identifying the variations between and within different species enables genetic breeding programs to select hybrid clones that produce their desired material. This practice is already in use in the pulp industry but has not been completely implemented in the lumber and timber industries. Furthermore, even with good availability for the timber industry, the wood of most *Eucalyptus* species generally features drying defects (Cunha *et al.* 2015).

Wood drying (natural or artificial) is an important process in the lumber industry that adds value to the product because it increases the dimensional stability and strengthens against attacks by xylophagous organisms. On the negative side, drying defects can arise during this phase, causing problems in the anisotropic variation of the dimensions of the lumber pieces and generating defects such as twisting, cracking, warping, and collapse (Anjos *et al.* 2011).

The main purpose of wood air drying is to take out as much water as possible through evaporation using the forces of nature (Ponce and Watai 1985). During air drying, wood reaches equilibrium moisture slowly and smoothly. The drying time varies according to the climatic conditions of each region (Mendes *et al.* 1996).

Wood defects resulting from the drying process are among the main challenges to make eucalyptus wood economically viable for the timber industry (Oltean *et al.* 2007). Therefore, it is important to determine the characteristics of the *Eucalyptus grandis* × *Eucalyptus urophylla* clones with the genetic materials that present better results from natural wood drying.

Despite what is known regarding wood drying of eucalyptus wood, there is still limited information regarding air drying of different *E. grandis* × *E. urophylla* hybrid clones. The knowledge about the difference in wood clones can improve the eucalyptus drying process through understanding the variations between the genetic materials formed by these different clones. The objective of this study is to evaluate the air drying process of these different hybrid clones and the interaction of genetic material with wood properties (wood apparent density, drying rate, anatomical characteristics, and drying defects).

EXPERIMENTAL

Materials

Sets of six trees obtained from seven different clones of 13-years-old *Eucalyptus grandis* × *Eucalyptus urophylla* hybrid (a total of 42 trees) obtained from a plantation located in Alcobaça, Brazil were used in this study. The trees were moved to a sawmill and were broken down into logs. All trees used in this study were processed at the same time to ensure similar conditions for all samples tested. The material came from logs 2 m in length obtained between 5 m and 7 m of the tree height described by França *et al.* (2017a). The 84 pieces selected for this study were cut from the sapwood section, located in the peripheral region of the logs, which is the section located under the bark (Fig. 1).

Samples were obtained from this position since they present less defects such as knots, and it is where boards derived from the wood generally exhibit better physical and mechanical properties. In addition, this sawing method (plain sawing) is the most used in the eucalyptus lumber industry, aiming for superior quality of wood, and greater values in the market. França *et al.* (2017b) detailed the plantation and some dendrometric variables used during the tree selection.

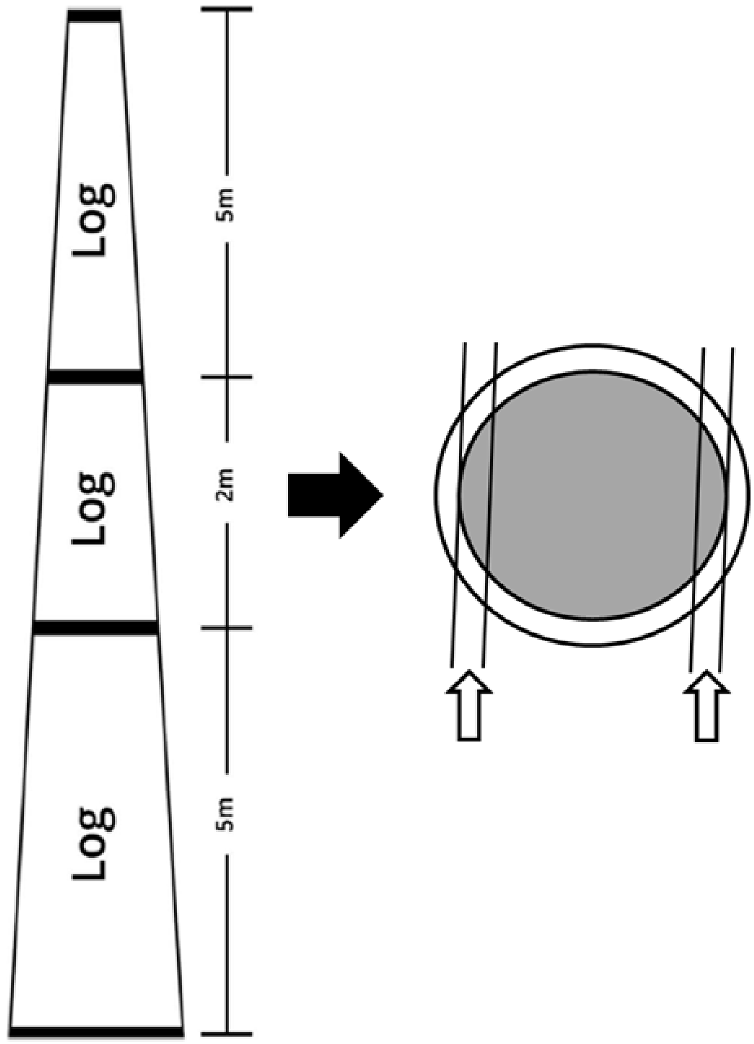

Fig. 1. Scheme of sampling location of *Eucalyptus grandis* × *Eucalyptus urophylla* hybrid clones (arrows indicate the location from samples were obtained)

Initial moisture content and air drying samples were prepared according to the method proposed by Simpson (1991), as shown in Fig. 2.

