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INFLUENCE OF SOIL TYPE ON WOOD DENSITY AND MEAN ANNUAL INCREMENT IN TWO COMMERCIAL *Eucalyptus* CLONES[1]

INFLUÊNCIA DO TIPO DE SOLO NA DENSIDADE DA MADEIRA E INCREMENTO MÉDIO ANUAL EM DOIS CLONES COMERCIAIS DE *Eucalyptus*

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ABSTRACT - In forest plantations, the productive potential of a given site results from the interaction between genetic materials and environmental conditions. Both are fundamental factors for wood quality and Mean Annual Increment. Knowing the performance of different *Eucalyptus urophylla* commercial clones under different soil conditions is important for forest planning. Our objective is to evaluate the influence of soil types on Wood Basic Density and Mean Annual Increment - MAI in two *E. urophylla* clones. We analyzed the Wood Basic Density of 3- to 8-year-old trees and MAI from two clones grown in four soil types in 14 localities of São Paulo state. ANOVA and Tukey test at 5% probability were performed to test the effect of soil type on Wood Basic Density and MAI. Linear and exponential regression equations were performed between Wood Basic Density x MAI and between MAI x Clay Content, respectively. In general, some soils showed significant differences in Wood Basic Density, possibly from climatic variation among sites. Also, the MAI increased exponentially with increase of Soil Clay Content (up to about 25 to 35% of clay), but no correlation was observed between MAI and Wood Density.

Keywords: *Eucalyptus*; Forestry; Reforestation Species; Tree growth; Wood properties; Wood quality.

RESUMO - Nas plantações florestais, o potencial produtivo de um determinado local resulta da interação entre materiais genéticos e condições ambientais. Ambos são fatores fundamentais para a qualidade da madeira e Incremento Médio Anual. O conhecimento do desempenho de diferentes clones comerciais de *Eucalyptus urophylla* em diferentes condições do solo é importante para o planejamento florestal. O objetivo foi avaliar a influência dos tipos de solo na densidade básica da madeira e no Incremento Médio Anual - MAI em dois clones de *E. urophylla*. Analisou-se a densidade básica da madeira de árvores de 3 a 8 anos e o MAI de dois clones cultivados em quatro tipos de solo em 14 localidades do estado de São Paulo. Os testes de ANOVA e Tukey, com 5% de probabilidade, foram realizados para testar o efeito do tipo de solo na densidade básica da madeira e no MAI. Equações de regressão linear e exponencial foram realizadas entre densidade básica da madeira x MAI e entre MAI x teor de argila, respectivamente. Em geral, alguns solos apresentaram diferenças significativas na densidade básica da madeira, possivelmente devido à variação climática entre os locais. Além disso, o MAI aumentou exponencialmente com o aumento do teor de argila do solo (até cerca de 25 a 35%), mas não foi observada correlação entre o MAI e a densidade da madeira.

Palavras-chave: Eucalipto; Silvicultura; Espécies de reflorestamento; Crescimento de árvores; Propriedades da madeira; Qualidade da madeira.

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1 INTRODUCTION

Eucalyptus stands out as the main source of pulp and paper in Brazil owing to its high growth rate and good adaptation to Brazilian environmental conditions. With the expansion of forest plantations in Brazil, the development of genetic improvement programs for cellulose production has grown, and among the innumerable objectives of these programs, a key target is the improvement of wood density (Hein et al., 2012), essentially because it directly affects yield during pulp production, as well as cellulose quality, which, in turn, influences digester productivity, wood volumetric consumption and tailings content (Silva Junior et al., 1993; Silva et al., 1997; Gava, 2005). Wood density strongly influences the pulping process and cellulosic pulp quality (Fantuzzi Neto, 2012; Feuchard, 2015). Gomide et al. (2010) observed that higher wood densities provided lower specific consumption of wood, which favored cellulose production in the digester and the maintenance of chip pile volumes in factories. Thus, wood density could easily serve as an indicator of the specific consumption of wood in the cellulose and paper industry (Queiroz et al., 2004), a metric useful in predicting the quantity of reagents in chips. Therefore, the estimation of wood density turns out to be extremely important for the cellulose sector (Gallo et al., 2018).

In addition, the precise assessment of wood characteristics helps in choosing appropriate genetic materials for specific conditions of climate, soil, growth, wood quality and wood destination (Sturion et al., 1987; Borges, 2012). Several studies have found an association between growth rate and wood quality and edaphoclimatic conditions (Ferreira and Kageyama, 1978; Marcati et al., 2001; Gava and Gonçalves, 2008; Gouvea et al., 2012; West, 2014; Sette Junior et al., 2016). Other studies also demonstrated that the environmental quality of the area directly affects forest productivity. More specifically, the increase in growth rate influences the formation of juvenile tissue, altering fiber features, thus causing differences in basic density (Larson et al., 2001). Santana et al. (2012) also reported that basic density of *Eucalyptus urophylla* increased with age, with marked differences between clones, indicating strong genetic control for this character. Strong age-age correlation for wood density at clone level was also reported for *E. grandis* (Osorio et al., 2003).

Breeders face the challenge of achieving reasonable genetic gains in both productivity, which is commonly measured by mean annual increment, and wood density. Even more difficult is the identification of clones that are adapted to the environmental conditions of planting sites. As well discussed in the classical book of Zobel and Talbert (1984), the common sense is that growth rate is inversely proportional to wood density. However, for *Eucalyptus* species, the published results are inconsistent. Indeed, some have reported a significant negative correlation between these characteristics (McDonald et al., 1997; Costa and Silva et al., 2009, Hein et al., 2012), while other authors found no correlation (Muneri and Raymond, 2000; Gallo et al., 2018). Complicating the matter even more, the same studies found that varying environmental conditions at planting sites could differentially affect growth rate and wood density.

