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TECHNOLOGICAL POTENTIAL OF *Eucalyptus dunnii* WOOD FROM DIFFERENT FERTILIZATION AND GENETIC SOURCES FOR THE PRODUCTION OF EDGE GLUED PANELS

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ABSTRACT

Several methods are implemented to improve the quality and productivity of *Eucalyptus* plantations, including genetic improvement and seedling fertilization. These practices, combined with the favorable soil and climate conditions across much of Brazil, have enabled high yield forest production. These plantations supply raw materials for a wide range of industrial uses, notably the manufacture of wood panels. Among them, edge glued panel are produced by joining battens laterally or on their surface using adhesive bonds. This work aimed to evaluate the technological potential of *Eucalyptus dunnii* (white gum) wood from different fertilization treatments and genetic sources for the production of edge glued panels. The material was collected from a plantation with trees 8,5 years old in Pinhais, Parana, and included 24 trees: 12 from clonal material and 12 from selected seeds. Each genetic source was subjected to two fertilization treatments (conventional and slow-release) and one control, resulting in six treatments. The wood was analyzed for volumetric, chemical and physical properties. After drying, battens were glued and the strength of the adhesive joints was tested. Clonal trees exhibited the highest volume and the lowest basic density. The lowest anisotropic coefficient was found in wood subjected to slow release fertilization. Fertilization also influenced all aspects of chemical composition. Overall, the treatments with clonal trees and slow release fertilization showed the highest suitability for edge glued panel production, justifying the investment in silvicultural practices from the point of view of wood technology.

Keywords: Bonding strength, edge glued panel, *Eucalyptus dunnii*, engineered wood products, wood bonding, wood panels.

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INTRODUCTION

Among the most planted forest species for industrial purposes in Brazil, those of the *Eucalyptus* genus occupy the highest percentage, representing 78 % of the total planted area, which is mainly concentrated in Minas Gerais, Mato Grosso do Sul and São Paulo.

According to Dobner Júnior (2008) among the eucalyptus trees planted in temperate climates, white gum (*Eucalyptus dunnii* Maiden) ranks first in volumetric growth, reaching a productivity of 50 m^3/ha/year. Paludzyszyn-Filho and Santos (2005) state that the species grows annually, on average, 3 m in height and 3 cm in trunk diameter. The characteristic of the bole in adult and dense stands is the absence of branches up to 30 m in height. The bark can assume different appearances and gradually detaches from top to bottom in the trunk, in the form of long stripes. The basic density of wood falls within the grouping of medium-density wood species (around 500 kg/m^3), according to Oliveira and Pinto Júnior (2021), which means it has potential and suitability for various uses in the wood industry.

With a constantly growing market, products from forests stand out worldwide, especially wood, due to its renewable origin, expressive quality, competitive cost and pleasant aesthetics. Wood panels, products made from wooden elements, have several applications in everyday life, from skateboards, toys, packing, decoration, furniture and even recent buildings built in wood structure.

Edge Glued Panels (EGP), used in both the furniture industry and civil construction, are, in a way, still recent in Brazilian production and consumption but they are relevant with regard to products with higher added value, mainly due to the fact that they add value through the use of sawmill by-products, such as sidewalls and non-conforming samples, that would be discarded or used for energy generation, or by the use of small-diameter logs, including those from thinning or young forests, which have lower value and, consequently, reduce production costs (Trianoski and Iwakiri 2020).

The use of small-diameter trees, thinnings, or young forests is not only influenced by cost factors but also by the limited availability or shortage of raw materials for the manufacturing process, as well as by the strategies employed by foresters to achieve higher yields, that is, greater volume per year. Among these strategies, the introduction of genetically improved seedlings in the field, using vegetative propagation techniques, and the improvement of methodologies and products applied in forest fertilization. On the other hand, these silvicultural techniques can impact the quality of the wood and consequently its application or the quality of the final product.

Regarding genetic materials, the main difference between clonal and seminal origins is genetic variability. Materials from seeds are not genetically identical to each other or to their parent trees, although they may be related. Clones are genetically identical to their parents. The materials differ from each other in terms of growth, wood properties, resistance to pests and diseases, and edaphoclimatic conditions (soil and climate). Therefore, the choice of material to be planted is basically determined by two factors: the purpose and location of planting (Cipriani *et al*. 2015). Research and development activities carried out by large Brazilian companies in favor of genetic improvement and forest management optimization generated significant gains in the average annual increase (AAI) of their forest bases (ABRAF 2013).

For the second strategy, forest fertilization, is a practice that occurs through the addition of products of mineral or organic origin with amounts of macronutrients and micronutrients controlled according to the identified plant needs or as recommended for a specific condition.

