

PLANT RESIDUES AS AN ALTERNATIVE FOR SUBSTRATE COMPOSITION IN THE PRODUCTION OF *Eucalyptus grandis* SEEDLINGS

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Resumo

*Resíduos vegetais como alternativa para a composição do substrato na produção de mudas de *Eucalyptus grandis*.* A seleção de constituintes para formulações de substratos é de fundamental importância quando se busca a produção de mudas de qualidade. O objetivo deste trabalho foi avaliar o crescimento inicial de mudas de *Eucalyptus grandis*, utilizando casca de café carbonizada e *in natura*, esterco bovino, fibra de coco e casca de arroz carbonizada como constituintes de substrato, em diferentes combinações. Como tratamento controle foi utilizado o substrato comercial Maxfértil. O experimento foi instalado em viveiro, em delineamento de blocos casualizados, constituído de oito tratamentos e quatro repetições, com unidade amostral de 16 mudas. Para avaliar a qualidade das mudas formadas, foram medidas as variáveis biométricas, biomassa vegetal e também foi realizada a caracterização das propriedades físicas e químicas dos substratos formulados, em relação às características das mudas produzidas. Foram utilizadas análises qualitativas, avaliando-se a facilidade de retirada das mudas do tubete e a agregação das raízes ao substrato. Após a análise dos dados, constatou-se que o uso da casca de café foi adequada para produção de mudas de *Eucalyptus grandis* para a maioria das variáveis analisadas, com valores superiores às mudas formadas no tratamento controle. Dessa forma, indica-se a casca de café como constituinte alternativo de substratos para a produção de mudas da referida espécie.

Palavras-chave: esterco, fibra de côco, casca de arroz carbonizada, casca de café carbonizada, casca de café *in natura*.

Abstract

Selecting constituents for substrate formulations is of fundamental importance for the production of quality seedlings. The objective of this work was to evaluate the initial growth of *Eucalyptus grandis* seedlings, using carbonized and fresh coffee husks, cattle manure, coconut fiber and carbonized rice husks as substrate constituents, in different combinations. As a control treatment, the commercial substrate Maxfértil was used. The experiment was set in a nursery, in a randomized block design, consisting of eight treatments and four replications, with a sample unit of 16 seedlings. To evaluate the quality of the seedlings formed, the biometric variables, and plant biomass were quantified and the characterization of the physical and chemical properties of the formulated substrates was also carried out, regarding the characteristics of the seedlings produced. Qualitative analyses were used, where the ease of removing the seedlings from the tube and the aggregation of the roots to the substrate were assessed. After data analysis, it was found that the use of coffee husks was adequate for the production of *Eucalyptus grandis* seedlings for most of the analyzed variables, with higher values than the seedlings formed in the control treatment. Thus, coffee husks are indicated as an alternative constituent of substrates for the production of seedlings of the referred species.

Keywords: carbonized coffee husks, carbonized rice husks, coconut fiber, fresh coffee husks, manure.

INTRODUCTION

Because of the increasing demand for wood products, the formation of productive forest stands is necessary (MUNGUAMBE *et al.*, 2020). To satisfy this demand, it is necessary to plant highly productive species, which allow a relatively short-cutting cycle, associated with good silvicultural characteristics adopted, from the initial phase to growth in the field (SANTOS *et al.*, 2010; MIQUELONI *et al.*, 2013).

Among the species cultivated for commercial purposes, those of the genus *Eucalyptus* stand out, particularly for their characteristics of rapid growth, productive capacity, and adaptability in different environments (FERREIRA *et al.*, 2017). However, for the formation of productive systems, it is necessary to produce quality seedlings, which directly interferes with the final production (SILVA *et al.*, 2020).

For the formation of quality seedlings, several factors must be considered, among which, the substrate stands out. It has the function of sustaining the seedling and providing adequate conditions for its growth (UYOH

et al., 2016). The material used as a constituent of the substrate must be easily accessible and low cost, free of invasive plant seeds, pests, and pathogens, as well as good physical and chemical characteristics (KRATZ *et al.*, 2013a; ABREU *et al.*, 2017).