Therefore, it is in this context that we seek to analyze and discuss the influence of soil type on Wood Basic Density and Mean Annual Increment in two clones of *Eucalyptus urophylla* S.T. Blake. Here, we aimed to i) characterize Wood Density in three age classes, ii) measure the Mean Annual Increment in relation to soil type and iii) correlate MAI with soil Clay Content and wood density.

2 MATERIAL AND METHODS

2.1 Study sites

The experimental plantations of *Eucalyptus urophylla* S.T. Blake evaluated in this study are located on the properties of International Paper Brasil, in different municipalities of São Paulo state, southeastern Brazil (Figure 1, Table 1). The fifteen stands were planted under varying climatic conditions and in four soil types (Table 1): Quartzarenic Neossol (RQ), Red Latosol (LV), Red Yellow Latosol (LVA) and Red Yellow Argisol (PVA), coded in accordance with the Brazilian System of Soil Classification SiBCS (EMBRAPA, 2019). The correspondence of SiBCS classes (Santos et al., 2018) with WRB/FAO and with Soil Taxonomy is presented in Table 2. Soil types and geographic locations per site were obtained from the International Paper Brasil database. Average precipitation data were obtained from the National Institute of Meteorology (National Institute of Meteorology, 2019).

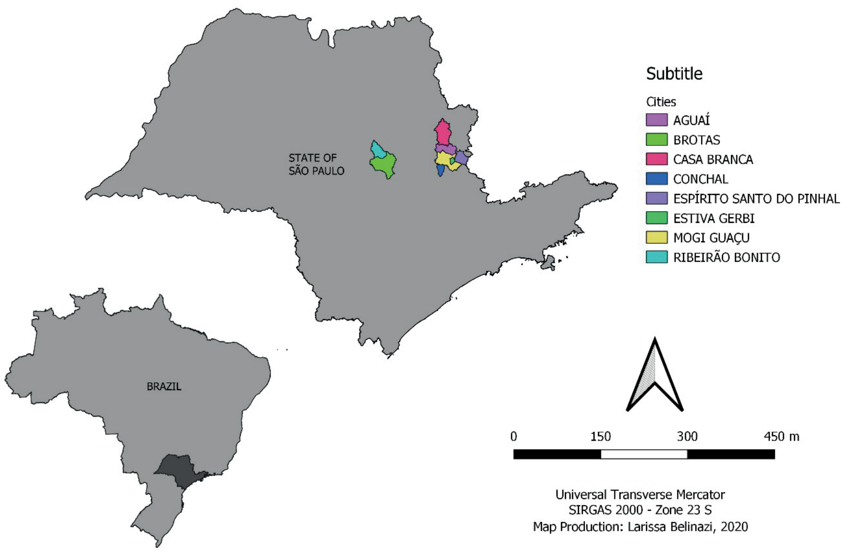

Figure 1. Location of experimental stands of *Eucalyptus urophylla* in São Paulo state, Brazil.

Figura 1. Localização dos talhões experimentais de *Eucalyptus urophylla* no estado de São Paulo, Brasil.

Table 1. Geographic and edaphoclimatic information of the evaluated *Eucalyptus urophylla* experimental stands.

Tabela 1. Informações geográficas e edafo-climáticas dos talhões experimentais de *Eucalyptus urophylla* avaliados.

Municipality	Farm	Soil type	Longitude	Latitude	Altitude	Mean annual precipitation (mm)
Espírito Santo do Pinhal	Paineiras	PVA	46W 54’ 36”	22S 10’ 52”	660	888
Estiva Gerbi	Nossa Senhora das Graças	PVA	47W 57’ 29”	22S 16’ 27”	647	1337
Mogi Guaçu	São Marcelo	PVA	47W 48’ 21”	22N 14’ 25”	647	1337
Mogi Guaçu	Nova Louzã	PVA	47W 53’ 52”	22N 12’ 31”	647	1337
Conchal	Ouro Verde	LVA	46W 55’ 45”	22S 19’ 04”	684	1273
Casa Branca	Mairiporã	LVA	47W 53’ 16”	21S 02’ 23”	684	1273
Mogi Guaçu	Mogi Guaçu	LVA	46W 56’ 53”	22S 22’ 01”	591	1300
Mogi Guaçu	Santa Terezinha	LVA	46W 27’ 28”	22S 18’ 21”	870	1531
Mogi Guaçu	Nossa Senhora Aparecida	LVA	46W 30’ 22”	22S 18’ 52”	622	1365
Casa Branca	Areia Branca	LVE	47W 50’ 21”	22S 00’ 53”	590	1589
Aguaí	Gigante	LVE	46W 51’ 09”	22S 04’ 38”	617	1589
Brotas	Santa Fé C	RQ	48W 21’ 44”	22S 02’ 14”	617	1344
Brotas	Santa Fé A	RQ	48W 23’ 41”	22S 30’ 18”	617	1344
Brotas	Santa Fé B	RQ	48W 00’ 13”	22S 21’ 25”	617	1344
Ribeirão Bonito	Santa Fé H	RQ	48W 45’ 19”	22S 16’ 56”	617	1344

PVA: Red Yellow Argisol; LVA: Red Yellow Latosol; LVE: Red Latosol; RQ: Quartzarenic Neossol
PVA: Argisolo Vermelho Amarelo; LVA: Latosolo Vermelho Amarelo; LVE: Latosolo Vermelho; RQ: Neossolo Quartzarênico.