Regarding products and application methods, conventional fertilization (CF) and slow-release fertilization (SRF) are usual. CF is carried out, normally in three stages, the starter fertilization, which occurs about 1 month after planting; topdressing fertilization, applied about 2 months after planting; and maintenance fertilization, approximately, between 15 and 30 months after planting (Souza 2015).

SRF is a more recent product, but it was relevant because the creation of this technology was due, among other reasons, to the need to reduce leaching losses and the possibility of gradually supplying nutrients to the plant, thus eliminating the need of topdressing fertilization, reducing costs. It also avoids injuries to seeds and roots resulting from excessive applications, and are not susceptible to losses, minimizing the risks of environmental pollution (Scivittaro *et al*. 2004).

As mentioned, genetic improvement and fertilization affect volumetric production and consequently the properties of the wood, especially the anatomical, physical and chemical properties. These, in turn, impact the variables of the EGP production process and the quality of the final product, as reported by many authors.

According to Frihart and Hunt (2021), the physical and chemical properties of the wood influence the quality of the adhesive bonds, with low-density woods being more porous and permeable, consequently facilitating the mobility of the adhesive in their structure, allowing greater anchoring and not requiring the application of high pressure at the time of pressing. On the other hand, woods with this characteristic may imply excessive absorption of the adhesive, resulting in a "hungry" and fragile glue line, and consequently in low bonding quality (Marra, 1992, Frihart and Hunt 2021, Trianoski and Iwakiri 2020). Regarding chemical properties, especially extractive content, high levels of these components may inhibit the chemical reactions of polymerization of the adhesive, preventing fluidity, wettability and absorption, thus impairing the development of adequate strength and cohesion of the glue line. Regarding inorganic materials or ashes, low proportions are desired for the production of EGP's because these components can cause wear on cutting tools during the preparation of the battens for gluing and during planning of the panel, as well as abrasives used in surface finishing (Trianoski and Iwakiri 2020).

In addition to the influence of the wood properties, the quality of the EGP bonding is influenced by the production process variable type of adhesive, which must be selected according to the wood species and its characteristics, which may have been influenced by genetic improvement and fertilization, the end use, and in order to obtain a product that meets the regulatory requirements. The most commonly used adhesives for these types of panels are polyvinyl acetate (PVA) and polymeric isocyanate emulsion (EPI) (Rojas *et al* 2020, Trianoski and Iwakiri 2020). PVA is an adhesive resulting from the polymerization of vinyl acetate, which presents high mechanical resistance of the products glued with it in a dry environment, however, limitations of use in environments with high temperatures and relative humidity (Pizzi 2018). The EPI adhesive is composed of a polyvinyl acetate base and a polymeric isocyanate, whose function is to catalyze the curing of the adhesive, which occurs through the reaction of the isocyanate groups with the hydroxyl groups of the wood, allowing high resistance to water and temperature, good stability, fast curing, but has the disadvantage of higher cost (Frihart and Hunt 2021). For products that require greater resistance to humidity, or species that are more difficult to glue, such as species of the *Eucalyptus* genus, especially those from young plantations, the use of the EPI adhesive can be recommended. Furthermore, the use of EPI adhesive, instead of PVA, is more recommended for species that have greater growth stresses, as well as for juvenile woods that are characterized by greater dimensional instability.

In this context, and considering that no studies were found in the international literature that evaluate the quality of wood gluing under silvicultural or genetic conditions and/or clonal x seminal materials that received different fertilizations for gluing purposes, it is necessary to develop research on this topic. Thus, the objective of this research was to evaluate the technological potential of *Eucalyptus dunnii* Maiden wood, originating from different fertilization treatments and genetic materials, for the production of Edge Glued Panels.

MATERIALS AND METHODS

The species used in this research was white gum (*Eucalyptus dunnii* Maiden) and the material was collected at the Canguiri Experimental Farm, belonging to the Federal University of Paraná (Universidade Federal do Paraná), located in the municipality of Pinhais - PR (Metropolitan region of Curitiba), located at the coordinates 25°23'14,9"S and 49°07'35,5"W. Trees were collected at 8,5 years of age. The planting consisted of two parcels of genetic material (clonal and seminal) with 48 individuals each (without the border plants), with a spacing of 3 m x 2 m. The seedlings of each parcel received three fertilization treatments: CF - fertilization in the conventional formulation, SRF - slow-release fertilization and C - control, without fertilization. After selecting the material for the research (24 arboreal individuals), the experimental outline of the present work was established, as shown in Table 1. This outline, characterized as a completely randomized outline, was used in all analyses carried out in this research. The profile of the forest can be seen in Figure 1.

Table 1: Experimental design.