Regarding the formulation of substrates, it is common to mix several constituents, to form a substrate with suitable conditions (SOUSA *et al.*, 2016), which can facilitate the development of the root system and promote the growth of seedlings. Among the most used constituents in the formulations are: manure, carbonized rice husk, coconut fiber, vermiculite, peat, sawdust, and sewage sludge biosolids (SILVA *et al.*, 2012). However, it is recommended to select low-cost and easily accessible components, near the seedling production site.

Therefore, the option for regional constituents is indicated, as in addition to the simplicity of obtaining the material, the final cost of seedling production can be reduced (MELO *et al.*, 2014; SILVA *et al.*, 2020). Among the residues with the potential to be used as constituents of the substrate, coffee husk stands out, which can be obtained in several Brazilian states that cultivate this crop (SILVA *et al.*, 2020). Among the coffee-producing states in Brazil, Minas Gerais stands out as a major producer (CONAB, 2018), generating a significant amount of waste at the end of its processing. This material presents the possibility of being used as a constituent in this region, and replacing materials that are more difficult to be obtained, due to the distance and high freight prices.

The use of coffee husks as a constituent of the substrate can generate a series of benefits to nature, providing a reduction in the volume of waste, which in many cases is simply discarded in nature. It can reduce the final cost for the producer in the seedling production process and also contribute to improving the physical-water relations of the formulated substrates (SILVA *et al.*, 2021).

In search for new constituents for substrate formulations, and to propose alterations that allow adequate growth and quality in the production of seedlings, the objective of this work was to evaluate the effect of alternative substrates in different combinations, for the production of *Eucalyptus grandis* seedlings.

MATERIALS AND METHODS

The experiment was conducted from August 2018 to March 2019 at the Forestry Nursery of the Federal University of Lavras, located in the city of Lavras, Minas Gerais, Brazil, with the following coordinates: latitude 21° 14'19,6 "S and longitude 44°58'28,5" W, 905 meters above sea level. According to the Köppen-Geiger classification, the climate in the region is of the Cwa type, with dry winter and rainy summer, where the temperature of the hottest month is greater than 22°C, with an average temperature of 19.9°C, and average annual precipitation of 1486 mm (ALVARES *et al.*, 2013). In the experiment, (carbonized and fresh) coffee residues were evaluated, as well as carbonized rice husks, cattle manure, and coconut fiber, in different combinations for the production of *Eucalyptus grandis* L.

Production of the constituents for substrate formulation

The coffee husk used in the experiment was acquired through a donation from INOVACAFE, from waste generated in the collection of coffee from its experimental fields, located within UFLA. The rice husk was obtained from producers close to the seedling production region. Cattle manure was provided by a rural producer from a farm close to the nursery. It was collected from dairy cow pens, previously selected and tanned for 30 days. The coconut fiber and the commercial substrate were purchased in the city of Lavras, in fertilizer stores.

Coffee and rice husks, both fresh, were submitted to the carbonization process in the open air. In an open area in the UFLA forest nursery, 500 L of the coffee by-product was added. This was heaped evenly around the base of a carbonizer and then fired on the sides of the carbonizer. With the aid of a shovel and hoe, the material was handled until complete carbonization and subsequently spread. At the end of the carbonization process, water was sprinkled on the carbonized material, with the aid of a hose, to put out any traces of fire. The same procedure was applied to the carbonization of rice husks.

After obtaining the constituents for the composition of the substrates, the proportions of each one were determined, according to the objectives of the project. Immediately, the mixture was made according to the proportion intended for each treatment. For better growth of the seedlings, during the mixture of the constituents, slow-release fertilizer (Osmocote) was added in the proportion of 4 kg m⁻³ of the substrate.

The experiment was set up in a randomized block design, consisting of eight treatments and four replications, with a sample unit of 16 seedlings. The evaluated treatments were prepared from mixtures of the following sources: bovine manure (MN), coconut fiber (CF), carbonized rice husks (CRH), carbonized coffee husks (CCH), and fresh coffee husks (FCH). As a control, the commercial substrate Maxfértil was used, consisting of carbonized pine bark, vermiculite, lime, and NPK 4-14-8 (Table 1).