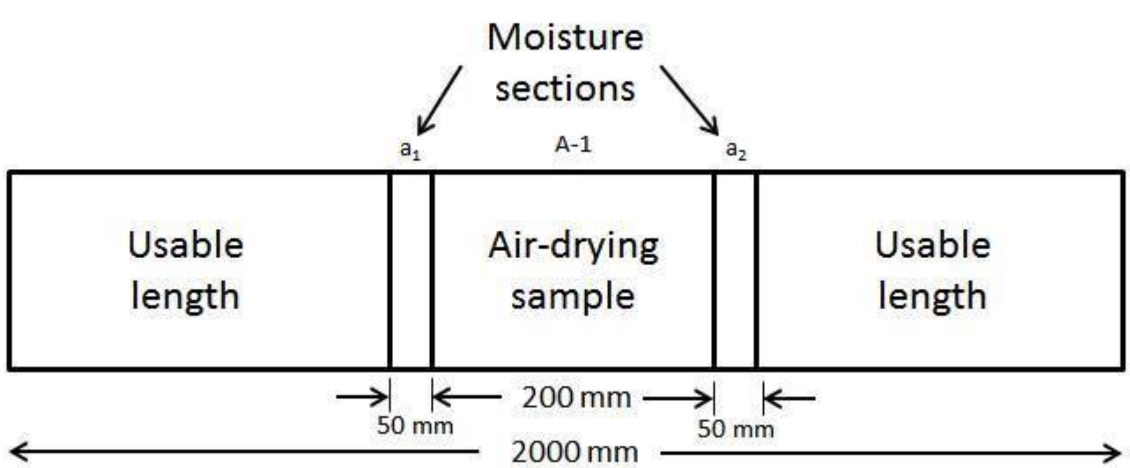

Fig. 2. Scheme of preparation of initial moisture content and air drying samples

The selected boards were cut into 2000 mm in length. For each clone, two initial moisture samples were prepared with 50 mm thickness and a total of eight samples per clone (Fig. 2 a1 – a2). For air drying samples, it was cut four samples per clone with 200 mm in thickness (Fig. 2 A-1). This procedure ensured that the drying samples from the same clone were selected from different trees for better representation.

Both initial moisture control samples and air drying samples were put inside the stack in order to provide similar drying conditions. It is known that on the longitudinal direction the rate of water movement is higher, and to prevent different drying rates on the cross section, paint was applied on the end of the samples.

Methods

Control samples

The gravimetric method was used to estimate the initial moisture content of the samples. An average of the two initial moisture content samples was calculated for each lumber piece. Based on the result, the estimated dry mass (EDM) of the control samples was calculated using Eq. 1, which was used to calculate the moisture content of the control samples during the natural drying process,

$$EDM = \frac{100 \times M_{\mathrm{i}}}{100 \times U_{\mathrm{i}}} \tag{1}$$

where *EDM* is the estimated dry mass of the control sample (g), M_i is the initial wet mass of control sample (g), and U_i is the average initial moisture content of samples (%).

A round, treated eucalyptus structure with dimensions of 20 mm × 50 mm × 1,100 mm (thickness × width × length) was built to support the drying stack. To evaluate the natural drying process, the pieces were stacked forming a box stack (Fig. 3) with approximate dimensions of 850 mm × 1,100 mm × 2,000 mm (height × width × length), established in an open location with plenty of air circulation.

Four stickers with dimensions of 20 mm × 35 mm × 1,100 mm (thickness × width × length) were positioned between the layers of boards to permit the air access. The naturally drying control samples were randomly positioned, always on the outside of the stack. The stack was covered with cement tiles for protection against rain.

Fig. 3. Stacked side view of the positioning of the control samples

The drying stack was set at the Department of Forest and Wood Sciences of the Espírito Santo Federal University, located in Jerônimo Monteiro, Brazil, on April 18th, 2013. The average temperature in Jerônimo Monteiro ranged between 19 °C and 29 °C with a relative humidity ranging from 56% to 89% during the drying period.

The control samples were weighed once every two days during the first month and once every four days from the second month until August 12th, 2013, when the control samples reached average moisture content of 13%. The drying cycle ended with the total time being 116 days. The drying rate of the moisture control samples was calculated according to Eq. 2,

$$DR = \frac{(H_i - H_f)}{\text{Time}} \tag{2}$$

where DR is the drying rate (percent points per day – pp × day^{-1}), H_i is the initial moisture content of the control sample (%), H_f is the final moisture content of the control sample (%), and time is the total drying time (d).