Treatment	Material Origin	Fertilization
T1 - (CLO/CF)	Clonal	Conventional fertilization
T2 - (CLO/SRF)	Clonal	Slow-release fertilization
T3 - (CLO/C)	Clonal	Control
T4 – (SEM/CF)	Seminal	Conventional fertilization
T5 - (SEM/SRF)	Seminal	Slow-release fertilization
T6 - (SEM/C)	Seminal	Control

Figure 1: *Eucalyptus dunnii* plantation on experimental design.

After felling, the volume of the trees was obtained using the *Smalian* cubing method adapted from measurements in the sections (base-above stump, DBH, 25 %, 33 %, 50 %, 75 %, 100 % of commercial height) and full height. The shell thickness was also obtained in the mentioned sections. The trees were sectioned into logs to obtain small boards and later the battens, and material was collected from the DAP region to determine the physical and chemical properties. In Figure 2 it is possible to see de logs from the DAP region, also in the different treatments.

Figure 2: Logs from the DAP region to determine the physical and chemical properties.

The physical properties evaluated were the basic and apparent specific gravity at 12 % moisture and dimensional stability, which followed the procedures of the NBR 7190 (1997). The evaluation of chemical properties followed the methodology recommended by the TAPPI standards and consisted of determining the total extractives TAPPI 204 (1997), pH TAPPI 252 (2002) and inorganic materials or ash TAPPI 211 (2002). From the slats with 12 % moisture and dimensioned with 31 cm x 5,5 cm x 2 cm, respectively for length, width and thickness, the material was glued. Akzo Nobel's two-component emulsion polymeric isocyanate (EPI) adhesive was used, in a ratio of 100:15 parts by weight (resin: catalyst). The weight of the glue line adopted was 180 g/m². The specific pressure applied to the joints was 1 MPa, exerted by means of a torque wrench (Figure 3) for a period of 60 min.

Figure 3: Joints glued and pressed.

For each treatment, 5 glued joints were produced where, after pressing, they were conditioned at room temperature (20 ºC) for 1 week for full curing of the adhesive. After this period, specimens were produced to evaluate the shear strength of the lateral glue line, which followed the procedures of standard EN 13354 (2008). Depending on the classification of the adhesive, the specimens were submitted to pre-treatments of immersion in water at a temperature of 20 ºC for 24 hours and immersion in boiling water for 6 hours. As a control, the dry test was carried out, that is, in acclimatized specimens. For each pretreatment condition of specimens mentioned (and per treatment). 15 samples were tested in a universal testing machine of the EMIC brand equipped with a load cell of 20000 N.

After the test, a visual evaluation of the percentage of failure in the wood of the glue line was performed according to EN 314-1 (2004) and the lower fifth percentile was calculated according to EN 326-1 (2002). The results were compared with the requirements in EN 13353 (2008), where this value must be equal to or greater than 2,5 MPa and if not met, the average percentage of wood failure of each treatment must be greater than 40 %. However, when the density of the wood studied is above 600 kg/m³, the standard does not establish this minimum requirement of percentage of failure in the wood.

The data was subjected to statistical analysis using the outlier test and sequentially analyzed according to a completely randomized outline, using the factorial splitting scheme (2 x 3), in order to simultaneously evaluate the interaction of genetic material (clone x seeds) and fertilization (conventional, slow and control). The analysis included the Shapiro-Wilk data normality test and Analysis of Variance (ANOVA). When the equality hypothesis was rejected, the Tukey test was performed. When there was no homogeneity of variances or when the residuals were not normal, data transformation was performed by Box-Cox.

In the analysis of physical properties, the data did not meet the assumptions of the Analysis of Variance, therefore, they were evaluated according to the non-parametric Kruskal-Wallis test, which compares the medians of two or more groups, followed by the post hoc test of Dunn, with P-value adjustment by Bonferroni. As there is no relationship with the average, these results should not present the coefficient of variation, but the interquartile range of the data. All statistical analysis was performed using RStudio software, version 4.1.0 (2021-05-18), with all tests applied with 95 % reliability.

RESULTS AND DISCUSSION

The dendrometric characteristics, the volumes and the increments between the factors of the treatments used in this research are presented in Table 2. In all the analyses there was no statistical difference by the Tukey test at the 5 % confidence level, therefore, these letters are absent in Table 2, because according to the F test, the averages of each factor were statistically equal, implying a non-significant interaction.

It is possible to observe that in relation to the genetic material, clonal individuals present higher average values than seminal individuals, so all derived variables reflect the condition. This behavior was expected, since one of the objectives of clonal plantations is a greater increase in individuals.

Regarding fertilization, the conventional one provided a better performance in all variables, followed by the slow-release fertilization, and finally, the treatments that did not include any fertilization, the so-called controls. These results express the performance of fertilizers, so both the conventional and the slow-release ones played a fundamental role, providing nutrients that provided the observed superiority, increasing the stems of these individuals. Therefore, this analysis emphasizes the gains in volume using seedlings of clonal origin and the application of fertilizers.