Table 2. Correspondence of SiBCS soil classes with WRB/FAO and Soil Taxonomy.

Tabela 2. Correspondência entre classes de solo do SiBCS, com WRB/FAO e com a Taxonomia do solo.

Classification system	Soil types			
SiBCS	Quartzenic Neossol (RQ)	Red Yellow Latosol (LVA)	Red Latosol (LVE)	Red Yellow Argisol (PVA)
WRB/FAO	Arenosols	Ferralsols	Ferralsols	Lixisols
Soil Taxonomy	Entisols (Quartzip-samments)	Oxisols	Oxisols	Ultisols

All 15 stands are commercial plantations of *E. urophylla* with the same 3.0 × 2.5 m spacing and identical silvicultural treatments, including fertilization, as well as ant and weed control, according to International Paper Brasil standard protocols. We evaluated Mean Annual Increment - MAI and wood basic density in two *E. urophylla* clones grown in four soil types. Estimations of MAI per clone and per site and clay content per stand were provided by International Paper Brasil for statistical analyses. We did not report detailed values for MAI per clone or MAI per site because these data are under proprietary control.

2.2 Wood Basic Density

We measured basic density in trees from ages 3 to 8 years. We selected three trees from each plot, totaling 197 samples, 91 from clone 1 and 106 from clone 2. For each stand, selected trees had Diameter at Breast Height - DBH within one standard deviation of the average DBH estimated in the inventory. Samples were taken at positions 25%, 50% and 75% of trunk commercial height, an acceptable range is 28 to 32m and then chips were obtained, thus forming a composite sample (Figure 2). We used the Maximum Moisture Content method NBR 11941 (ABNT, 2003) to determine basic density and kiln-dried mass at 105 ± 2 °C per unit of maximum volume of wood in discs or chips.

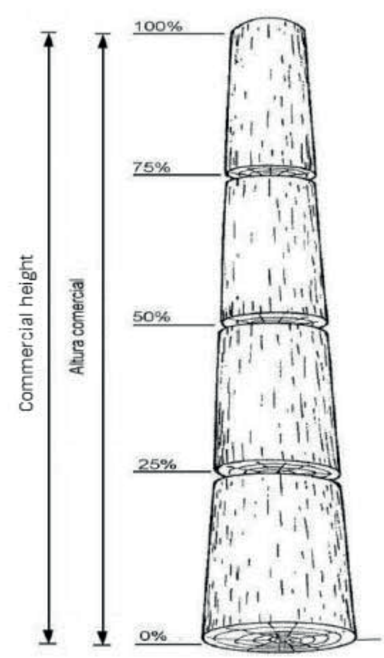

Figure 2. Schematic representation of disc collection in each tree. Source: (adapted from Costa, 2011).

Figura 2. Esquema de coleta de discos em cada árvore. Fonte: (adaptado de Costa, 2011).

2.3 Mean Annual Increment - MAI

MAI estimations were provided by International Paper Brasil through annual inventories that measured Height - H and DBH over the years. In inventories, 9 ha plots were assembled within each stand where DBH was measured with a caliper, and height was measured with a Vertex IV hypsometer (Pacforest Supply Co., Springfield, OR). Tree volumes were calculated based on the formula proposed by Schumacher-Hall (Batista et al., 2014), following Eq. 1.

$$Vol = \exp(b0 + b1 * DBH + b2 * H) \qquad \text{Eq.1}$$

where $b0$, $b1$ and $b2$ are confidential information from International Paper, and H is tree height (m).

The volume per hectare was calculated by multiplying the number of plants per hectare in each stand by the average tree volume. Then, the MAI was calculated by dividing volume per hectare by the age of planting. MAI was estimated from age 3 to 8 years.

2.4 Data Analyses

We initially undertook descriptive statistical analysis and used boxplots to detect outliers for the variables MAI and basic density. Thus, values 1.5 times higher than the 3rd quartile and values 1.5 times lower than the 1st quartile were considered outliers and were excluded from the analysis. Shapiro-Wilk tests were performed to check the distribution of data, and when a normal distribution was not observed, data were square-root transformed. To evaluate the variation of basic density with age, we grouped data into three age classes, 3-4 years, 5-6 years and 7-8 years. Then parametric one-way analysis of variance (ANOVA) and Tukey's post-hoc test was performed to compare ages for each clone. Subsequently, for each age class, we compared clones with t-tests. To evaluate the variation of basic density and MAI with soil type, we used data from the 5-6-year age class for both clones. For that, we used ANOVA and Tukey's post-hoc test. Pearson's correlations and simple regressions between MAI and clay content and between wood density and MAI were carried out.

3 RESULTS

3.1 Wood Density

Wood Basic Density increased with age, varying from 468 $kg.m^{-3}$ at 3 to 4 years old to 518 $kg.m^{-3}$ at 7 to 8 years old for clone 1 ($F = 47.381$, $P < 0.001$) and from 472 $kg.m^{-3}$ at 3 to 4 years old to 536 $kg.m^{-3}$ 7 to 8 years old for clone 2 ($F = 65.152$, $P < 0.001$) (Figure 3a-b).

When comparing clones of the same age, significant differences were observed only in trees at 7 to 8 years old. Clone 2 presented denser wood (536.6 $kg.m^{-3}$) than clone 1 (520.5 $kg.m^{-3}$) at this age (Figure 4).