Photomicrographs and apparent density

At the end of the drying process, the control samples were collected and cut down to prepare specimens for the photomicrographs and the apparent density, according to Fig. 4. The specimens used for the photomicrographs were prepared using a microtome with a sharp blade. The photomicrographs were taken using a Zeiss Discovery V12 stereomicroscope (50×) (Leica, Wetzlar, Germany). Images of an area of 4 mm² were taken on both cross-sections of every specimen.

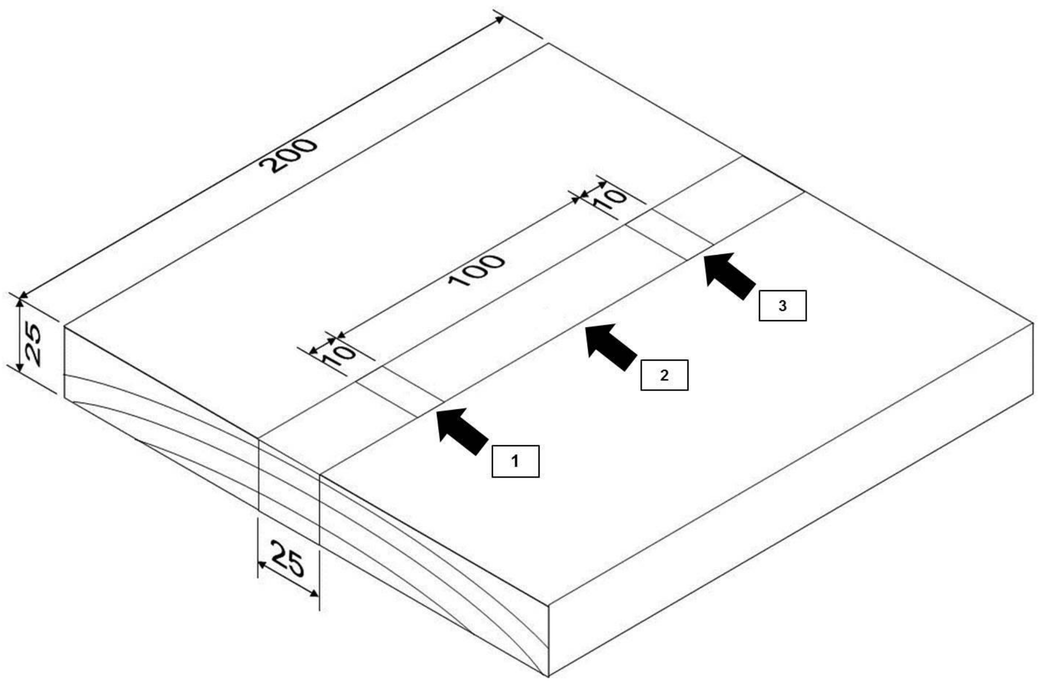

Fig. 4. Sampling scheme of the specimens for photomicrographs (1 and 3) and apparent density (2) (dimensions in mm)

The apparent density was determined after the specimens reached an equilibrium moisture of approximately 12% in a chamber with a temperature of 20 °C and a relative humidity of 65%. Four replications with dimensions of 20 mm × 20 mm × 30 mm (radial × tangential × longitudinal) were collected from each board, for a total of 24 specimens per clone. A digital caliper (0.01-mm) and a digital scale (0.01-g) were used to obtain the respective measurements and weights of the specimens.

Drying defects

This study analyzed the drying defects of cupping and splitting. Cupping was evaluated by recording the values of the largest deviation observed in the transverse direction of the boards and then dividing by the width of the piece. Board end splits were evaluated according to the standard ABNT NBR 14806 (2002) by quantifying the sum of each individual split length and then dividing by the length of the board. The calculation to find the cupping percentage is shown below in Eq. 3,

$$Cupping = \frac{Deviation}{Width} \times 100 \tag{3}$$

where *Cupping* is a drying defect (%), *Deviation* is the largest deviation observed in the transverse direction (mm), and *Width* is the width of the piece being measured (mm).

Statistical analysis

A statistical analysis was performed in a randomized design (5% significance for all tests). The effect of the clones on the drying rate, apparent density, initial moisture contents, and final moisture contents was verified by applying the analysis of variance (ANOVA), and for its validation, the Bartlett's test was applied that evaluates the homogeneity of the variances between treatments. The F test was applied, and the null hypothesis was confirmed ($P > 0.05$), and Tukey's test was used to compare the means. In cases where at least one of the variances was not statistically equal ($P < 0.05$), the Kruskal-Wallis' H test and an analysis of the box graph for the differentiation of the medians were applied.

Additionally, this study applied a linear regression analysis that used both the coefficient of determination (R^2) and graphical analysis to verify the relationship between the apparent density and the drying rate of the variables. The ANOVA was used to verify the significance of the coefficients in the equation. The statistical analyses were conducted using SAS 9.4 software (SAS Institute Inc., version 9.4, Cary, NC, USA).

RESULTS AND DISCUSSION

Drying Process

The natural air-drying was completed during a period between part of autumn (April 18th) and part of winter (August 8th) in 2013. With a total of 116 days, the lowest temperature was recorded on July 26th and the highest on July 2nd. The driest day during the experiment was recorded as July 8th, while the most humid day recorded was June 25th. Figure 5 shows the drying curves per clone for the analyzed period. Each curve represents the mean of the four control samples per clone.

