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EVALUATION OF EUCALYPTUS UROPHYLLA X EUCALYPTUS GRANDIS CLONES PLANTED IN TOCANTINS, AIMING AT QUALITY FOR ENERGY USE

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ABSTRACT

The world energy matrix has been questioned, as climate change, trends of decline in oil reserves, as well as political instability in producing regions have led the world to reflect on the need for important changes in its sources. Wood from planted forests presents itself as one of the solutions for a renewable source of energy. The objective of this work is to identify among the five clones of the hybrid of Eucalyptus urophylla x Eucalyptus grandis planted in Tocantins, those that produce satisfactory quality for energy use. The experiment was carried out according to a completely randomized design, with five treatments and four replications. The data were submitted to analysis of variance and, when differences were established between them, the Scott-Knott test was applied at 5% probability. The results confirmed that the five clones have adequate physical and energetic characteristics to increase energy quality. However, clones 2 and 3 stood out for presenting the best performances in the evaluations carried out.

Keywords: Bioenergy. Biomass. Clone. Energy Density.

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INTRODUCTION

The global energy matrix is still predominantly composed of the burning of fossil fuels, which represents about 80% of the total energy supply, especially oil, coal, and natural gas (IEA, 2024). However, this dependence raises significant concerns, such as pollution that contributes to climate change, declining oil reserves, and political instability in the regions that produce these resources. In view of this, there is a growing need for a change in the global energy matrix, with an increase in the share of renewable and clean sources (DUARTE; COLLICCHIO, 2020).

Unlike the global scenario, Brazil stands out for the predominance of renewable sources in its energy matrix, which represent 40.5% of the total, with agroenergy accounting for 27.1% of this share (MME, 2022), placing the country among the leaders in the sector (IEA, 2024). The use of products derived from planted forests, such as those of the genus *Eucalyptus* spp., is an important strategy to reduce dependence on fossil raw materials.

The genetic material of *Eucalyptus* spp. has been used both in the production of charcoal for the steel industry and in the generation of energy through biomass, offering alternatives to mineral coal and fuel oil (MAGALHÃES et al., 2017; SCANAVACA JÚNIOR; GARCIA, 2023).

Planted forests have several purposes, with energy use being one of the main ones. These forests are planned to maximize biomass production per area and in a short period of time, which requires the planting of a large number of trees per hectare and short growth cycles (IEE/USP, 2019). *Eucalyptus* spp. are species widely used in this type of planting, with a great diversity, having more than 700 species adaptable to different types of climate and soil (PINTO JÚNIOR; SANTAROSA; GOULART, 2014; THORNHILL et al., 2019).

In Brazil, reforestation has been an effective strategy to meet the global demand for wood, being relevant both from an environmental and economic point of view, as it contributes to the fight against deforestation and reduces the use of wood from native forests. The development of technologies, management and management of forest production is essential to improve the production chain (ASSIS et al., 2009).

The planting of forests with fast-growing species, such as *Pinus* spp. and *Eucalyptus* spp., experienced a significant expansion in Brazil from the 1960s onwards, especially with the tax incentives in force from 1966 to 1988 (KENGEN, 2001). From that time on, systematic scientific work was carried out to select *Eucalyptus* spp. clones that were more suitable for the environment and industrial exploitation (LIMA-TOIVANEN, 2013).

In 2023, the area planted with *Eucalyptus* spp. in Brazil was 7.55 million hectares (IBGE, 2024), and the country is the world leader in charcoal production, with 12% of the global market (FAO, 2024), being the main supplier to pig iron producing steel mills (IBA, 2024).

Tocantins, in turn, saw a large expansion of eucalyptus plantations between 2010 and 2017, mainly due to the production of charcoal aimed at the steel sectors of Pará and Maranhão, in addition to the installation of a pulp industry in Imperatriz, Maranhão, in 2013. However, from 2017 onwards, there was a decline in the planted area in the state. In 2023, Tocantins ranked 14th among the states with the largest area of forest planted with *Eucalyptus* spp. in Brazil (IBGE, 2024).

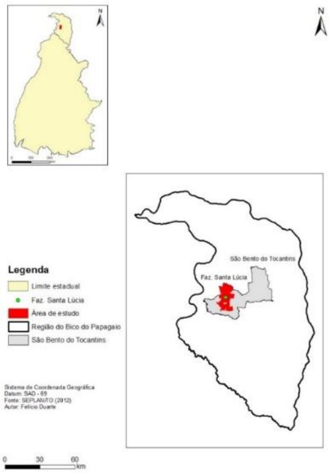
The states with the highest consumption of charcoal in Brazil are: Minas Gerais, Maranhão, Pará and Mato Grosso do Sul, and, therefore, much of the research on the production of energy quality charcoal was developed in these states, leaving Tocantins lacking relevant information on the subject.