Both clones presented higher density in LVA soil (504 and 512 $kg.m^{-3}$ for clone 1 and clone 2, respectively), while clone 2 had a lower density when grown in PVA soil (Figure 5). Except for PVA, where both clones had similar densities, clone 2 showed higher density than clone 1 in all soil types (Figure 6).

3.2 Mean Annual Increment

For both clones, a variation in MAI according to soil types was observed with RQ showing the lowest growth (Figure 7).

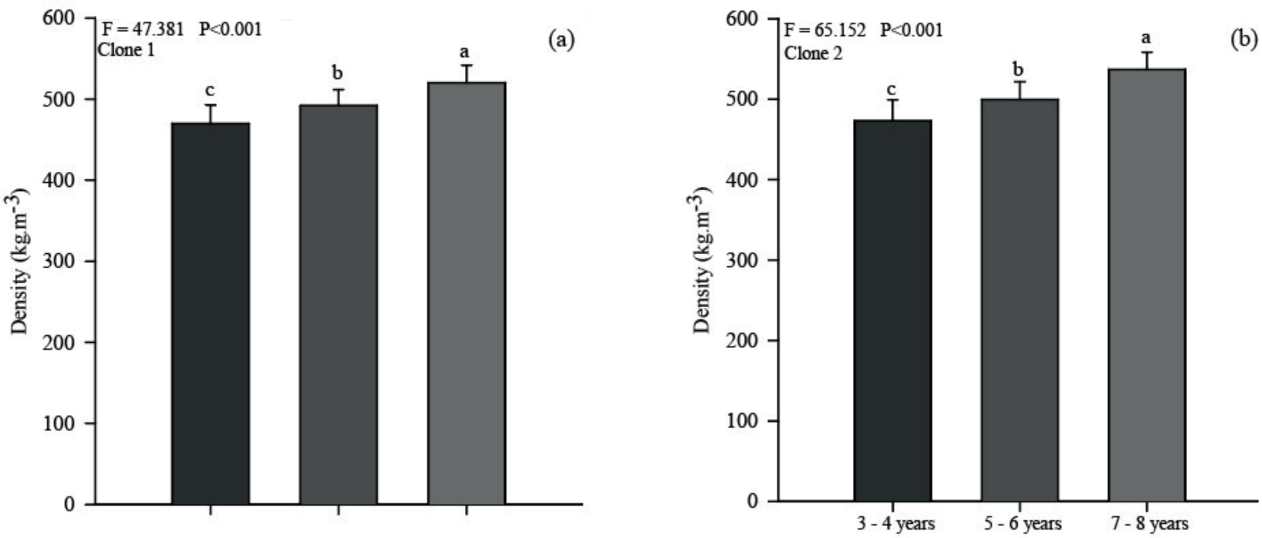

Figure 3. Comparison of basic density in different age classes (3-4, 5-6 and 7-8 years) in Clone 1 (a) and Clone 2 (b) of *Eucalyptus urophylla*. Different letters indicate that they statistically differ by Tukey's test ($p < 0.05$). Bars represent the standard deviations.

Figura 3. Comparação da densidade básica nas diferentes classes de idade (3-4, 5-6 e 7-8 anos) no Clone 1 (a) e Clone 2 (b) de *Eucalyptus urophylla*. Letras distintas diferem entre si estatisticamente pelo teste de Tukey ($p < 0,05$). Barras representam o desvio padrão.

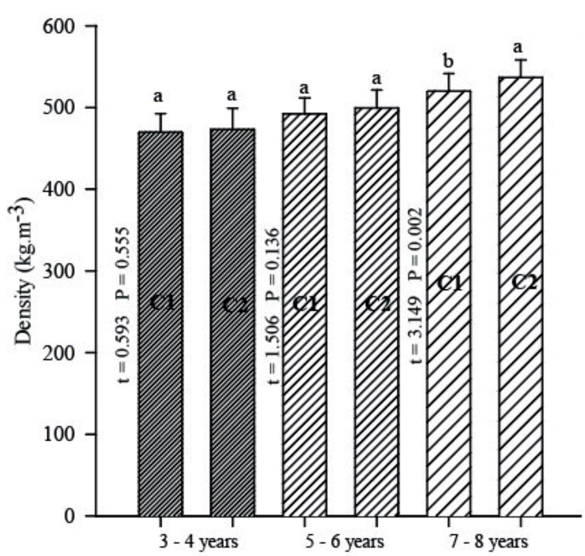

Figure 4. Comparison of basic density between two clones (C1 and C2) in *Eucalyptus urophylla* in different age classes (3-4, 5-6 and 7-8 years). Same letters indicate that the two clones do not differ statistically by t test. Probability values are represented alongside the columns. Bars represent the standard deviations.

Figura 4. Comparação da densidade básica entre os dois clones (C1 e C2) de *Eucalyptus urophylla* em diferentes classes de idade (3-4, 5-6 e 7-8 anos). Letras iguais indicam que os dois clones não diferem estatisticamente pelo teste t, os valores de probabilidade são representados ao lado das colunas. Barras representam o desvio padrão.