Table 1. Volumetric proportion of the materials (%) used as compounds of alternative substrates for the production of *Eucalyptus grandis* seedling.

Tabela 1. Proporção volumétrica dos materiais (%) utilizados como compostos de substratos alternativos para produção de mudas de *Eucalyptus grandis*.

Treatments	Volumetric proportion of the materials %				
	MN	CF	CRC	CCH	FCH
T1	30	20	50	0	0
T2	30	20	30	20	0
T3	30	20	20	30	0
T4	30	20	0	50	0
T5	30	20	30	0	20
T6	30	20	20	0	30
T7	30	20	0	0	50
T8	commercial substrate 100%				

Where: Manure (MN), Coconut fiber (CF), carbonized rice husk (CRH), carbonized coffee husk (CCH), fresh coffee husk (FCH)

Physical-chemical analysis of the substrates

For physicochemical characterization, the samples of the formulated substrates were sent to the Substrate Laboratory of the Department of Horticulture and Forestry at the Federal University of Rio Grande do Sul (UFRGS). For the chemical characterization of the substrates, evaluations of the hydrogen potential (pH) determined in water, dilution 1:5 (v/v), and electrical conductivity (EC) obtained in solution 1:5 (v/v) were carried out, according to the methodology described in Normative Instruction No. 17, of May 21, 2007 (MAP, 2007). For the physical analysis, wet density (DU), dry density (DS), total porosity (TP), and water holding capacity (WHC) under suction of 10, 50, and 100 cm were evaluated.

Eucalyptus grandis seedling production

Seeds were obtained from the seed bank of the Department of Forestry Sciences at the Federal University of Lavras, provided by the Laboratory of Forest Seeds. For the production of seedlings in the nursery, the seeds were sown in 55-cm³ tubes, and then placed in plastic trays, where they were supported on supports suspended at 80 cm from the ground.

Sowing was carried out in September 2018, directly in the tubes, placing three to four seeds per tube. Subsequently, the seeds were covered with the same substrate used to fill the containers. At 15 days after germination, thinning was performed, leaving one seedling per tube, selecting the one with the greatest vigor and the most centralized one. During the experiment, the seedlings were irrigated using a micro-sprinkler system, three times a day.

At 90 days, the seedlings were interchanged, a process applied to reduce the seedlings' competition for water, light, and nutrients. During the production process, cleaning was carried out, removing weeds from the tubes, which could harm the growth of the seedlings. Every 15 days, the seedlings were fertilized with KCl (potassium chloride) and MAP (monoammonium phosphate), at a dose of 100 g and 1000 g, respectively, diluted in 100 L of water, being applied with the aid of a watering can, directly on the seedlings.

Morphological and qualitative characterization of *Eucalyptus grandis* seedlings

To evaluate the influence of substrates on seedling growth, the survival rate (S) was evaluated 30 days after germination. Measurements of morphological characteristics were also made, such as the height of the aerial part (H) by measuring at the substrate level until the insertion of the last leaf, with a ruler graduated in centimeters and diameter (D) also at the substrate level, using a caliper digital graduated in mm. These evaluations were made at 30, 60, 90, and 120 days.

At 120 days after germination, four seedlings per treatment were selected. They presented values closer to the mean for the variables diameter and height. So, the simplicity of removing the seedlings from the tubes and aggregation of the roots to the substrate was evaluated, according to the methodology described by Wendling *et al.* (2007).

For the ease of removing the seedlings from the tubes, grades from one to ten were given after three taps on the top of the tube, where the lowest grade was the maximum difficulty and the highest was the best ease of removing the seedlings. To evaluate the aggregation of the roots to the substrate, the seedlings were released in

free fall about one meter from the ground. For the aggregation, a score from one to ten was assigned, one being for the substrate that was crumbly and ten for the substrate that remained intact.