In view of the above, the present work aimed to evaluate the energy quality of the wood of five clones of *Eucalyptus urophylla* x *Eucalptus grandis*, planted in São Bento do Tocantins - TO.

METHODOLOGY

The experimental area of the present study is located at the Santa Lúcia Farm owned by the company Sinobras Florestal, at the geographic coordinates 06º01'13" South and 47º54'08" West, in the municipality of São Bento do Tocantins, in the northern region of the State of Tocantins, known as the Bico do Papagaio region (Figure 1).

Figure 1 – Location of the Bico do Papagaio region, the municipality of São Bento do Tocantins and the Santa Lúcia Farm, where the experiment area is located.



Source: Prepared by the authors

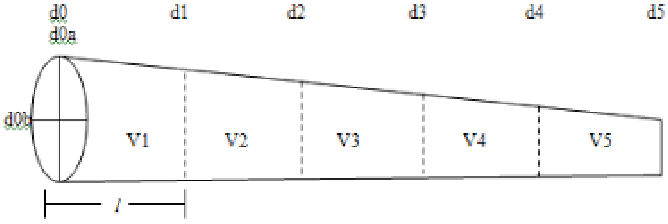
The region where the experimental area is located, has a dry season in winter, where the driest month has less than 60 mm of precipitation and is equivalent to 4% of the total annual precipitation. The predominant soil type is the Quartzarenic Neosols, and in the region the average altitude is 230 meters, with an average annual temperature of 26.1 °C and an average annual rainfall of 1,597 mm. (SEPLAN, 2017; COLLICCHIO et al., 2022).

The experimental area was composed of five *Eucalyptus* clones, hybrids of *E. urophylla* x *E. grandis* from planting for commercial purposes, implanted in the spacing of 3.5 x 2.85 meters, corresponding to a population of 1,002 trees/hectare with 14 years of age. The selected clones correspond to the most productive in the area, taking into account the forest inventory carried out periodically.

Four trees were randomly selected per clone evaluated, totaling 20 sampled trees. The selected trees were the most representative (health, DBH, canopy height), in addition, we avoided choosing trees close to the border. The trees were felled with the help of a chainsaw at a height of 0.10m from the ground

The cubing of eucalyptus trees was carried out using the Smalian method, as illustrated in Figure 2.

Figure 2 – Measurement scheme for cubing by the Smalian method



Source: Adapted from Machado; Figueiredo Filho (2009)

The total height of the trees was measured individually with a tape measure, being defined as the distance from the base of the ground to the apex. Diameters were determined without bark in sections along the trunk, starting at 0.10 m and continuing at two-meter intervals, including measurements at 1.30 m, 2.10 m, 4.10 m and so on, until the final commercial height, which was established as the point where the trunk reached a barked diameter of 7 cm, according to the company's convention.

To calculate the total volume of each tree, the individual volumes of each section along the trunk were considered. The volume of a section was estimated by the average of the cross-sectional areas without bark at the base and top, multiplied by the length of the section. The sum of the volumes of all the sections resulted in the total volume without bark of the tree.

Wooden discs with a thickness of 2.5 cm were removed from five positions along the trunk, corresponding to 2%, 10%, 30%, 50% and 70% of the commercial height. An additional disc was extracted 1.30 m from the ground (DBH), as shown in Figure 2.

The discs were duly identified and sent to the Forest Biomass Energy Laboratory of the Federal University of Lavras (UFLA) for analysis of the properties of wood and charcoal.

Each disc was sectioned into four opposite wedges, dividing the medulla. Two of the smaller wedges were used to determine the basic density of the wood, according to the NBR 11941 standard (ABNT, 2003). The wedges were initially saturated by immersion in water, and the saturated volume was measured without shell. After this procedure, the wedges were dried in an oven at 103 ± 5 °C for 48 hours, or until they reached a constant mass. The basic density was then calculated by dividing the dry mass by the saturated volume.

The average basic density of each position along the trunk was obtained by the arithmetic mean of the densities of the two opposite wedges. The average basic density of the tree was calculated as the average of the densities in all the sampled positions, except for the DBH position.