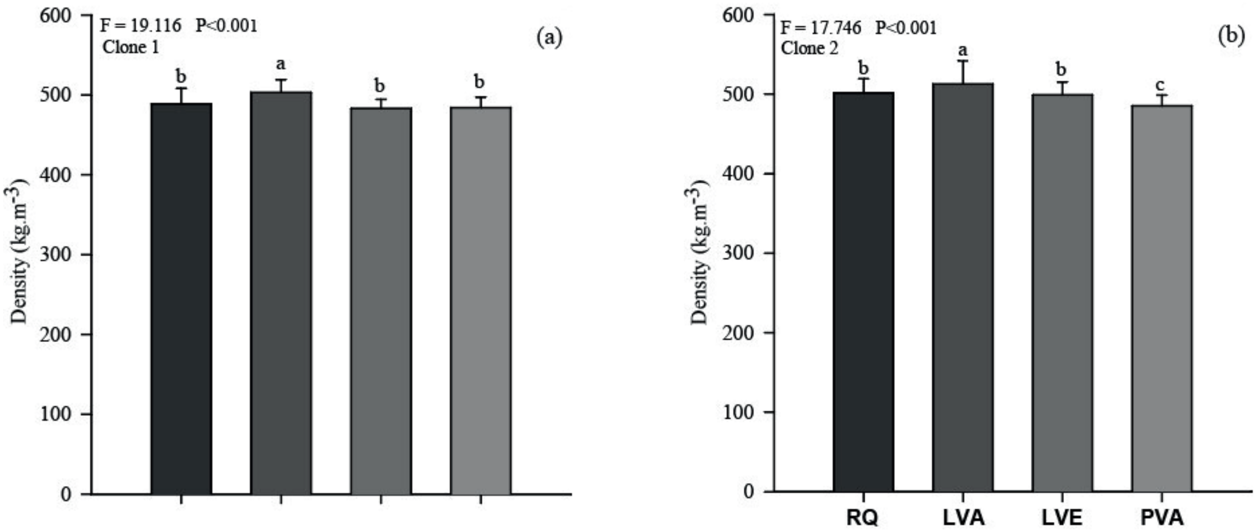

Figure 5. Comparison of basic density in four soil types in Clone 1 (a) and Clone 2 (b) of *Eucalyptus urophylla* at 5 to 6 years. Same letters indicate that the columns do not differ statistically by the Tukey test (p < 0.05). Bars represent the standard deviations. Soil types are RQ: Quartzarenic Neossol; LVA: Red Yellow Latosol; LVE: Red Latosol and PVA: Red Yellow Argisol.

Figura 5. Comparação da densidade básica nos quatro tipos de solo no Clone 1 (a) e Clone 2 (b) de *Eucalyptus urophylla* aos 5-6 anos de idade. Letras iguais indicam que as colunas não diferem entre si estatisticamente pelo teste de Tukey (<0,05). Barras representam o desvio padrão. Os tipos de solo são: RQ: Neossolo Quartzarênico; LVA: Latosolo Vermelho Amarelo; LVE: Latosolo Vermelho e PVA: Argisolo Vermelho Amarelo.

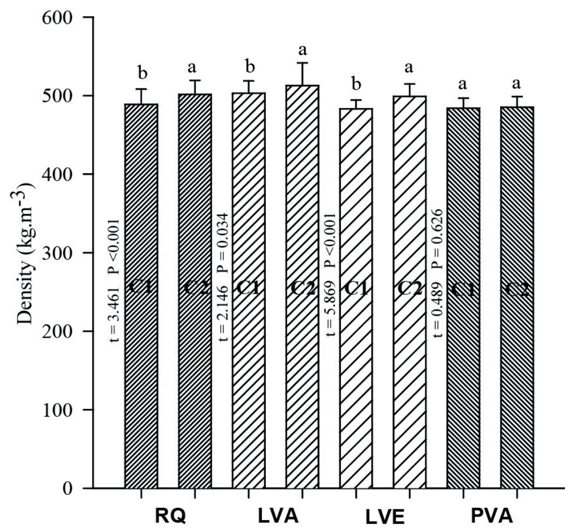

Figure 6. Comparison of basic density between clones 1 (C1) and 2 (C2) in *Eucalyptus urophylla* at 5 to 6 years in different soil types. Same letters indicate that the clones do not differ statistically by t test. Probability values are represented alongside the columns. Bars represent standard deviations. Soil types are RQ: Quartzarenic Neossol; LVA: Red Yellow Latosol; LVE: Red Latosol and PVA: Red Yellow Argisol.

Figura 6. Comparação da densidade básica entre os clones 1 (C1) e 2 (C2) em *Eucalyptus urophylla* aos 5-6 anos de idade nos diferentes tipos de solo. Letras iguais indicam que os clones não diferem estatisticamente pelo teste t, os valores de probabilidade são representados ao lado das colunas. Barras representam o desvio padrão. Os tipos de solo são: RQ: Neossolo Quartzarênico; LVA: Latosolo Vermelho Amarelo; LVE: Latosolo Vermelho e PVA: Argisolo Vermelho Amarelo.