Destructive analyses of the seedlings were carried out, where the roots were washed in running water to remove the substrate, and the aerial part of the root system was also separated. Then, these materials were duly identified and packed in paper bags and placed in an oven for 72 hours at a temperature of 65°C. Afterwards, they were weighed on an analytical balance with a precision of 0.001g, to obtain the dry mass of the area (APDM) and dry mass of the roots (RDM). Subsequently, with the quantification of the APDM and RDM, the total dry mass (TDM) was calculated.

After data collection, the relationship between the height of the seedlings and the diameter of the collar (H/D) was evaluated, as well as the relationship between the dry mass of the aerial part and the dry mass of the root system (RMSPAR). The Dickson Quality Index (DQI) was also calculated (DICKSON *et al.*, 1960):

$$IQD = \frac{TDM \text{ (g)}}{H(\text{cm})/D \text{ (mm)} + APDM \text{ (g)}/RDM(\text{g})}$$

Where: TDM is the total dry matter; H is the height; D is the diameter; APDM is the aerial part dry matter; and RDM is the root dry mass.

Statistical analysis

The data obtained were subjected to analysis of normality, using the Shapiro-Wilk test at a 5% probability of error. Subsequently, an analysis of variance was used to assess the influence of the treatments used. For these analyses, the Tukey test at 5% error probability was used, using the SISVAR software, version 5.6 (FERREIRA, 2019).

RESULTS

Statistical analysis

According to the results of the chemical analyses, the treatment that presented the highest pH value was T3 (7.98). All other treatments based on manure, coconut fiber, carbonized rice husks, carbonized coffee husks, and fresh coffee husks showed similar results. The control treatment (T8) presented the lowest result (5.53), according to the analyses carried out in this experiment (Table 2).

Table 2. Physical-chemical analysis of the substrates formulated for the production of *Eucalyptus grandis* seedlings.

Tabela 2. Análise físico-química dos substratos formulados para produção de mudas de *Eucalyptus grandis*.

Parameters	Unit	Treatments							
		T1	T2	T3	T4	T5	T6	T7	T8
pH	-	7.35	7.28	7.98	7.57	7.62	7.69	7.97	5.53
CE	mS cm ⁻¹	0.72	0.93	1.00	1.27	0.82	1.05	1.06	0.23
DU	kg m ⁻³	258.03	406.82	283.19	396.14	271.13	265.73	247.84	625.47
DS	kg m ⁻³	221.29	240.08	231.37	271.88	221.61	222.37	203.67	308.80
PT	%	82.74	86.93	78.41	78.62	79.78	70.42	66.76	85.49
CRA (10)	%	38.81	45.97	50.03	43.99	36.98	32.79	30.13	57.32
CRA (50)	%	24.30	30.76	32.18	32.21	29.48	26.95	26.01	37.90
CRA (100)	%	23.77	30.00	31.49	31.65	28.93	26.44	25.69	35.66

Where: pH = hydrogen potential; EC = electrical conductivity; DU = wet density; DS = dry density; PT = total porosity; CRA = water retention capacity at 10, 50, and 100 cm.

In the evaluation of the electrical conductivity (EC), the highest result was obtained in the T4 treatment (1.27 mS cm⁻¹), with values close to the other treatments based on manure, coconut fiber, carbonized rice husk, carbonized coffee husk, and in nature. The lowest value was observed in the T8 control (0.23 mS cm⁻¹). Overall, there were no large variations in EC levels in most treatments, except the control.

Regarding wet density (DU) and dry density (DS), all substrate values based on manure, coconut fiber, carbonized rice husk, carbonized coffee husk, and fresh coffee husk achieved values between 203 kg m⁻³ and 403 kg m⁻³. In contrast, the control (100% commercial substrate) achieved a DU of 625.47 kg m⁻³, exceeding the value of 500 kg m⁻³, which is the maximum DU limit, according to Nogueira *et al.*, (2014). In the evaluation of DS, the

control treatment presented a value of 308.80 kg m⁻³, being superior to the other formulations.

The treatments that showed the highest porosity (TP) of the combinations used were treatments T2 and T8, while the lowest was T7, with values of 86.93%, 85.49%, and 66.76% respectively. Substrates based on manure, coconut fiber, carbonized rice husks and carbonized coffee husks showed higher porosity values. The porosity value was reduced as the proportion of fresh coffee husks was increased. These values were observed mainly in treatments T6 and T7.