Based on the weight of the control samples, the averages of the moisture content (initial and final) and the average time to reach the fiber saturation point (FSP, 30%) per clone were calculated as shown in Table 1.

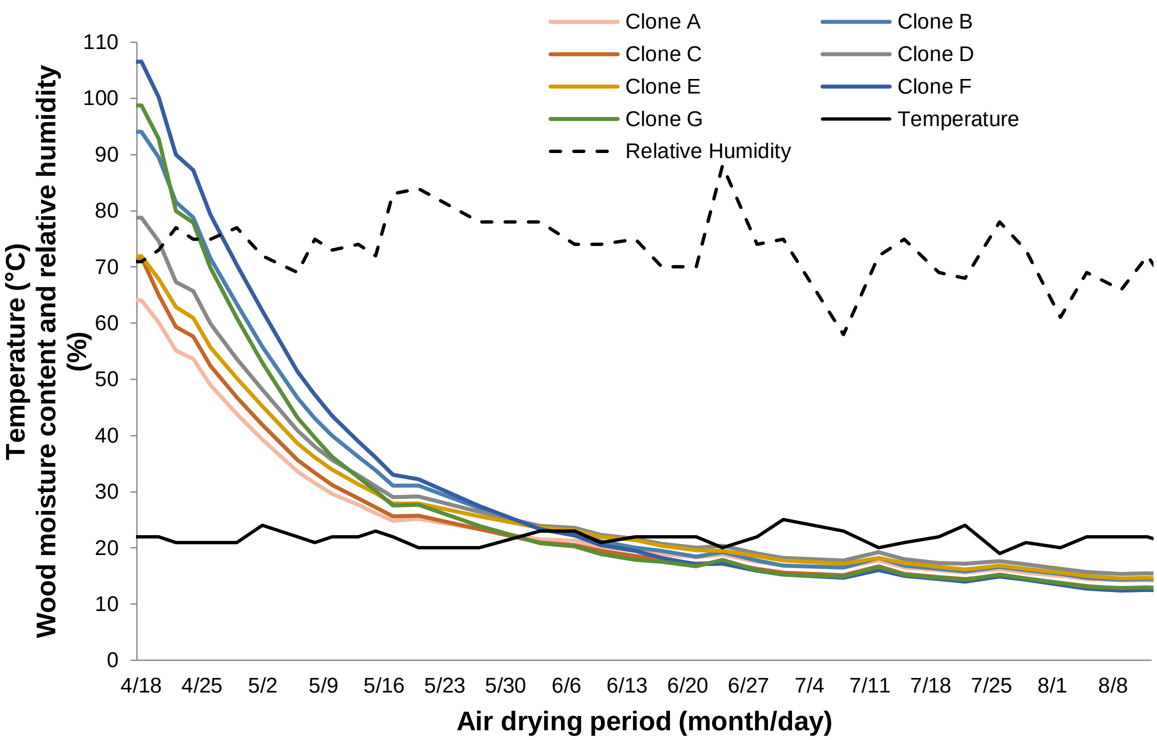

Fig. 5. Air-drying curve for *E. grandis* × *E. urophylla* boards

Table 1. Averages of Outdoor Drying Parameters Per Clone

Clone	Moisture Content		Average Time to Reach FSP (days)	Drying Rate (pp × day^{-1})
	Initial (%)	Final (%)		
A	64.10 *D*	14.21 (14.99) *	22.3 (21.52)	0.430 *D* (7.75)
B	94.08 *B*	14.49 (5.54)	33.5 (19.11)	0.686 *B* (6.84)
C	71.71 *CD*	12.83 (23.16)	23.5 (19.81)	0.508 *CD* (10.37)
D	78.78 *C*	15.46 (4.80)	29.3 (24.40)	0.546 *C* (11.86)
E	71.93 *CD*	14.68 (11.87)	26.0 (16.32)	0.494 *CD* (15.89)
F	106.56 *A*	12.57 (12.55)	36.0 (16.67)	0.810 *A* (8.00)
G	98.78 *AB*	13.01 (2.61)	27.8 (12.26)	0.739 *AB* (14.49)
Bartlett test	1.31 ^{ns}	2.01 *	-	1.26 ^{ns}
F calculated *via* ANOVA	15.99 **	-	-	-
Kruskal-Wallis' test H	-	9.69 ^{ns}	12.35 ^{ns}	17.82 **

*Numbers in parenthesis are the coefficient of variation (%). Averages followed by the same vertical letter do not differ statistically from each other according to Tukey's test (P > 0.05).

For the initial moisture content, there was a significant difference between the clones. Clones A, C, and E had the lowest averages, and clone A had the lowest absolute average (64.1%). Clones F and G had the highest averages, and clone F had the highest absolute average (106.6%).

The heterogeneity of the initial moisture content between the pieces was undesirable for a combined drying process, which uses the natural drying as a pre-drying process. The drying rate was higher for capillary water, and this implied that pieces of different clones will reach the FSP at different times. This mix led to drying defects because the pieces of the different clones exhibited different drying characteristics.