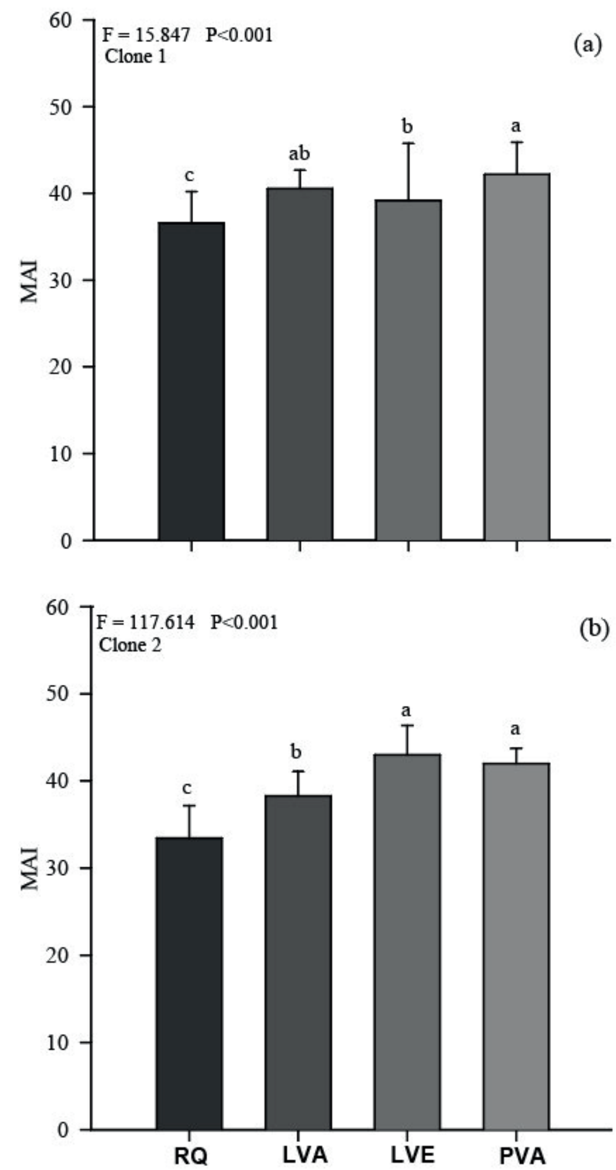

Figure 7. Comparison of Mean Annual Increment - MAI of *Eucalyptus urophylla* Clone 1 (a) and Clone 2 (b) at 5 to 6 years old grown in different soil types. Same letters indicate that the clones do not differ statistically by the Tukey test (<0.05). Bars represent standard deviations. Soil types are RQ: Quartzarenic Neossol; LVA: Red Yellow Latosol; LVE: Red Latosol and PVA: Red Yellow Argisol.

Figura 7. Comparação do Incremento Médio Anual - IMA no Clone 1 (a) e Clone 2 (b) de *Eucalyptus urophylla* aos 5-6 anos de idade. Letras iguais indicam que os clones não diferem entre si estatisticamente pelo teste de Tukey (<0,05). Barras representam o desvio padrão. Os tipos de solo são: RQ: Neossolo Quartzarênico; LVA: Latosolo Vermelho Amarelo; LVE: Latosolo Vermelho e PVA: Argisolo Vermelho Amarelo.

Clone 1 and clone 2 had similar growth rates in PVA soil, but clone 1 grew better in RQ and LVA than clone 2 (Figure 8). Higher MAI value in clone 2 in comparison with clone 1 was observed only when they were grown in LVE (Figure 8).

It was observed a positive relationship between MAI and Clay Content (Figure 9).

It was not observed significant relationships between Wood Density and MAI in the two *E. urophylla* clones (Figure 10).

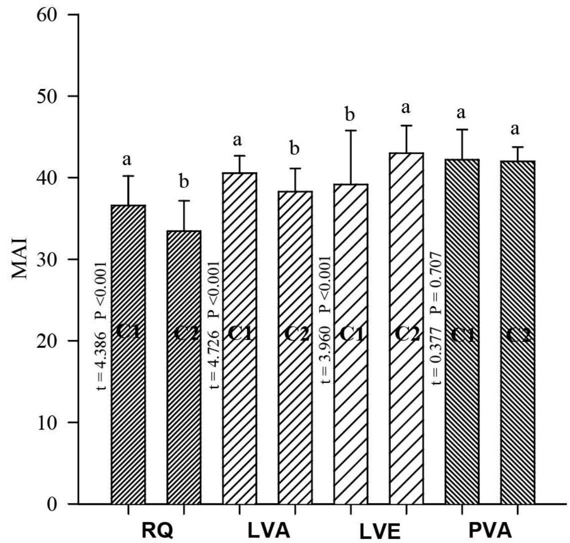

Figure 8. Comparison of Mean Annual Increment – MAI between clones 1 (C1) and 2 (C2) in *Eucalyptus urophylla* at 5 to 6 years in different soil types. Same letters indicate that the clones do not differ statistically by t test. Probability values are represented alongside the columns. Bars represent standard deviations. Soil types are RQ: Quartzarenic Neossol; LVA: Red Yellow Latosol; LVE: Red Latosol and PVA: Red Yellow Argisol.

Figura 8. Comparação do Incremento Médio Anual - IMA entre os clones 1 (C1) e 2 (C2) em *Eucalyptus urophylla* aos 5-6 de idade nos diferentes tipos de solo. Letras iguais indicam que os clones não diferem estatisticamente pelo teste t, os valores de probabilidade são representados ao lado das colunas. Barras representam o desvio padrão. Os tipos de solo são: RQ: Neossolo Quartzarênico; LVA: Latosolo Vermelho Amarelo; LVE: Latosolo Vermelho e PVA: Argisolo Vermelho Amarelo.

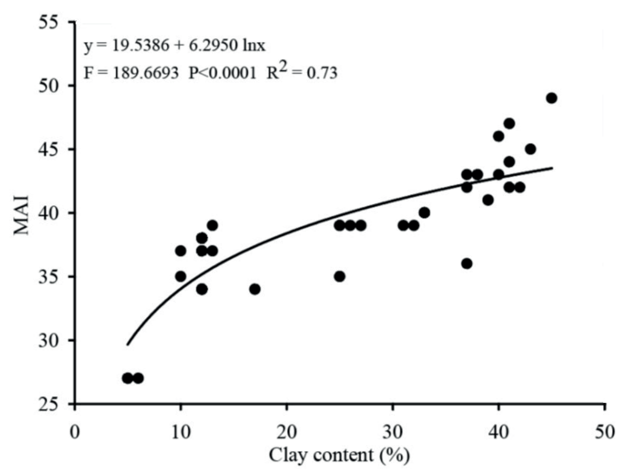

Figure 9. Relationship of Mean Annual Increment - MAI as a function of Clay Content in Eucalyptus urophylla at 5 to 6 years.