The dry mass of the trunk was estimated by multiplying the average basic density of the tree by the total volume without bark, adjusting the result to kilograms.

The higher calorific value was determined by means of an IKA C-200® digital calorimeter, following the ASTM E711-87 standard (ASTM, 2004). Based on the results, the energy density was obtained by multiplying the calorific value by the apparent relative density of the wood or charcoal.

Regarding the performance of statistical analyses, it is noteworthy that the experiment was developed using a completely randomized design containing five treatments (clones) and four replications (sample tree). For the normality test, the "ASSISTAT 7.7" software was used, and for univariate comparisons, the "Agroestat" software was used (MALDONADO, 2020) and the Scott and Knott test was adopted, considering a significance level of 5%.

RESULTS AND DISCUSSION

According to the characteristics of the wood of the clones analyzed, Table 1 shows that the mean values of average basic density (DBm), dry mass (DM), commercial volume without bark (VCSC), higher calorific value (PCS) and wood energy density (DEM), showed significant differences between the clones. No significant differences were observed in the mean values for the SCW.

Table 1 – Mean values of the average basic density (DBm), dry mass (DM), commercial volume without bark (VCSC), higher calorific value (PCS) and wood energy density (DEM) of the clones evaluated

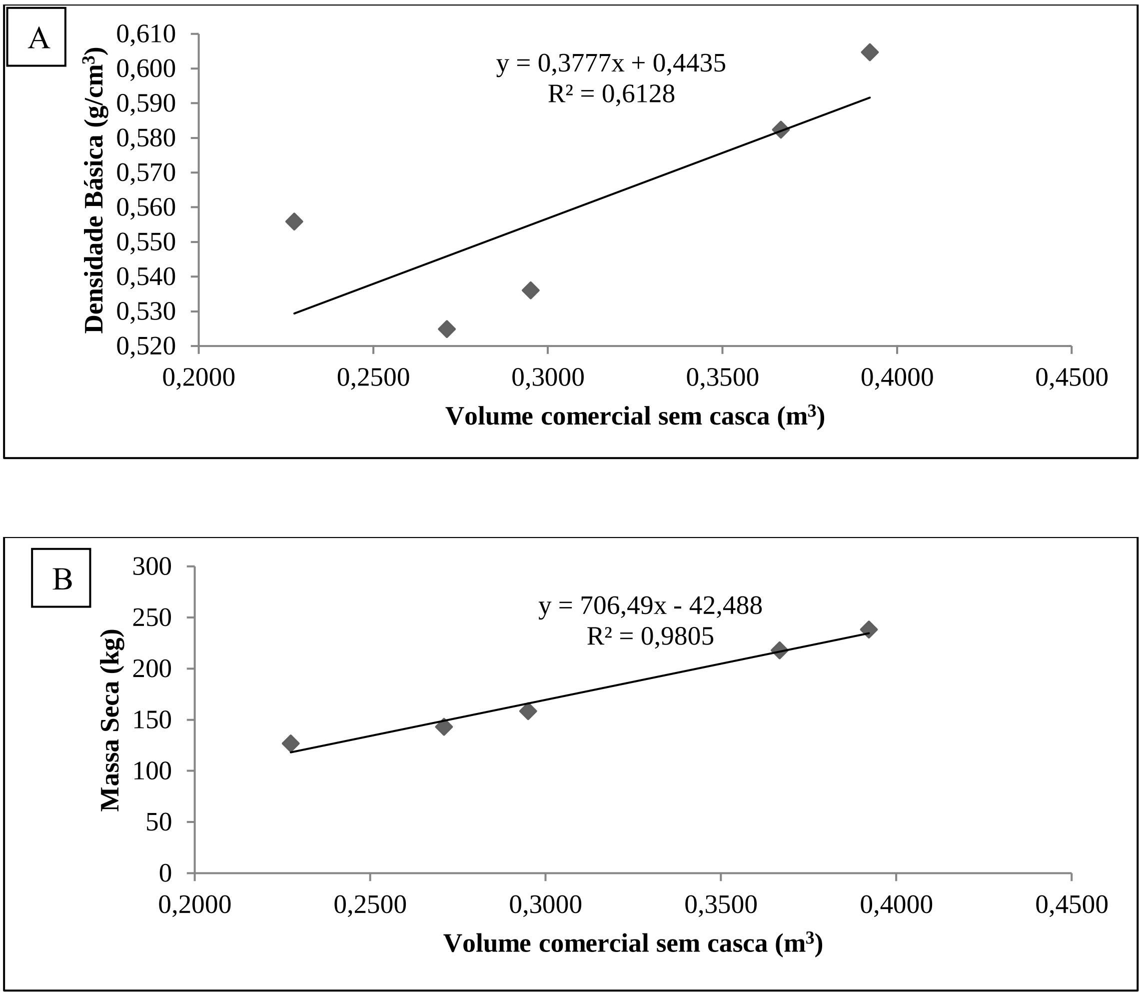
Clone	MS (kg)		VCSC (m^3)		DBm (g/cm^3)		PCS (cal/g)	DEM ($Gcal/m^3$)	
1	126,85	b	0,2274	b	0,556	b	4.661 a	2,59	b
2	252,86	a	0,4152	a	0,607	a	4.590 a	2,79	a
3	238,31	a	0,3922	a	0,605	a	4.683 a	2,83	a
4	142,95	b	0,2711	b	0,525	c	4.666 a	2,45	c
5	158,50	b	0,2951	b	0,536	c	4.626 a	2,48	c