Kruskal-Wallis' H test results for the time it took to reach FSP showed that there was no significant difference between the averages of the clones. Clone A boards took approximately 22 days to reach the FSP, while clone F boards reached the FSP in approximately 36 days. Even if it was not significant, in terms of the drying process this difference of 14 days represents costs that cannot be neglected during decision-making regarding the combined drying processes.

Compared with the values obtained by Rosso (2006) for the natural drying of *Eucalyptus grandis*, the average time for the boards to reach the FSP for all clones was among the values obtained by Rosso for the autumn (37 days) and winter (15 days) seasons. Carvalho (2006) studied *E. grandis* with the same thickness and found it took 18 days to reach the FSP. Ciniglio (1998) studied thinner pieces (25 mm) of *Eucalyptus grandis* and *Eucalyptus urophylla*, resulting in 15 days and 19 days to reach the FSP, respectively. This difference may have been influenced by the differences in the thickness and the initial moisture content of the pieces, as well as factors related to the climatic conditions of the place where the drying was performed.

Approximately 25% of the drying curve (Fig. 5) shows the linear characteristic of the capillary water drying (above the FSP), in which the drying rate was nearly constant. Around the FSP, the transition from capillary water to hygroscopic water was observed, and the drying rate began to decrease. Below the FSP, the hygroscopic water drying predominated and the curve had a smaller slope, represented by the decreased drying rate.

The behavior of the wood drying curve of the seven clones similarly reflected the results from the studies by Ciniglio (1998) for *E. grandis* and *E. urophylla*, and Pizzol (2010) for *E. grandis*. Visually, the transition phase between the drying of the capillary and the hygroscopic water occurred smoothly, as described by Santos *et al.* (2003) for *E. grandis*. When the boards reached the FSP (between May 8th and May 24th), the transition from the drying phases was observed, showing a dramatic decrease in the moisture content variation between the measurements due to the reduction in the drying rate.

According to the Kruskal-Wallis' H test, there was no significant difference between the average final moisture of the clones. The highest absolute average for the final moisture content was 15.5% for clone D, and the lowest absolute average was 12.6% for clone F. It is desirable that the final moisture content of the boards be homogeneous because this permits the best subsequent processing. The greatest difference in the final moisture content between clones was only 2.89 pp × day^{-1}, which was an acceptable variation for natural drying. The variation of moisture content between the pieces above the FSP, as discussed before, was not necessarily a problem because it was possible to obtain a homogeneous final moisture, even when naturally drying.

Clones F and G had the highest averages for the drying rate (0.810 pp × day^{-1} and 0.739 pp × day^{-1}, respectively), while clones A, C, and E had the lowest averages (0.430 pp × day^{-1}, 0.508 pp × day^{-1}, and 0.494 pp × day^{-1}, respectively). This difference was influenced by the initial moisture content (Table 1) and showed that a higher initial moisture content implied a higher drying rate of capillary water and *vice versa*. However, the differences in the drying rate did not significantly influence the final moisture content of the clones because there was no significant difference between the clones for that variable. The drying rate results were set between the values of 0.39 pp × day^{-1} for *Eucalyptus grandis* and 1.00 pp × day^{-1} for *Eucalyptus urophylla* (Carvalho 2006; Pizzol 2010).

Anatomical Evaluation

Representative photomicrographs of the cross-sections of the control samples per clone are shown in Fig. 6. As indicated by the arrows, there were tyloses in all of the analyzed clones. Tyloses are common in eucalyptus wood (Santos *et al.* 2003). The diameter and the quantity of the clogged vessels had a negative influence on the drying process *via* decreasing the permeability of the boards. However, quantifying such phenomena requires a specific study in this area with an appropriate method. The wood of the *E. grandis* × *E. urophylla* clones was considered to have low permeability, according to the drying curve characteristics mentioned in Fig. 6 and due to the presence of tyloses blocking the vessels. This result was in accordance with the description for *E. grandis* by Santos *et al.* (2003).

Diameter and Frequency of Vessels

The frequency of pores varied from 2 pores to 13 pores per mm^2 and the averages were significantly different between the clones (Table 2). Clones G, F, and C had the lowest averages of pore frequency, and clones D, A, and E had the highest averages. Alzate (2004) reported pore frequency varying between 9 pores to 14 pores per mm^2 for eight-year-old *E. grandis* trees. Oliveira *et al.* (2012) reported values between 3 pores and 30 pores per mm^2 for five-year-old *E. grandis* trees. Bamber *et al.* (1982) studied the lower frequency of pores in a fast-growing eucalyptus plantation and its relation to higher densities when compared with trees that grow at normal rates. In this study, clones with larger and more frequent vessels exhibited lower apparent density and faster air drying.

