

Production of *Eucalyptus urograndis* plants cultivated with activated biochar

Danieli Lazarini de Barros¹, Fabiana Abreu de Rezende², Alessandro Torres Campos³

¹ Instituto Federal de Roraima, Boa Vista, RR, Brazil. E-mail: danieli.lazarini@gmail.com (ORCID: 0000-0003-3037-943X)

² Embrapa Agrosilvipastoral, Sinop, MT, Brazil. E-mail: fabiana.rezende@embrapa.br (ORCID: 0000-0001-7631-7897)

³ Universidade Federal de Lavras, Departamento de Engenharia, Setor de Construções Rurais e Ambiente, Lavras, MG, Brazil. E-mail: campos@deg.ufla.br (ORCID: 0000-0002-4653-9453)

ABSTRACT: The search for new substrates for the production of seedlings is of great importance for the evolution of the nursery sector. Biochar is an alternative for the use of plant residues, both in soils and as a component of substrates. The main objective of the study was to correlate substrates using biochar (B) and substrates using activated biochar (AB) in different concentrations with biometric and nutritional variables, aside from its effect on the growth of *Eucalyptus* seedlings. The experiment was conducted in a nursery, located in Sinop, MT, Brazil. The experiment was design in four blocks of ten treatments; commercial substrates (CS), nursery substrate (NS - 50% CS and 50% carbonized rice husk and coconut fiber) and eight treatments represented by B and AB additions to each commercial substrate (concentration of 25; 50, 75 and 100% - determined as B25, B50, B75, B100, AB25, AB50, AB75, AB100). At the end of a 90 days cycle after staking, plant height, stem diameter, leaf number and Dickson Quality Index (DQI), fresh and dry biomass accumulation and nutrient concentration in the aerial part were determined. The substrates with activated biochar and the nursery substrate presented superior results for biometric variables.

Key words: sawdust; substrates; waste

Produção de mudas de *Eucalyptus urograndis* cultivadas com carvão vegetal ativado

RESUMO: A busca por novos substratos para a produção de mudas é de grande importância para a evolução do setor de viveiros. O biocarvão é uma alternativa para aproveitamento de resíduos vegetais, tanto nos solos como na forma de componente de substratos. O objetivo do trabalho foi comparar o efeito de diferentes substratos comerciais com o carvão vegetal sobre o crescimento de mudas de *Eucalyptus urograndis*, em condições de viveiro florestal. O delineamento experimental utilizado foi o de blocos ao acaso, sendo os tratamentos constituídos por dez substratos: substrato do viveirista (50% substrato comercial, 50% casca de arroz carbonizada e fibra de coco), substrato comercial (Mec Plant[®]) e oito tratamentos com carvão vegetal não ativado e ativado adicionados no substrato comercial em diferentes concentrações, (B25, B50, B100, BA25, BA50, BA75, BA100) com 4 repetições. Ao final do ciclo (90 dias após o estaqueamento), determinou-se a altura, diâmetro do coleto, índice de qualidade de Dickson (IQD), o acúmulo de massa fresca e seca e a concentração de nutrientes na parte aérea. Os substratos com biocarvão ativado e o substrato do viveirista apresentaram resultados superiores para as variáveis biométricas analisadas.

Palavras-chave: pó de serra; substratos; resíduos

Introduction

The final destination of organic waste from agricultural and industrial activities is a constant concern of society, since it can cause several damages to the environment, such as soil and water reserves contamination.

Wood industry generates large amounts of waste, especially sawdust. One alternative to its use is the production of biochar that can return to the sector of agricultural activities, as well as being used in nursery as a substrate component. One species that can benefit from the use of biochar in its production chain is *Eucalyptus* spp., this species presents national and international demand, given its importance for the supply of wood for several purposes, besides reducing the pressure of the exploration of native species.

Eucalyptus is considered important because it has high productivity, a reduced growing cycle and high flexibility to the edaphoclimatic conditions. Consequently, it's the most cultivated genus worldwide (Gonçalves et al., 2008). Brazil presents a growing area of 7.4 million hectares of eucalyptus plantation (IBGE, 2017).

The *Eucalyptus* genus has over 600 species, from which it is possible to obtain products for various purposes, such as wood for coal, cellulose and paper, use in furniture industry, extraction of essential oils, fence posts, sleepers, poles, among others (Mora & Garcia, 2000). However, the success of *Eucalyptus* implantation begins with obtaining good quality seedlings, guaranteed in part by the grown substrate, nutritional and hydric management.

Biochar is a carbon rich product obtained from the thermal decomposition of organic materials in absence or minimal presence oxygen atmosphere at temperatures ranging from 300 to 1000°C (Zhang et al., 2015), in a process known as pyrolysis. It is also considered a soil conditioner, due to its physical-chemical characteristics, and it can be applied to soil (Lehmann, 2009; Petter et al., 2012), aside from its use in capturing atmospheric CO₂ (Mukherjee et al., 2011).