Table 2: Average dendrometric values, volumetry and increments of interactions between the factors studied.

Factor		Ht (m)	Hc (m)	DBH w/b (cm)	DBH wo/b (cm)	Vcom w/b (m^3)	Vcom wo/b (m^3)	AAIvcomw/b (m^3/ha/year)
Genetic Material	CLO	26,06	21,56	17,27	14,87	0,2684	0,2060	40,33
	SEM	22,62	17,51	15,32	12,57	0,1864	0,1368	26,80
Fertilization	CF	25,50	21,21	17,76	15,12	0,2777	0,2128	41,69
	SRF	24,05	19,46	16,76	13,96	0,2395	0,1773	34,75
	CONTROL	23,50	17,94	14,7	12,10	0,1648	0,1238	24,27
	CV	18,1 %	26,5 %	21,1 %	24,4 %	58,4 %	60,17 %	60,23 %

ht, total height; hc, commercial height; dbh w/b, diameter at breast height with bark; dbh wo/b, diameter at breast height without bark; vcom w/b, average commercial volume with bark; vcom wo/b, average commercial volume without bark; aai vcoms/c, annual average increase in commercial volume without bark per hectare; cv, coefficient of variation.

In comparison with the literature, Dobner and Huss (2019) verified in dominant individuals of white gum (*Eucalyptus dunnii* Maiden) planted in Santa Catarina, with seminal origin and fertilized with 240 kg/ha NPK (5-20-10) that when the trees were around 8 years old, the 100 dominant individuals in all thinning variants grew on average approximately 2 cm/year, highlighting the enormous potential for growth at early ages. Knowing that the method of selection of trees in this research was not by the method of thinning from above, that is, they were not trees in direct competition with the dominant ones, the results of average annual increment of the diameter are plausible.

Serpe *et al*. (2018), studying the effects of different fertilization rates on the initial growth of camden white gum (*Eucalyptus benthamii* Maiden & Cambage), a species that also has tolerance to the harshest winters, found average values of DBH and total height at 6 year old planting, varying between 11,6 cm and 17 m respectively, for treatment without any dosage of fertilizer and 15,3 cm and 19,8 m for treatment with the highest dosages of fertilizers. Due to the higher age, the values mentioned are relatively proportional to those of the present work, although white gum (*Eucalyptus dunnii* Maiden) has a tendency to present greater total heights, when compared to camden white gum (*Eucalyptus benthamii* Maiden & Cambage).

Table 3 presents the results of the medians of the physical properties of wood, namely, basic and apparent density (12 %), shrinkage (radial, tangential and volumetric) and the anisotropy coefficient, so that the clonal material and seminal material interaction be evaluated.

Table 3: Results of the medians of physical properties by factor.

Factor		Density (kg/m³)		Shrinkage (%)			Anisotropy Coefficient
		Basic	Apparent	Radial	Tangential	Volumetric	
Genetic Material	CLO	434 (40)	592 (90)	5,62 (1,58)	16,00 (1,69)	21,00 (2,87)	2,88 (0,66)
	SEM	475 (60)	653 (90)	5,71 (1,48)	15,40 (2,10)	20,30 (2,89)	2,75 (0,87)
p-value*		0,0237	0,0963	0,8489	0,0786	0,1437	0,4526
*Post-hoc***		*	ns	ns	ns	ns	ns
Fertilization	CF	436 (80)	648 (122)	4,91 (0,98)	15,50 (1,76)	19,40 (2,94)	3,03 (0,44)
	SRF	478 (60)	612 (80)	6,32 (1,83)	15,30 (2,71)	20,60 (3,96)	2,38 (0,64)
	CONTROL	445 (50)	639 (90)	5,91 (1,22)	15,90 (1,47)	20,90 (1,80)	2,74 (0,49)
p-value*		0,0024	0,6546	0,0008	0,1523	0,0399	0,0016
*Post hoc***	C-L	**	ns	**	ns	ns	**
	C-T	ns	ns	**	ns	*	*
	L-T	*	ns	ns	ns	ns	ns

*p-value for the Kruskal-Wallis Test; ***Post hoc* Dunn Test with adjustment of the p-value by Bonferroni; Values in parentheses represent the interquartile range.
C-L (Between Conventional and Slow Fertilization);
C-T (Between Conventional Fertilization and Control);
L-T (Between Slow Fertilization and Control).