In addition, the diameter of the pores varied significantly between the clones, and the overall values ranged from 53 μm to 204 μm. Clones E, C, A, and B had the lowest pore diameter averages and clones D and F had the largest pore diameter averages. Alzate (2004) reported an average pore diameter of 106 μm. Oliveira *et al.* (2012) reported approximate values of 100 μm for five-year-old *E. grandis* trees planted in two different regions. Bamber and Humphrey (1963) studied *E. grandis* trees and reported a significant difference between juvenile wood and mature wood (64 μm and 141 μm, respectively). Additionally, Bamber *et al.* (1982) studied the lower pore diameters of fast-growing eucalyptus trees and how they compared with trees that grow at normal rates. The results of this study showed that vessel variation between clones was explained by the juvenile and mature wood growing characteristics of the clones.

Apparent Density

The apparent density (12%) ranged from 0.40 g × cm^{-3} to 0.65 g × cm^{-3}. Only clones B, F, and G, which were the least dense, showed similar averages to those reported in the literature for the species *Eucalyptus grandis* × *Eucalyptus urophylla* (Lobão *et al.* 2004; Trevisan *et al.* 2007; Sette, Jr. *et al.* 2014). The remaining clones had higher apparent densities because the samples came from the outer wood of the trees.

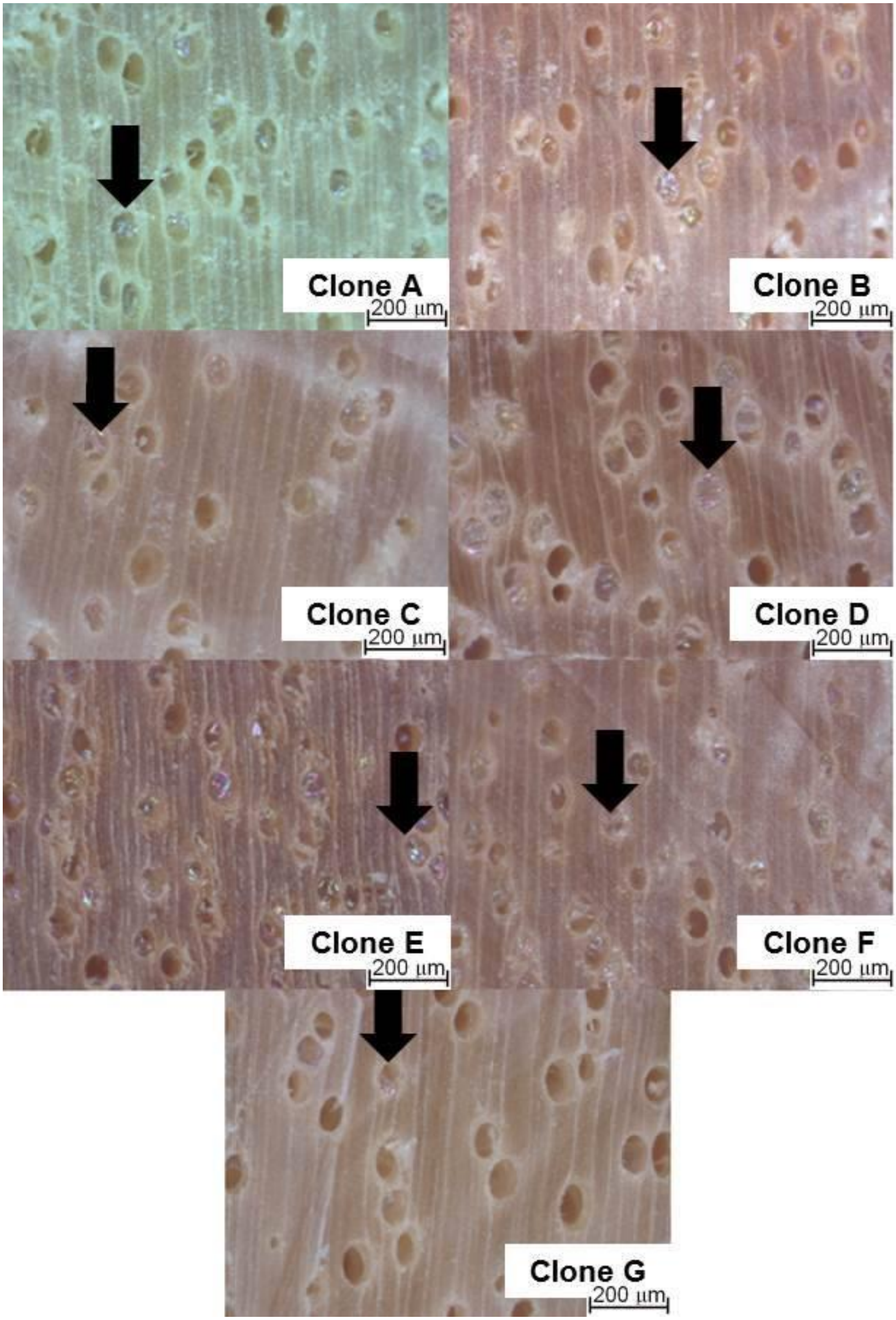

Fig. 6. Photomicrographs of the cross-sections per clone; arrows show tyloses inside the pores

Queiroz *et al.* (2004) reported apparent density values between 0.447 g × cm^{-3} and 0.552 g × cm^{-3} for *E. grandis* × *E. urophylla* wood. Santos and Sansígolo (2007) reported apparent density values between 0.44 g × cm^{-3} and 0.51 g × cm^{-3} for *E. grandis* × *E. urophylla* wood. This may have been related to the effect of hybridization, the different genetic materials of the clones, and the various factors that influence the density, *e.g.*, tree age, planting site, and timber sampling position.