The results of water retention in 10 cm of water column showed that the lowest value obtained was in treatment T7 (30.13%) and the highest was in T8 (57.32%). For the water retention capacity at 50 and 100 cm, the treatment with the highest value was the T8 control, with 37.9% and 35.66%, respectively. The lowest value was obtained at T1, with 24.30% at 50 cm and 23.77% at 100 cm (Table 2). Considering a range between 24% and 40% for this variable, most formulations reached adequate levels.

Survival, height, and diameter of the *Eucalyptus grandis* seedlings

In the evaluation of seedling survival, a significant difference was verified by the analysis of variance between the evaluated substrates (Table 3). It is observed that the seedlings produced in the control treatment (T8) presented statistically different values from the treatments T1, T2, T3, T6, and T7. Nevertheless, it was similar to the data from T4 and T5.

Table 3. Mean squares and survival values (S), diameter (D) at 60, 90, and 120 days, and height (H) at 30, 60, 90, and 120 days after germination of *Eucalyptus grandis* seedlings.

Tabela 3. Quadrados e valores médios de sobrevivência (S), diâmetro (D) aos 60, 90 e 120 dias, altura (H) aos 30, 60, 90 e 120 dias após a germinação das mudas de *Eucalyptus grandis*.

Mean squares			Days after germination								
T	DF	S	30		60		90		120		S
			S	D	S	D	S	D	S	D	
T	7	239.78*	8.56*	0.58*	28.57*	0.42ns	98.05*	0.50*	137.30*		
Mean	-	90.04	5.17	1.58	10.67	2.20	18.55	2.90	27.10		
Cv	-	8.11	11.9	17.19	11.18	20.48	21.09	4.52	13.34		
Mean values											
T		S	30 D		60 D		90 D		120 D		
			S	D	S	D	S	D	S	D	
T1		93.75a	5.58 a	1.65 a	10.84 ab	2.28 a	21.10 a	3.02 a	26.81 a		
T2		93.75 a	5.48 a	1.67 a	10.75 ab	2.25 a	21.83 a	2.99 a	27.41 a		
T3		90.62 a	5.19 a	1.94 a	10.57 a	2.19 a	22.58 a	2.96 a	29.17 a		
T4		85.94 ab	5.39 a	1.69 a	10.98 ab	2.52 a	22.06 a	3.00 a	29.01 a		
T5		89.06 ab	6.32 a	1.80 a	13.37 a	2.47 a	25.91 a	3.22 a	33.17 a		
T6		95.31a	6.24 a	1.71 a	12.65 a	2.29 a	22.29 a	3.06 a	28.51 a		
T7		98.44 a	5.44 a	1.54 a	11.61 ab	2.41 a	23.51 a	3.09 a	29.33 a		
T8		73.44 b	1.69 b	0.68 b	4.53 c	1.42 b	9.37 b	2.07 b	13.37 b		
CV%		8.11	11.90	17.19	11.18	20.48	21.09	4.52	13.34		

Where: * = significant at 5% probability of error; ns = not significant at the 5% error probability level by the F analysis; DF degrees of freedom; CV experimental coefficient of variation. The same letters in the column mean equal to a 5% probability of error, according to the Tukey test.

In the evaluation of growth in height, the statistical analysis for the evaluations at 30, 60, 90, and 120 days revealed a significant difference between the eight treatments. It was considered that for 30, 90, and 120 days, the T8 control was statistically different from the other formulations, where the seedlings produced in this substrate presented much lower values when compared with the seedlings of the other treatments.

According to the growth trend in height, the seedlings from the other treatments showed upward growth. As a result, all formulations reached adequate levels for the production of *Eucalyptus grandis*. There was no statistically significant difference between treatments based on manure, coconut fiber, carbonized rice husks, and fresh coffee husks.