In the production of biochar, any source of biomass can be carbonized (Maia & Sohi, 2010), being considered as an advantage, due to the availability and ease in finding residues for its manufacture. Agroindustry and forestry waste are the main sources of biomass in Brazil, and about 597 million tons of waste are produced yearly from the main crops, such as soybean, corn, sugarcane, rice, cassava, citrus and from forest activities (Ferreira-Leitão et al., 2010). In addition, it's considered a strategy for integrated environmental benefits, associating clean energy production, waste recycling and C storage at soil (Novotny et al., 2015).

Biochar presents a porous, reactive structure and appropriate physical and hydraulic properties. It increases water retention and aeration, conditioning an environment more favorable to the development of seedlings (Souza et al., 2006; Verheijen et al., 2010; Marimon-Júnior et al., 2012). It can be applied as substrate component for the production of forest seedlings.

In this context, the objective of the study was to compare the effect of different commercial substrates with activated biochar on the growth of *Eucalyptus urograndis* plants under forest nursery conditions.

Material and Methods

The experiment was conducted at Flora Sinop nursery, from May to July 2013. The nursery is located in Sinop, Mato Grosso, Brazil and geographical location of 11 ° 52 '23" South, 55 ° 29' 54" West, 384 m above sea level. The mean annual temperature is 24.0 °C, annual rainfall of 1900 mm and relative humidity ranging between 35 and 80% throughout the year (Souza et al., 2012).

The biochar used in this trial was produced from sawdust from native species obtained from timber industries located in Sinop/MT region. The sawdust was processed in a slow pyrolysis reactor (vertical furnace), with 25 minutes of residence time in the oven, at 450 °C to obtain the biochar.

For the making of activated biochar, the temperature of the pyrolysis reactor (horizontal tubular oven) was set to 650 °C, with 60 minutes of residence time under steam injection during the production process.

The different substrate compositions were homogenized with an electric mixer and chemical slow release fertilizers were added equally for all treatments (225g Basacote® 6M (time of release of nutrients, 6 months), 225g Basacote® 3M (time of release of nutrients 3, months), and 600g FH Eucalipto Heringer® to 150 L of substrate). The composition of Basacote® 6M and Basacote® 3M was 16-08-12 NPK, with micronutrient content of Mg-2%, S-5%, Fe-0.4%, B-0.02%, Zn- 0.02%, Cu - 0.05% and Mn - 0.06%; the composition of FH Eucalipto Heringer® was 4-31-4 NPK, containing Zn - 0.4% and Co - 22%, respectively.

The activation treatment was carried out with the purpose of eliminating residues from the pyrolysis process, unclogging the pores of the biochar and allowing the availability of organic radicals on the surface of the biochar.

For the production of eucalyptus (*Eucalyptus grandis* X *Eucalyptus urophylla*) seedlings, minicuttings of dimensions, ranging from 4 to 6 cm, were collected in the mini-clonal hedges and staked by minicutting method. Plastic tubes of 53 cm³ of capacity were used for the seedlings.

The experiment was maintained under controlled conditions, at 30 °C and relative humidity above 80%. The seedlings were irrigated twice a day.

Ninety days after staking, the morphological parameters of the seedlings were evaluated. The height of the seedlings was measured with a millimeter ruler positioned at substrate level to the apical meristem of each seedling, while the stem diameter of the seedling was measured with a digital pachymeter.

The plant material was divided into aerial part (leaves and stem) and root. The root system was separated from the substrate by a stream of water. The material was then packed in paper bags and placed in forced air circulation oven at

65 °C until reaching a constant mass, and then weighed on a precision scale to determine the dry biomass of the aerial part, roots and total dry biomass.

After collecting the shoot dry biomass (SDB) and root dry biomass (RDB) values, the Dickson Quality Index (DQI) was calculated. It is determined as a function of the height of the aerial part, stem diameter, dry shoot, root and total dry biomass, according to the following Equation 1 (Dickson et al., 1960).

$$QID = \frac{TDB}{\frac{\text{height}}{\text{stem}} + \frac{SDB}{RDB}} \quad (1)$$

considering, DQI – Dickson Quality Index; TDB – total dry biomass (g); SDB – shoot dry biomass (g); RDB - root dry biomass (g); height (cm) and stem diameter (mm).

The aerial part (leaves) were milled with Willey-type knives and sent to the laboratory for analysis of macronutrients.

The plastic tubes were kept in trays containing 40 seedlings each, but only 10 central plants were evaluated, thus avoiding the edge effect. The experiment was designed in four blocks, with ten treatments each, totaling 40 experimental plots. The treatments are shown in Table 1.

Table 1. Substrate composition.

Treatments	Substrate composition
CS	Pine bark and vermiculite (4:1, m/m) (Mec Plant®)
NS	50% CS and 50% carbonized rice husk and coconut fiber (1:1, m/m)
AB25	25% AB with 75% CS
B25	25% B with 75% CS
AB50	50% AB with 50% CS
B50	50% B with 50% CS
AB75	75% AB with 25% CS
B75	75% B with 25% CS
AB	100% AB
B	100% B

CS – commercial substrate; NS – nursery substrate; AB – activated biochar; B – biochar.