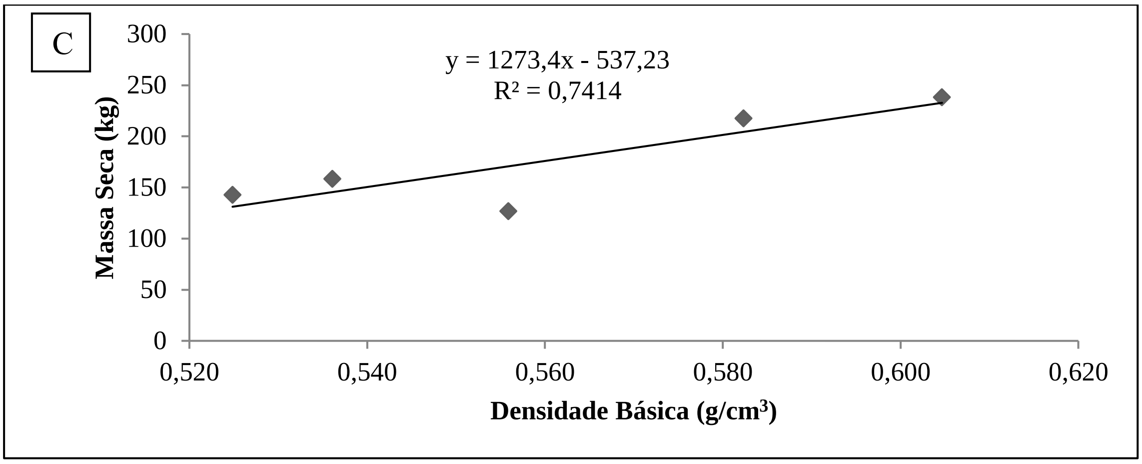
Values followed by the same letter vertically did not differ significantly from each other by the Scott and Knott test ($p < 0.05$).

It is noteworthy that clones 2 and 3 obtained higher mean values than the others for all traits, except for the PCS, where all clones did not differ in value. Clones 4 and 5 presented the lowest values for DBm and DEM. Clone 1, with the exception of PCS, obtained intermediate mean values for all the traits analyzed.

Figure 3 shows that there is a positive trend of increasing the mDB with the volumetric growth of the tree, i.e., higher volumetric growth is associated with wood with higher basic density.

Figure 3 – Functional relationship between the commercial volume without peel and the basic density (a); commercial volume without peel and estimated dry mass (b); average basic density and estimated dry mass (C).





Source: Prepared by the authors

Wood is a heterogeneous material, considering the anatomical, chemical, physical and mechanical characteristics. This heterogeneity is related to genetic material, age, edaphoclimatic conditions, crop spacing, forest management, and wood position along the tree (SOARES et al., 2014). DBm is one of the main properties of wood, influenced by factors such as age, species, and silvicultural management, and is associated with mechanical and energetic characteristics of wood (OLIVEIRA et al., 2021).

To determine the best use of wood, it is essential to evaluate several parameters related to its quality. For the multiple use of wood, the analyses of DBm along the trunk reveal the uniformity of the clones, which is a determining factor for their use as solid or transformed wood. In addition, it is necessary to consider other parameters, such as anatomical characteristics, chemical composition and mechanical properties, as well as technological tests and silvicultural aspects. These evaluations are fundamental for the proper selection of clones (ALZATE; TOMAZELLO FILHO; PIEDADE, 2005).