In evaluating the growth in diameter of *Eucalyptus grandis* seedlings, the statistical analysis at 60, 90, and 120 days revealed a significant difference between the eight treatments. For these periods, the seedlings

produced with the alternative constituents showed higher values when compared to the control (T8), thus demonstrating that these alternative constituents are more suitable for the production of seedlings of this species than the commercial substrate used.

Relationship between height and collar diameter (H/CD), aerial part dry mass (APDM), root dry mass (RDM), total dry mass (TDM), and aerial part dry mass/root relationship (APRDMR).

According to the height/diameter relationship of the collar, dry mass of the aerial part, dry mass of roots, and total dry mass, the data revealed in all cases a significant difference among the eight treatments. On the other hand, the aerial part /root dry mass ratio did not result in a significant difference among treatments (Table 4).

Table 4. Mean squares and mean values of the height/collar diameter ratio (H/D), aerial part dry mass (APDM), root dry mass (RDM), total dry mass (TDM), aerial part /root mass ratio (APRDMR) of the *Eucalyptus grandis* seedlings.

Tabela 4. Quadrados médios e valores médios da relação altura/diâmetro do coleto (H/D), massa seca da parte aérea (MSPA), massa seca de raiz (MSR), massa seca total (MST), relação massa parte aérea/raiz (RMSPAR) das mudas de *Eucalyptus grandis*.

Mean squares						
T	DF	H/D	APDM (g)	RDM (g)	TDM (g)	APRDMR (g)
T	7	5.38*	0.52*	0.07*	0.97*	0.38ns
Mean	-	9.13	1.12	0.56	1.68	2.04
Cv	-	11.85	13.39	23.29	13	23.21

Mean values				
Treatments	H/D	APDM (gr)	RDM (gr)	TDM (gr)
T1	8.84 ab	1.13 a	0.54 ab	1.67 a
T2	9.18 a	1.10 a	0.56 a	1.66 a
T3	9.82 a	1.24 a	0.56 a	1.80 a
T4	9.66 a	1.27 a	0.54 ab	1.81 a
T5	10.28 a	1.45 a	0.67 a	2.13 a
T6	9.31 a	1.22 a	0.62 a	1.85 a
T7	9.47 a	1.29 a	0.67 a	1.96 a
T8	6.46 c	0.27 b	0.25 c	0.52 b
CV%	11.85	13.39	23.29	13.00

Where: * = significant at 5% probability of error; ns = not significant at the 5% error probability level by the F analysis; DF degrees of freedom; CV experimental coefficient of variation. The same letters in the column mean equal to a 5% probability of error, according to the Tukey test.

According to the height/diameter ratio of the H/D, an average of 6.6 and 8.1 are considered adequate values for the production of *Eucalyptus grandis*. Therefore, according to this variable, all treatments have the potential to produce seedlings of this species. However, it can be observed that the seedlings cultivated in the control treatment (T8) presented a value of 6.46, which is considered low, mainly because of the lower growth in height, not representing a good value for H/D.

Regarding dry mass of the aerial part (APDM) and total dry mass (TDM), there was a statistical difference between treatments, where T8 differed from the others, obtaining the lowest values for this characteristic, demonstrating that the seedlings conducted in this formulation had growth below expectations.

For root dry mass (RDM), the T8 control (0.25 g) was statistically different from the other treatments. Regarding this variable, no clear preference response was observed for any of the components of the alternative substrates. It can be seen that the control treatment, formulated with a commercial substrate, was the least efficient, as it was observed for the other characteristics.

Dickson Quality Index (IQD), Simplicity in removing seedlings from tubes (SRS), and Aggregation Index (AGR)

The statistical analysis showed that the Dickson Quality Index (DQI) showed a significant difference among the treatments (Table 7), where the T8 control presents the lowest value (0.07) and differs from the other substrate combinations with means greater than 0.15.

Table 5. Squares and mean values of the Dickson's quality index (IQD), simplicity in seedling removal (SRS), and aggregation index (AGR) of the nursery production of *Eucalyptus grandis*.

Tabela 5. Quadrados médios do índice de qualidade de Dickson (IQD), facilidade de remoção de mudas (FRT) e índice de agregação (AGR) das mudas de *Eucalyptus grandis*.