Table 2. Apparent Density, Pore Characteristics, and Drying Defects Averages

Clones	Apparent density	Pore		Drying Defects	
		Diameter (μm)	Frequency ($n \times mm^{-2}$)	Cupping (%)	End Splits (%)
A	0.68 AB (6.23)*	129.73 *B* (5.37)	7.71 *A* (10.27)	2.96 *BC* (15.59)	27.02 *BC* (29.77)
B	0.51 BC (5.50)	129.91 *B* (8.72)	7.19*B* (4.87)	3.05 *BC* (13.49)	26.08 *BC* (27.90)
C	0.65 A (1.44)	129.48 *B* (11.74)	6.01 *C* (13.77)	2.59 *C* (13.92)	38.77 *AB* (48.73)
D	0.59 BC (13.01)	154.90 *A* (9.32)	7.75 *A* (12.48)	1.94 *D* (19.55)	13.13 *C* (36.76)
E	0.58 AB (13.56)	122.89 *B* (15.35)	7.64 *AB* (16.10)	2.50 *CD* (10.37)	12.79 *C* (31.62)
F	0.50 D (4.30)	131.29 *B* (10.67)	5.98 *C* (10.37)	3.91 *A* (15.44)	23.44 *C* (25.63)
G	0.52 CD (7.94)	139.59 *AB* (9.38)	5.78 *C* (9.81)	3.28 *AB* (14.83)	43.50 *A* (20.92)
Average	0.57	133.95	6.86	2.89	26.24

Note: Averages followed by the same vertical letter do not differ statistically from each other according to Tukey's test (P > 0.05)
*Numbers in parenthesis are the coefficient of variation (%).

For the apparent density (12%), the Kruskal-Wallis' H test was performed, and there was a significant difference between the medians of the clones. The box chart (Fig. 7) was used for the graphical analysis of the clustering of clones by their apparent density. The boxes of the clones that are comprised in the same pair of parallel lines have medians that do not differ significantly from each other (P > 0.05).

Four groups of the apparent density (12%) among the clones were identified. First, were clones A and C with the highest densities, next were clones D and E, then clone G, and lastly clones B and F with the lowest densities. For industrial practice, the heterogeneity of the density between the boards was undesirable for the composition of the drying load, and it was one of the factors inherent to wood that influenced the drying rate the most. Therefore, boards with different densities additionally had different drying rates during the process, which caused complications with the drying quality.

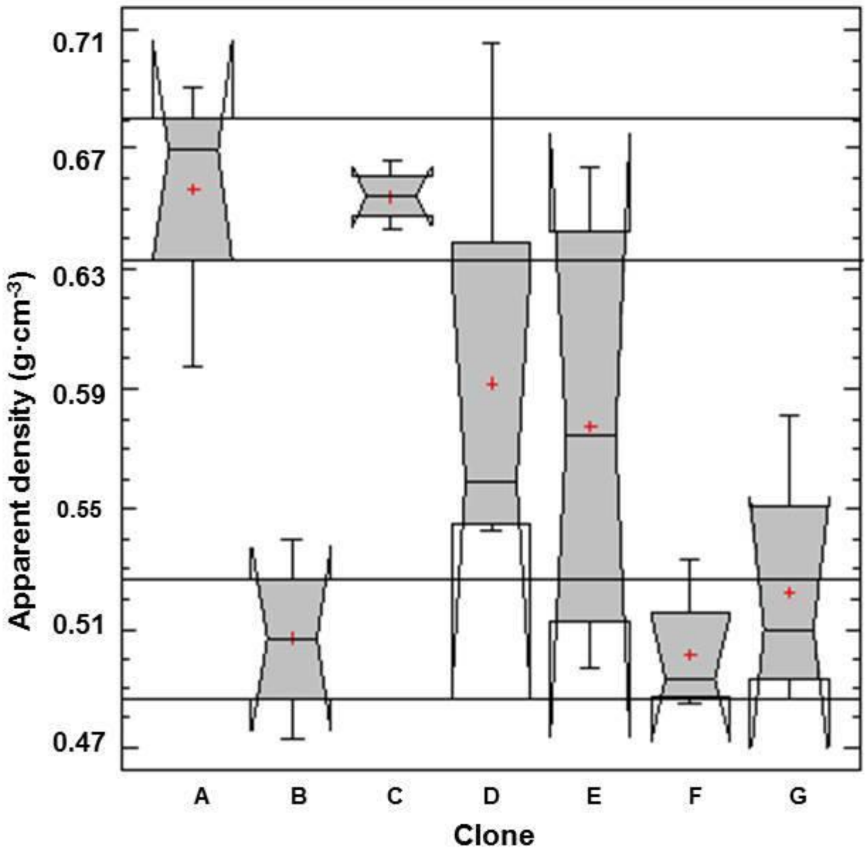

Fig. 7. Box chart for wood apparent density per clone

Drying Defects

The averages for the cupping ranged between 1.49% and 3.52% with an overall average of 2.89%, and there was a significant difference between the clones ($P < 0.05$). Clones D and E had the lowest averages of cupping after the drying process, while the boards from clones F and G had the highest cupping averages. Board cupping can be associated with the flatsawn breakdown process because the board shrank more on the surface away from the center of the wood causing the board to curl.