The basic density of wood is a prior knowledge for edge gluing of paramount importance due to the relationship with porosity, which will justify the behavior of the adhesive bond. Because of this, regarding the genetic material factor, the values found were 434 kg/m³ for wood from clones and 475 kg/m³ for wood derived from seeds. The apparent density varied between 592 kg/m³ and 653 kg/m³ among genetic materials. The radial, tangential and volumetric contractions presented very high values and this is related to the anisotropic coefficient found, which was 2,88 for the clones and 2,75 for the seminal ones, being, therefore, woods classified as very unstable.

The observation of higher values in the densities for the seminal genetic material and lower values in the shrinkage and in the anisotropic coefficient in relation to the clonal material is related to the way of growth of the trees, and with the diameters and volumes presented above. This relationship, in a way inversely proportional to the volume, occurs because the slower the increase of individuals during the years of their development, the cells will present thicker walls, causing greater mass per volume (density). With this higher density, a greater contraction or expansion is expected, however, a controversy of this statement is contemplated mainly to the genus *Eucalyptus*, as happened in the results of this work and that of (Oliveira *et al*. 2010), where the woods with higher density (gympie messmate (*Eucalyptus cloeziana* F.Muell.) and (lemon-scented gum *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S.Johnson)) showed lower shrinkage results than those with lower density (timor white gum (*Eucalyptus urophylla* S.T.Blake) and blackbutt (*Eucalyptus pilularis* Sm.)).

Regarding the effect of the fertilization factor on the physical properties of the wood, some statistically significant differences were observed between the material that received conventional fertilization, slow fertilization, and no fertilization. The results of the observed basic density stand out, where the effect of conventional fertilization presented the lowest density (434 kg/m³), followed by the control (445 kg/m³) and the slow-release fertilization (478 kg/m³). This result was reflected in the dimensional stability, where the anisotropy coefficients found were 3,03; 2,74 and 2,38 respectively for conventional, control and slow fertilization.

Bellote *et al.* (2007), evaluating the quality of loblolly pine (*Pinus taeda* L.) wood, state that the minerals Ca, Mg, and Mn present a negative correlation with the wood density. Corroborating the results of this research in the conventional fertilization treatment, Ca and Mg were present and their basic density results were lower than the others. Therefore, it is stated that the fertilization applied in the field altered the behavior of the physical properties of the wood, as well as the fact that the slow-release fertilization generated a greater wood density and a greater dimensional stability, represented by the lower value of observed anisotropy coefficient.

The anisotropic factor is the relationship between the tangential over the radial shrinkage and the greater the result of this ratio, the greater the chance that the wood will suffer from defects such as warping and cracks during humidity variations, and also with tensions in the glue line during the gluing, and during the use of the final product, especially if used in regions or environments with a high variation of relative humidity.

Therefore, this result, despite being high like the others, may indicate an advantage of slow-release fertilization over conventional, especially when purchasing inputs in the early stages of planting. It is noteworthy that no studies were found that evaluated the quality of wood, specifically the movement caused by hygroscopic changes, depending on the type of fertilization used in planting, which is a gap for comparative purposes.

Iwakiri *et al.* (2021), in research with big badja gum (*Eucalyptus badjensis* Beuzev. & M.B.Welch), a species that also has potential for planting in the coldest regions of Brazil and production of EGP, found the average results of basic density (475 kg/m³), apparent density (585 kg/m³), volumetric contraction (16,11 %) and anisotropic coefficient (2,35). In comparison with loblolly pine (*Pinus taeda* L.), a highly commercial species in the South region of Brazil for several purposes including the production of EGP, (Lau 2017) found average results of basic density of 370 kg/m³, apparent density at 15 % humidity of 510 kg/m³, radial, tangential and volumetric contraction, respectively, of 2,83; 6,07 and 8,90 and anisotropic coefficient equal to 2,43. (Talgatti *et al.* 2020) found for the woods of clones of *Eucalyptus grandis* and hybrids of the species with others of the genus, with 7 years of age, average values of basic density in the range of 393 kg/m³ to 510 kg/m³. Table 4 reports the average results of the chemical properties of white gum (*Eucalyptus dunnii* Maiden) wood and the interactions between the treatment factors.

Table 4: Average results of chemical properties - unfolding of fertilization x genetic material interactions.