		Mean squares		
T	DF	DQI	SRS	AGR
T	7	0.00*	0.12ns	0.25ns
media	-	0.14	9.8	9.89
cv	-	18.59	3.65	2.68

Where: * = significant at 5% error probability level; ns = not significant at the level of 5% error probability. DF degrees of freedom; CV= coefficient of variation.

Thus, all treatments based on manure, coconut fiber, carbonized rice husks, carbonized coffee husks, in fresh coffee husks, in their different combinations, presented a minimum average of 0.15, showing the possibility of producing *Eucalyptus grandis* seedlings in these proportions. Regarding the simplicity of removing the seedlings from the tubes (SRS) and the aggregation index (AGR), no significant difference was found among treatments.

DISCUSSION

When relating the chemical analysis data with the formed seedlings, a small difference is observed in the pH among the treatments based on plant residues; however, a remarkable difference was found regarding the T8 control. The latter was considered the least favorable to seedling growth. Farias *et al.* (2012) recommend that the substrates used in the production of seedlings of forest species is in the range of 6.0 to 7.0. These variables are important to assess the quality of seedling production, as they directly interfere with nutrient absorption, an essential factor for seedling growth in the initial phase. Values off the desired pH range can impair substrate quality and negatively affect seedling growth.

It was observed that the mixture of different substrates contributed to rising the electrical conductivity of the substrate, compared to the commercial substrate, which coincides with the data found by Farias *et al.* (2012), who evaluated the physicochemical characteristics of the substrates, pointing out that these combinations produce a synergistic reaction, causing an increase in the conductivity of the substrate to acceptable levels.

Density is an important parameter in assessing substrate quality for the production of forest seedlings (Silva *et al.*, 2020). According to Nogueira *et al.* (2014) and Wendling *et al.* (2007), the formulations that form denser substrates tend to have less space between the particles, which hinders gas exchange and water circulation, offering greater resistance to root growth. This information may be related to the substrate quality of the T8 treatment (control), which presented higher density and probably hindered root growth, negatively affecting seedling growth in this treatment.

Regarding the total porosity, the data were similar to those found by Silva *et al.* (2020), who, in the evaluation of constituents based on coconut fiber, composted rice husk, composted coffee husk, and commercial substrate, in different formulations, for the production of *Eucalyptus urophylla* seedlings, obtained values between 85.8% and 87.7%, with the use of alternative constituents, considering these values adequate for the elaboration of substrates for the species. This fact may be related to the similarity of the constituents used in the treatments, in which when there was a combination of light materials, consisting of rice husks and coffee, the results were better. These data corroborate Sousa *et al.* (2016), who recommend mixing different materials in the formulations to formulate a substrate with ideal conditions to promote seedling growth.

Total porosity is an important parameter in the formulation of substrates. The formulation of the substrate used must be porous enough to allow efficient gas exchange (SILVA *et al.*, 2020), avoiding the lack of oxygen to breathe and the activity of microorganisms. However, in substrates with greater porosity, the nurseryman must have greater control over the irrigation used, to avoid flooding and even reduce the root growth of the seedlings (WENDLING *et al.*, 2007; SILVA *et al.*, 2020).

The water retention capacity can affect the quality of the substrate, through which it is possible to plan more adequate management of irrigation, a fundamental factor in the production of seedlings. The water retention capacity varies according to the characteristics of the constituents used in the substrate formulation (Silva *et al.*, 2020). Wendling *et al.* (2007) mention that substrates with low WRC need more irrigation time, in contrast, for substrates with high CRA, the amount of irrigation must be controlled, as the seedling can be damaged by excess moisture. This factor could be inferred in the T8 treatment, in which the high WRC value can be one of the causes of the quality of the substrate, which negatively affected the growth of the *Eucalyptus grandis* seedlings.

Many factors interfere with the germination and survival of a seed. Exploring the data referring to the control treatment, based on a commercial substrate, seedlings with a lower percentage of germination and survival were presented. This probably occurred because the substrate exceeded the maximum limit of wet density (NOGUEIRA *et al.*, 2014), which contributed negatively to the initial phase of growth of seedlings of this species.