Board end splits ranged between 8.3% and 52.6% with an overall average of 26.2%. There was a significant difference in the board end splits between the clones. Clones D, E, and F exhibited lower rates at the end of the air-drying process. Clones G and C had the highest averages of board end splits. Rocha and Tomaselli (2002) reported values between 14.6% and 23.5% for the *E. grandis* dried board end splitting, which is similar to values found in this study. Many authors have reported end splits above 40% (Del Menezzi 1999; Rocha 2000; Haselein *et al.* 2004).

Relationship between Variables

According to Table 3, there was a high and direct correlation between the clones used and the drying rate, drying time, and initial moisture content. These correlations occurred due to the different initial moisture content in the wood that the clones possessed. A higher initial moisture content implied higher drying rates due to a larger amount of free water and the need for longer drying times.

Table 3. Relationship Between the Variables

	Clone	Drying Rate	Pore Diameter	Pore Frequency	Apparent Density (12%)	Drying Time	Initial Moisture Content	Final Moisture Content	End Splits	Cupping
Clone	1	0.819 (< 0.001) *	-0.044 (0.840)	-0.108 (0.614)	-0.818 (< 0.001)	0.691 (0.002)	0.836 (< 0.001)	0.002 (0.993)	-0.053 (0.807)	0.408 (0.048)
Drying Rate		1	-0.164 (0.444)	-0.266 (0.210)	-0.828 (0.0001)	0.721 (< 0.001)	0.993 (0.0001)	-0.022 (0.298)	0.023 (0.9133)	0.482 (0.0170)
Pore Diameter			1	-0.375 (0.071)	0.241 (0.258)	-0.142 (0.508)	-0.13269 (0.5365)	0.291 (0.167)	-0.159 (0.458)	-0.166 (0.438)
Pore Frequency				1	-0.150 (0.485)	-0.108 (0.614)	-0.263 (0.214)	0.068 (0.753)	0.067 (0.754)	-0.361 (0.083)
Apparent Density (12%)					1	-0.659 (0.001)	-0.826 (< 0.001)	0.157 (0.465)	-0.112 (0.602)	-0.369 (0.076)
Drying Time						1	0.766 (< 0.001)	0.259 (0.221)	-0.019 (0.929)	0.255 (0.230)
Initial Moisture Content							1	-0.107 (0.617)	-0.009 (0.966)	0.444 (0.030)
Final Moisture Content								1	-0.278 (0.188)	-0.400 (0.053)
End Splits									1	0.337 (0.107)
Cupping										1

* Numbers in the parentheses represent the p-values

In contrast, the apparent density (12%) had a high correlation that was inversely proportional to these variables. This data corroborates the literature consulted, which states that the density is one of the properties inherent to wood that influences the drying rate the most.

An average correlation was found between the cupping and the clone, the cupping and the drying rate, and the cupping with the initial moisture content. An average correlation that was inversely proportional was found between the cupping and the frequency of pores, the cupping with the final moisture content, the cupping with the apparent density, and the frequency and diameter of the pores.

Separate analyses of the capillary and hygroscopic drying rates and the verification of factors that influence both variables are suggested for future studies.

CONCLUSIONS

1. The air-drying period to reach the FSP was approximately 30 days. The initial moisture content of wood significantly varied between the clones, although there was no significant variation in the final moisture content of the pieces. The clones exhibited similar drying curves.
2. Although no significant difference was identified among the clones for the average time to reach the FSP, there was a maximum absolute difference of approximately 14 days between clones, which must be considered when using the industry practice of combined drying.
3. The effect of the genetic material on the apparent density of the clones was significant. It was possible to separate the clones into four groups. Even from the same genotype, a load of boards made from *E. grandis* × *E. urophylla* exhibited heterogeneity in the drying rate due to factors inherent in the wood, especially the apparent density.
4. The effect of the apparent density on the drying rate of the clones was negative, and approximately 70.5% of the drying rate was explained by the apparent density. Denser pieces exhibited a lower drying rate. For a more homogeneous natural drying, it is recommended that the composition of the stacks uses pieces with the same apparent density and, therefore, have a similar initial moisture content.
5. In addition, the clones varied due to drying defects. Clone D had the lowest amount of cupping and Clone F had the highest amount of cupping. The Clones D, E, and F significantly presented the lowest amount of end splits, and Clone G had the highest rate of end splits. The air-drying process can be used to release any free water from the eucalyptus wood, which is commonly used as pre-kiln drying process to avoid drying defects that may occur during subsequent kiln drying, and to reduce kiln drying costs.

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