	Total Extractives (%)				pH (2h)				Ashes (%)
Factor	CLO	SEM	F	*p*	CLO	SEM	F	*p*	*
CF	3,68 (6,68) bB	5,81 (3,02) aA	333,202	0,0000	4,98 (0,10) aAB	4,98 (0,20) aC	0,0889	0,7684	0,45 (7,94) A
SRF	4,06 (2,61) bA	5,66 (1,59) aA	233,8417	0,0000	4,99 (0,17) aA	5,00 (0,38) aB	3,4830	0,0754	0,40 (3,37) B
CON-TROL	3,99 (2,42) bA	5,13 (4,47) aB	119,3070	0,0000	4,96 (0,17) bB	5,12 (0,25) aA	454,9273	0,0000	0,33 (8,25) C
F	6,4277	21,9843			8,2024	192,9278			44,480
p	0,0063	0,0000			0,0022	0,0000			0,0000

Averages followed by the same letter do not differ statistically from each other, by Tukey test at 95 % reliability; Being: lowercase in rows and uppercase in columns. Values in parentheses represent the coefficient of variation in percentage; *Ashes showed no interaction between the factors, and the genetic material was not significant, so only fertilization is shown.

Regarding the total extractives, wood from seminal material showed higher percentages in all fertilization treatments in relation to those from clones. However, as in pH, the behavior between fertilizations did not maintain the pattern between clones and seeds.

In general, an average value of total extractives varying between 3,68 % and 5,81 % is observed for wood under different conditions of genetic material and fertilization. This result is above that found by (Trianoski *et al.* 2020) for white gum (*Eucalyptus dunnii* Maiden) of 1,71 %, however, other factors that influence this result must be taken into account, as presented by (Vidaurre *et al.* 2020), as younger trees tend to have lower levels of extractives, which is directly related to the physiological changes during the formation of the heartwood and may also be dependent on the genetic material and the location of the tree's growth.

The pH measured 2 hours after the extraction, presented values between 4,96 and 5,12 in the different conditions of study. There was a statistically significant difference between clonal and seminal material when fertilization was not applied (control). It can be said that the values found are within the expected for the wood of the genus according to the literature, such as the average values of pH found by (Trianoski *et al.* 2020), corresponding to camden white gum (*Eucalyptus benthamii* Maiden & Cambage) (4,34), white gum (*Eucalyptus dunnii* Maiden) (4,77), rose gum (*Eucalyptus grandis* W.Hill)(4,45), blue gum (*Eucalyptus saligna* Sm.) (4,19) and timor white gum (*Eucalyptus urophylla* S.T.Blake) (4,22).

The results of wood ash did not differ significantly between clones and seeds, however, the opposite was observed in the fertilization interaction, where the percentage found for conventional fertilization was the highest (0,45 %), followed by slow-release fertilization (0,40 %) and the control treatment (0,33 %), which were statistically different from each other by the F test. The values found are within the range between 0,2 % and 0,9 % of the dry matter weight of temperate woods, and are still close to the values found in the literature by (Giesel *et al.* 2020) for loblolly pine (*Pinus taeda* L.) (0,16 % and 0,47 %) and by (Barreiros *et al.* 2007) for rose gum (*Eucalyptus grandis* W.Hill) (~0,26 %), the most used species for the production of EGP panels. (Barreiros *et al.* 2007) observed that the increase in ash content is related to greater absorption of nutrients, especially calcium, in treatments with sewage sludge application. This is significantly noted in the results presented, as conventional fertilization had calcium in its formulation, however, judging by the results, this relationship is assumed, but an analysis was not performed that contemplates the correlation of micronutrients with chemical properties.

The knowledge of the chemical properties of the wood as well as the confirmation that the results are close to those observed by other researchers is a step that allows validating certain uses, therefore, due to the chemical composition presented, a satisfactory behavior is expected in the gluing of the wood in question. In general, comparing these results with those found by (Lau 2017) for the most used species in the manufacture of EGP, loblolly pine (*Pinus taeda* L.), at 19 years of age the author found total extractives of 4,85 %, pH-2h of 4, 73 and pH-24h of 4,75, and the ash represented 0,25 %, so there is, in a way, some tendency for the wood of the present study to present good results in gluing.

Table 5 shows the average results of the glue line shear strength, the lower fifth percentile, and the percentage of wood failure of the specimens obtained from glued joints of white gum (*Eucalyptus dunnii* Maiden) after pre-treatment for internal use (cold water 24 hours) and for external use (boiling 6 hours) as well as specimens without pre-treatment (dry).

To evaluate these results, the standard EN 13353 (2008) establishes that when the lower fifth percentile of the shear stress of the specimens is equal to or greater than 2,5 MPa, it means that the species in question has good quality edge gluing and, therefore, is suitable for producing the EGP panel. If this condition is not met, the wood failure (assessed after the shear test) must be greater than 40 %, except when the wood density is greater than 600 kg/m³.

Regarding Table 5, no statistically significant difference was observed in the average results of material without dry pre-treatment and in the pre-treatment in 24h cold water, both in the analysis of data regarding genetic material, fertility, and the interaction of these.

Table 5: Average results of the glue line shear strength.