Figura 9. Relação do Incremento Médio Anual - IMA em função do Teor de Argila em Eucalyptus urophylla aos 5-6 anos de idade.

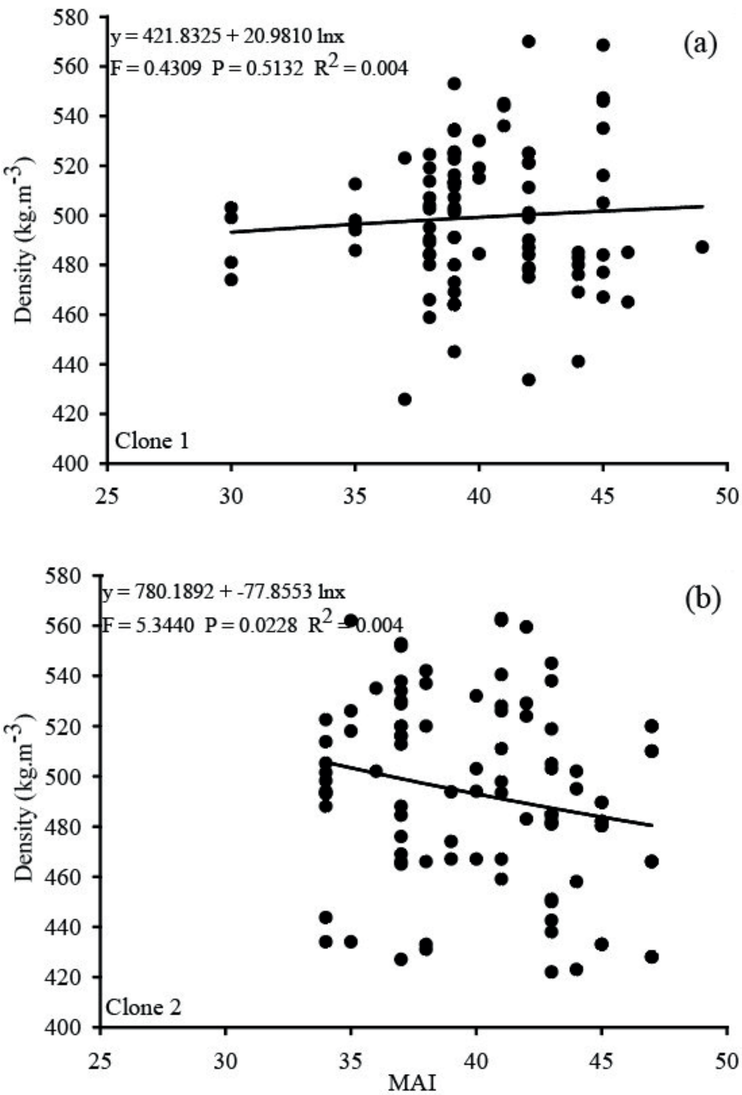

Figure 10. Relationship of Mean Annual Increment - MAI as a function of Basic Density in clone 1 (a) and clone (b) of *Eucalyptus urophylla* at 5 to 6 years.

Figura 10. Relação do Incremento Médio Anual - IMA em função da Densidade Básica no clone 1 (a) e clone 2 (b) em *Eucalyptus urophylla* aos 5-6 anos de idade.

4 DISCUSSION

Wood basic density was higher in 7 to 8-year-old trees. Sette Júnior et al. (2012) also observed a significant increase in *Eucalyptus grandis* basic density from the 2nd to the 6th year. This increase in density occurs as the adult wood is formed, mainly from changes in vascular cambium, such as an increase in fiber wall thickness and reduction in vessel density (Tomazello Filho, 1985; Trugilho et al., 1996; Castro Silva et al., 2004). Significant variation in basic density according to soil type was verified. Higher basic density was observed in LVA soil. In the pulp and paper industry, assessments of selected basic density must be very accurate about chip impregnation and process yield. Such assessments are usually associated with quality characteristics and physical strength of the pulp. Therefore, low density is considered a value close to 447 kg.m^{-3}, while high density is considered a value close to 552 kg. m^{-3} (Queiroz et al., 2004).

Density variation by soil type was higher in clone 2, the highest ones being related to LVA, in both clones and lowest values in PVA of clone 2. Clone 2 was higher in density values in all soil types evaluated. The largest variations of standard deviation occurred in LVA soil for both clones. This variation may be associated with textural variation presented within same soil unit, as in LVA and PVA. The sandy texture seems to favor wood density due to lower annual growth rate presented. This textural variation presented in LVA displaces the data, sometimes approaching RQ (sandy), due to medium thick texture of LVA, sometimes due to finer average texture of LVA. The same must occur with PVA and its textural variation within the soil class. Mean annual increment, on the other hand, behaved with higher values in LV, which presents a more homogeneous texture (average), in case of clone 2, in relation to LVA (medium to clayey texture) and PVA (sandy / medium and medium texture). The lower increase remains with sandy soils (RQ). For clone 1, the medium and clayey textures, from deepest and most homogeneous soils (LV and LVA), highlight higher values of mean annual increment. The relationship of these wood attributes with soil attributes can be indicating variations in accumulation and in disposition of water and nutrients during the year, (texture and structure of soil, they can indicate porosity and friability of these materials), that would affect directly in tree growth.