Data from the experiment show that the first height assessment was not enough to influence the characteristics of the constituents. Thus, the results of measurements taken before the final evaluation may not be sufficient, since a small variation in the growth trend was obtained between previous evaluations. These data corroborate those found by Kratz *et al.* (2013b) who, when evaluating the measures of *Eucalyptus benthamii* at 30, 60, and 90 days, observed a better prediction of this characteristic in the last evaluation. This will certainly vary according to the species, its genetic material, the type of management adopted, and the growth characteristics of each one.

As for the tendency to grow in height, all alternative substrates show favorable results, with values greater than 15 cm, being indicated for planting in the field (WENDLING and DUTRA, 2016). The data obtained are in agreement with Kratz *et al.* (2013b), who evaluated the growth in height of *Eucalyptus benthamii*, and demonstrated a significant difference between the evaluated substrates, for all evaluation periods (30, 60, and 90 days), using alternative components.

Regarding the diameter, Wendling and Dutra (2016) point out that the minimum diameter for the seedlings to be shipped must be 2 mm, which is consistent with the values observed in the present experiment. Similar values in diameter (2.14 to 3.21 mm, after 110 days of sowing) were also found by Melo *et al.* (2014), for *Eucalyptus grandis* seedlings, when evaluating different substrate formulations, which contained tanned manure, carbonized rice husks, and coconut fiber, constituents with characteristics similar to those used in this work.

As for the results of APDM, RDM, and H/D ratio, it was observed that the use of alternative constituents provided greater support for root growth, as well as greater development of the aerial part. This indicates that the combinations based on carbonized and fresh coffee husks in this work were suitable for the growth of seedlings of this species, corroborating data obtained by Kratz *et al.* (2013a) and Silva *et al.* (2020), which evaluated similar materials and obtained satisfactory data.

By relating the data on the removal of seedlings from tubes (SR) and aggregation of seedlings to the substrate (AGR), it is clear that rooting is directly related to SRS. The evaluated data brought favorable results for the production of *Eucalyptus grandis* seedlings, using carbonized coffee husks, and fresh coffee husks in their different combinations as constituents, which promote good root aggregation and easy SRS, allowing greater agility in the dispatching process of the seedlings for the field (WENDLING *et al.*, 2007; SILVA *et al.*, 2020).

Substrates with good rooting guarantee, through the solid phase, the mechanical maintenance of the root system, and guarantee the water-air balance, establishing in the liquid phase the supply of water, nutrients, and the gaseous supply of oxygen, facilitating the development of the roots. These data are similar to those found by Pagliarin *et al.*, (2017) who found in their results, an adequate state of aggregation for *Eucalyptus grandis* seedlings, produced with substrates based on sugarcane fibers, carbonized rice husks and vermiculite waste.

Regarding the Dickson Quality Index, it should be considered that each species behaves differently, its value is also influenced by the type of constituent used as a substrate, by the way the seedlings are managed in the nursery, in addition to other aspects. In this work, it was observed that all treatments, except T8 (control), were suitable for seedling growth, due to the characteristics offered by alternative materials. The advantage of using IQD lies in the fact that this parameter brings together several variables in a single index, and the higher its value, the better the quality of the seedling produced (CALDEIRA *et al.*, 2014; SANTOS *et al.*, 2017).

In general, the seedlings formed in the alternative constituents were taller than 20 cm at 120 days, except for the control treatment seedlings. The seedlings also had adequate diameter, well-developed aerial parts, and roots, and vigorous appearance, being indicated for planting in the field. Thus, the constituents of the coffee husk in its carbonized and fresh form, appear as an alternative option for the production of *Eucalyptus grandis* seedlings.

CONCLUSIONS

- All treatments based on plant residues, used as alternative substrates, showed the potential to be used as alternative constituents in the production of *Eucalyptus grandis* seedlings.
- The treatments with proportions of carbonized and fresh coffee husks, in all combinations, showed the potential to be used in the production of *Eucalyptus grandis* seedlings when compared to the control, with the best proportion being chosen according to the availability of the region and the purchase cost.

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