	Dry			Cold water (24h)			Boiling (6h)		
Genetic Material	SS (MPa)	5º P (MPa)	WF (%)	SS (MPa)	5º P (MPa)	WF (%)	SS (MPa)	5º P (MPa)	WF (%)
CLO	8,58 (18,84)	5,62	58	5,51 (15,96)	3,94	42	3,83 (25,99)	2,26	35
SEM	8,71 (26,37)	4,31	55	5,51 (23,60)	2,92	38	3,28 (46,04)	0,89	15
F	0,3696			0,1996			4,5374		
p	0,5448			0,6562			0,0361		
Fertilization	RC (MPa)	5º P	FM (%)	RC (MPa)	5º P	FM (%)	RC (MPa)	5º P	FM (%)
CF	8,97 (20,25)	5,02	50	5,39 (23,62)	3,21	35	3,58 (37,73)	1,65	19
SRF	9,02 (21,65)	5,62	62	5,62 (15,90)	4,18	45	3,81 (25,05)	2,52	29
CONTROL	7,94 (25,49)	4,25	58	5,52 (20,60)	3,74	41	3,28 (46,45)	0,95	26
F	2,9067			0,1889			1,4237		
p	0,0602			0,8282			0,2466		
Genetic Material x Fertility									
	Dry			Cold water (24h)			Boiling (6h)		
F	0,2631			1,1582			4,7762		
p	0,7693			0,3190			0,0108		

SS, Shear strength; 5º P, fifth percentile; WF, wood failure. Values in parentheses represent the percentage variation coefficient.

Regarding the pre-treatment at 6h boiling, there was a statistically significant difference between the genetic materials and in the interaction of genetic material x fertility, therefore, this interaction was unfolded and presented in Table 6.

Table 6: Average results of glue line shear strength - unfolding of fertilization x genetic material interactions for boiling pretreatment (6h).

	CLO			SEM				
	SS (MPa)	5º P (MPa)	WF (%)	SS (MPa)	5º P (MPa)	WF (%)	F	*P*
CF	3,50 (32,60) Aa	2,07	28	3,66 (42,90) Aa	1,29	11	0,1190	0,7390
SRF	3,88 (19,24) Aa	2,59	39	3,74 (30,50) Aa	2,41	19	0,958	0,7576
CONTROL	4,11a (24,79) Aa	2,89	38	2,44 (61,77) Bb	0,82	14	13,8749	0,0004
F	0,9355			5,2644			-	-
p	0,3964			0,0070			-	-

SS, Shear strength; 5ºP, fifth percentile; WF, wood failure. Averages followed by the same letter do not differ statistically from each other, by Tukey test at 95% reliability; Being: lowercase in rows and uppercase in columns. Values in parentheses represent the coefficient of variation in percentage.

The discussion will be described in terms of Table 5 and Table 6, but each effect studied will be presented separately.

For the effect between genetic materials, in the dry test, observed in Table 5, it is noted that the highest average value was from seminal genetic material 8,71 MPa, the clonal one showed 8,58 MPa. In the 24-hour cold water pre-treatment, the averages were identical at 5,51 MPa, and both in the dry test and in the cold water immersion test, the prerequisite of EN 13353 (2008) of 2,50 MPa was met, indicating suitability for indoor use.

In the 6-hour boiling pre-treatment, the clonal genetic material showed a superior result, with 3,83 MPa, and the seminal with 3,28 MPa, showing a statistically significant difference between them, but they do not meet the prerequisites required for the result of the 5th percentile, thus, it is stated that in the conditions of external use, the use of these panels is not indicated, when evaluated only by the genetic material in question. The ramifications with respect to fertilization treatments will be discussed later.

The difference in average results between the seminal and clonal material in the pre-treatment for external use raises a discussion point that is rarely addressed in the literature. To some extent, it can only be meaningfully compared and analyzed based on the data from this study, particularly in relation to dendrometric, volumetric, chemical, and physical properties. However, as this observation did not occur in the cold water pre-treatment, it is likely that this behavior is not a trend but a characteristic of the sampling performed. It is also evidenced by the existing gap caused by not carrying out anatomical analyses, but this is presented as a suggestion for future studies.

For the effect between the different fertilizations, in the results observed in Table 5, in relation to the specimens without treatment (dry), the highest average value was that of slow fertilization, followed by the conventional and the control material. In the 24-hour cold water pretreatment, the averages did not follow this order, being repeated in the 6-hour boiling test. Thus, it was not possible to observe a clear trend.

Another observation about this pretreatment regarding external use is that only slow fertilization met the prerequisites of EN 13353 (2008). Both in the dry pre-treatment and in the 24-hour cold water immersion, all fertilizations, including the control, meet the requirements of the aforementioned standard.