The result of our study differs from Gava and Gonçalves (2008) who reported that basic density of *Eucalyptus grandis* trees at 6.5 to 7 years old did not vary with soil types, different result may be due to they are different species. However, the authors reported that clay content, which influences water holding capacity, was the soil characteristic that most affected productivity and wood quality. Wood density may be influenced by soil types because of differences in some physical and/or physical-hydric characteristics, such as texture, homogeneous or heterogeneous arrangement of layers in depth, structure and porosity (Gava, 2005). Frederico (2009) did not find any difference in wood density in 7-year-old *Eucalyptus* sp. clones between regions, despite the variation in soil fertility and rainfall across regions. Environmental conditions other than soil type may have influenced basic density in our study. That is, other edapho-bioclimatic characteristics, such as texture, retention and availability of water may have affected wood density.

Mean Annual Increment - MAI also varied according to the soil type. For both clones, the worst MAI occurred in stands established in RQ soil. According to Zuo et al. (2008), Quartzarenic Neossols (RQ) in the municipalities of Brotas and Ribeirão Bonito in our study (Table 1) present low water and nutrient holding capacity and high erodibility, and such soils are, therefore, considered ecologically fragile. RQ also presents sand or sand texture up to 2 m deep and a clay content of less than 15%. Gava and Gonçalves (2008) observed that wood production in 7-year-old *Eucalyptus grandis* stands in the state of São Paulo varied with soil class and texture such that the lowest productivity was found in RQ and highest in LVA, which is very clayey. This study did find a positive correlation between MAI and clay content, a relationship that was also reported by Gava and Gonçalves (2008) and Braga et al. (1999).

According to Rocha (2018), drier locations would result in greater wood densities by the decrease in growth rate, but the author points out that this behavior can be intrinsic to each genetic material. Indeed, our study did not find a significant association between wood density and MAI (Figure 10). Rocha (2018) also did not observe that a higher wood density was associated with lower MAI in *E. urophylla* clones. Vigneron et al. (1995) drew similar conclusions, as sometimes higher MAI was associated with lower basic density, and this relationship was the inverse at other times. In *Eucalyptus grandis*, Ferreira et al. (1978) found lower basic density in more productive sites where trees exhibited greater growth potential.

For a better understanding about influences on the wood studied, some consideration of soil types is necessary. Latosols and Quartzarenic Neossols are weathered soils and present marked characteristics, such as low nutrient content, high acidity and the predominance of low activity clays (kaolinites and Fe and Al oxy-hydroxides) (Frazão et al., 2008). For our soils, according to Rossi (2017), Red -Yellow Argisol (PVA, Espírito Santo Pinhal and Mogi Guaçu regions, Table 1) texture varies from medium-sandy and medium, or medium-clayey, to abrupt medium-sandy, constituting a wide variation in infiltration-defluvium ratio (also according to the slope of the terrain). Specific water dynamics for PVA soils depends on the texture, which is quite variable. Likewise, the porosity and structure of these soils influence infiltration, retention and availability of water. Normally, these soils present low activity clay and high base saturation. Also, they may have been formed from different source materials in areas of flat to mountainous relief. Most PVA soils show an evident increase in clay in depth content (EMBRAPA, 2019). The texture of Red Latosols (LVE) and Red-Yellow Latosols (LVA, Mogi Guaçu, Aguaí and Casa Branca regions, Table 1) is sandy-clay with high levels of iron and aluminum oxides (EMBRAPA, 2006). Latosols are red, orange or yellow-colored soils, varying according to the amount and type of iron oxide present. They are very deep, friable, and porous, of variable texture, with low activity clay, and characterized as strongly weathered soils, thus presenting a very uniform morphology along the profile, with transition between horizons hardly visible (Silva et al., 2006).

In our case, LVA has a texture varying from medium to clayey, which can influence development of plants, considering that clayey soils can retain higher moisture content and, therefore, make more water available to plants, or decrease time of exposure to stress, owing to a lack of water in the system in drier periods. LV soils all exhibit medium texture, which, in theory, would provide less water than clayey soils, but more than RQ soils, even though similar to RQ data. PVA has a varied texture, some with thick sandy layers on the surface and others with medium texture. However, all soils of this class have a certain accumulation of clay in the subsurface, producing better water storage conditions, thereby providing variation in infiltration, retention and water availability. According to Rossi (2017), these conditions constitutes a wide variation of infiltration / defluvium ratio (also according to slope of terrain) and a specific water dynamic for each texture. The porosity and structure of these soils influence water infiltration, retention and availability, requiring more soil studies to better understand existing relationships.

5 CONCLUSION

Basic Wood Density from different clones is influenced in all analyzed regions, showing variations between clones and between trees of each clone, allowing us to infer that basic wood density is a property very influenced by environmental conditions, making anatomical and chemical studies necessary to understand climate x wood quality relationship. The Basic Density was higher for sandy soils, in this case, Mean Annual Increment was improved by soil attributes. For MAI, productivity is probably related to soil class and texture because both higher clay content and climatic conditions contribute to the higher growth. Based on the MAI x Wood Density correlation, for both clones, no interaction was indicated, but the highest wood density was linked to the lowest forest productivity. Clone 2 in terms of density, it is denser than clone 1 in any type of soil. Already growing only in PVA and LVE soils. Through these data the company can strategically choose the best choice of genetic material according to the interest in growth and density.

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