For the purposes of defining economic and ecological values and potential use of species, its chemical composition, especially the lignin content, is a good tool, in addition to DBm, to characterize it as a renewable and potential raw material, available for energy production (SANTOS et al., 2016). The DBm, the ratio of dry woody material per unit of green or saturated volume, is related to many fundamental technological characteristics for the production and use of forest products.

In this research, it was observed that the mDB of the wood ranged from 0.525 to 0.607 g/cm³, with emphasis on clones 2 and 3. These values are similar to those ideal for charcoal production (LIMA et al., 2020). Oliveira et al. (2010) evaluated the E*. pellita clone* at five years and found a DBm of 0.56 g/cm³, lower than that found for two clones studied and higher than the others. There are reports in the literature that the density of wood tends to increase with the age of the material up to a certain age of the tree (BENIN; WATZLAWICK; LIMA, 2021; SSEREMBA et al., 2021).

When evaluating the variation in the mDB of *E. grandis wood* at four ages (3, 6, 9, and 12 years), Sseremba et al. (2021) observed an increase in it with age, which can be explained by the increase in anatomical characteristics, such as fiber diameter. The mDB varies with genetic material. Couto et al. (2015) mention that, among three materials analyzed, the mDB ranged from 0.503 to 0.606 g/cm³, characterizing the genotype with a value higher than 0.606 g/cm³ as the most conducive to the production of charcoal for steel use among those analyzed.

Santos et al. (2011) found that average values for wood DBm higher than 0.54 g/cm³ are interesting for charcoal production, since when wood degrades, about 60% of its mass is lost. Consequently, the higher the DBm, the greater the mass of charcoal produced for a given volume. This indicates, in general, the obtaining of coal with greater mechanical resistance. In this sense, it can be assumed that clones 1, 2 and 3 are interesting for charcoal production. Trugilho et al. (2001) studied the energy potential of the wood of eucalyptus clones at seven years of age and found values for mDB ranging from 0.52 to 0.59 g/cm³, which were considered by the authors as potential for charcoal production.

Although Resquin et al. (2020) identified oscillations in the PCS variable at different ages, an increase over time was observed in *the species E. benthamii*, *E. dunnii,* and *E. grandis*. Castro et al. (2016), studying correlations between age, wood quality, and charcoal quality of eucalyptus clones at 3, 4, 5, and 7 years of age, concluded that age affected wood PCS, with a significant difference between clones at all ages.

Jesus et al. (2017) highlighted that the variation of the mDB directly influences the DEM, which occurs because the basic density is directly related to the energy production of the wood. This relationship was found in the present work, evidencing the importance of selecting denser woods for higher energy density.

Corroborating the results found by Castro et al. (2016), the values obtained in this research meet the demands of the steel industry. Lima et al. (2011) found for *E. benthamii* wood at 6 years of age, an MDD of 2.22 Gcal/m³. Vale et al. (2001) obtained an average DEM of 3.17 Gcal/m³ for charcoal from ten Cerrado species used as a source of bioenergy, surpassing the clones evaluated. Protásio et al. (2013), studying the steel and energy potential of charcoal from *Eucalyptus* clones at 3.5 years of age, found DEM ranging from

2.0 to 3.25 Gcal/m³. Protásio et al. (2015), studying the technological evaluation of charcoal from the wood of young clones of *E. grandis* and *E. urophylla*, observed DEM between 2.0 and 3.0 Gcal/m³.

Analyzing the DEM, Reis et al. (2023) found a value of 2.20 Gcal/m³ in *E. urophylla trees* at 6 years of age, values close to those obtained in the present study. In an energetic characterization of *E. benthamii* at 6 years of age, carried out by Lima et al. (2011), the DEM was 2.22 Gcal/m³, which is lower than the mean value observed in the present study (2.63 Gcal/m³).

CONCLUSION

The results obtained demonstrate that all the clones analyzed have adequate characteristics for the production of charcoal for steel use.

Among the clones evaluated, clones 2 and 3 stood out statistically, presenting parameters superior to the others in relation to the quality of the charcoal produced, meeting the requirements for application in blast furnaces These clones showed promise due to the combination of basic density and energy density, characteristics that directly influence performance as a source of bioenergy and as a reducer.

Although there are several studies on the subject, the results obtained reinforce the need to deepen investigations, especially with regard to energy and the reducing power produced per hectare, considering the volume of biomass generated per unit of area, through forest inventories.

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