Just as the clonal genetic material aims, among other objectives, at an increase in volume, the application of fertilizers in a certain way does too. Therefore, in the wood bonding quality, an analogous behavior was expected in the relationship (clonal x seminal) with the behavior (fertilized x without fertilization). However, despite the glue line resistance average being higher in treatments with genetic material that received slow-release fertilization, this advantage cannot be affirmed because there was no statistically significant difference between fertilizations in any pre-treatment.

As the behavior and quality of the gluing is highly influenced by the density of the wood, some authors have already tried to correlate the effect of different fertilization treatments with the density of the wood, which, in a way, presented itself without a standard behavior, or even without influence.

In a study by (Barbosa *et al.* 2014), studying the effect of fertilization on the wood quality of four eucalyptus clones, the authors observed that only one clone showed an increase in specific mass in treatment with fertilization, the others showed a reduction in this variable. (Sette Junior *et al.* 2014), evaluating the changes in the quality of rose gum (*Eucalyptus grandis* W.Hill) wood caused by mineral fertilization, noticed that the trees that received potassium and sodium application did not undergo significant changes in the average apparent density of the wood.

Regarding the effect of the genetic material x fertilization interaction, a statistically significant difference was found in this interaction only in the pre-treatment of external use (boil for 6 hours), so after unfolding in the results of Table 6, it is possible to conclude that the material from clones with both slow-release fertilization and without fertilization (control), met the prerequisites of EN 13353 (2008), but the others did not.

Another fact is the inferiority of the resistance of the glue line in the material from seeds and without fertilization, which presented the lowest result in relation to the genetic material and the other tested fertilizers, presenting a statistically significant difference in the interaction analysis. The fact that the material with conventional fertilization application did not present satisfactory results, was not expected and cannot be correlated with the results previously achieved in terms of physical and chemical properties.

Even so, the results are consistent and allow the use of this wood for outdoor applications with protection, guaranteeing its durability and performance, and also allowing the use of a product with greater added value, coming from young trees, for use in sawmills and other technological purposes, where the quality of the lumber is essential.

The results in Table 5 and Table 6 are similar to recent works with other species of the *Eucalyptus* spp. genus and loblolly pine (*Pinus taeda* L.).

About the gluing of *Eucalyptus* spp. with EPI adhesive, (França *et al.* 2020) obtained values between 8,45 MPa and 12,77 MPa for the dry pre-treatment and for the wet pre-treatment, values between 5,96 MPa and 8,84 MPa using 15-year-old woods.

The average values for the glue line shear results found by (Iwakiri *et al.* 2021) from big badja gum (*Eucalyptus badjensis* Beuzev. & M.B.Welch) at 13 years of age, using EPI adhesive with a weight of 180 g/m² and a pressure of 1 MPa, it was 11,58 MPa for the dry test and to 4,57 MPa for the 24 hours immersion in water test.

In relation to loblolly pine (*Pinus taeda* L.) and bonding with EPI, (Lau 2017) found average results for the glue line's shear strength of 5,31 MPa (dry); 3,42 MPa (cold water 24 hours), and 2,31 MPa (boiling 6 hours), and (Lopes *et al.* 2013) found 8,15 MPa and 3,24 MPa, respectively, for the dry and wet test.

Finally, it is feasible to affirm that the treatment with the greatest aptitude for the production of EGP panels was the one that included clonal trees that received slow-release fertilization.

CONCLUSIONS

Eucalyptus dunnii wood, originating from clonal and fertilized genetic material, presented the best dendrometric and volumetric results.

Regarding the properties of the wood, the genetic material significantly affected the density, but no significant effect was observed on dimensional stability. Fertilization significantly affected both density and dimensional stability. The chemical properties were influenced by both the genetic material and fertilization.

The genetic material and fertilization did not significantly affect the bonding quality. Edge glued panels produced with both clonal and seminal genetic material, and regardless of whether or not fertilizer was used, were approved for use in dry conditions (Solid Wood Panel 1 – SWP1).

The treatment (wood) with the greatest suitability for the production of EGP panels was the one that included clonal trees that received slow-release fertilization.

It is possible to add value to young *Eucalyptus dunnii* wood (8.5 years), uncommon in sawmills, through the production of edge glued panels.

Fertilization and genetic improvement are practices that promote not only the quality and growth of trees, but also the technological use of wood, thinking about higher value and added products and the multiple use of planted forests, because EGP panels produced from clonal trees and which received slow-release fertilization showed greater aptitude for production.

AUTHORSHIP CONTRIBUTIONS

A.C.B.B.: Formal analysis, investigation, methodology, visualization, project administration, writing – original draft. R.T.: Conceptualization, methodology, resources, visualization, project administration, supervision, writing – review & editing. S.I: Resources, writing – review & editing. A.C.A.: Resources, visualization, writing – review & editing.

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