Table 3. Height (H), stem diameter, total fresh biomass (TFB), total dry biomass (TDB), Dickson Quality Index (DQI) and number of leaves (Leaves) of *Eucalyptus urograndis* plants as a function of substrates (SUB).

SUB	H (cm)	IN ¹ %	Stem (mm)	IN ² %	TFB (g)	IN ³ %	TDB (g)	IN ⁴ %	DQI	IN ⁵ %	Leaves
CS	12.90 b		1.70 b		1.81 b		0.44 b		0.03 b		8.22 a
NS	14.11 a		1.92 a		2.79 a		0.65 a		0.05 a		7.97 a
AB25	14.84 a	17	1.92 a	21	2.46 a	32	0.60 a	37	0.04 a	50	8.97 a
B25	12.33 b		1.51 b		1.66 b		0.38 b		0.02 b		6.30 b
AB50	14.40 a	10	1.98 a	18	2.20 a	40	0.55 a	42	0.04 a	50	8.12 a
B50	13.01 b		1.63 b		1.32 b		0.32 b		0.02 b		7.47 a
AB75	14.17 a	7	1.88 a	14	2.53 a	32	0.61 a	20	0.05 a	40	8.32 a
B75	13.16 b		1.62 b		1.72 b		0.49 b		0.03 b		7.55 a
AB	15.68 a	24	2.04 a	70	3.04 a	70	0.74 a	70	0.06 a	67	7.65 a
B	11.97 b		1.62 b		0.92 b		0.22 b		0.02 b		6.20 b
CV%	7.03		7.00		29.39		27.08		27.29		31.72

*Means followed by the same letter do not differ by the Scott-Knott test ($p \geq 0.05$). CS – Commercial Substrate. NS- Nursery substrate. AB25; AB50; AB75 and AB - biochar activated at proportion of (25, 50, 75 and 100%). B25, B50, B75 and B - biochar without activation at doses (25, 50, 75 and 100%); ^{1,2,3,4,5} Increments of the biometric variables in the different proportion of biochar. CV: coefficient of variation

The physical characteristics of the substrate are shown in Table 2.

The chemical composition of the AB group was 10% phenol, 40% lactose, 50% carboxyl groups. The B group was composed of 49% phenol, 21% lactose and 30% carboxyl groups.

All data was submitted to the average test Scott-Knott at 5% probability using the statistical program SISVAR (Ferreira, 2011). All data was submitted to Principal Component Analysis (PCA) to identify which morphological and leaf parameters correlated with the substrates analyzed. The program used was Info-Gen.

Table 2. Physical characteristics of the substrate.

Substrates	Real density	Apparent density	Porosity %
	(g cm ⁻³)		
CS	1.16	0.47	59
NS	1.02	0.15	85
AB	1.67	0.24	85
B	1.27	0.31	75

CS – commercial substrate; NS – nursery substrate; AB – activated biochar; B – biochar.

Results and Discussion

The NS and treatments using activated biochar (AB) showed superior results when compared with biochar (B) only. NS and AB (25, 50, 75 and 100%) groups presented the best results for height, stem diameter, total fresh biomass (TFB), total dry biomass (TDB) and DQI. Results did not differ statistically between themselves (Table 3). B25 and B groups presented the lowest values when the number of eucalyptus seedlings were evaluated.

With the increase of the amount of AB group present at substrate, no difference between the biometric variables were seen. However, when AB and B groups were compared in the same concentration, AB results were increased (17, 10, 7 and 24%); (21, 18, 14, 70%); (32, 40, 32, 70%); (37, 42, 20, 70%); (50, 50, 40, 67%) in height, stem diameter, TFB, TDB and DQI, respectively (Table 3).

The values of height and total dry biomass (TDB) were higher than those found by Oliveira et al. (2014), who

evaluated substrates containing 50% carbonized rice husk and 50% vermiculite thin and found 11.69 cm height and 0.304g TDB for *Eucalyptus grandis* X *Eucalyptus urophylla*. Our values were lower than those found by Melo et al., (2014), who worked with farmyard manure with carbonized rice husks for *E. grandis* and by Batista et al. (2014), who evaluated solid residue urban composite for *E. urophylla*. However, height and stem diameter values were close to those determined by Gomes et al. (2002), who established values of 15 to 30 cm for shoot height and a minimum value of 2.0 mm for stem diameter for *E. grandis* seedlings.

Biochar activation also showed influence on DQI, ranging from 0.04 to 0.06 and corroborating the results of Batista et al. (2014). The higher the DQI, the better the quality of the seedling produced. However, the DQI is a variable characteristic that depends on the species studied, the management of seedlings in the nursery, the type and proportion of the substrate, the volume of the container and, mainly, on the age at which the seedlings were evaluated (Caldeira et al., 2012; Eloy et al., 2013; Gomes et al., 2013).

Analyzing macronutrients (N contents of the aerial part of the eucalyptus seedlings), the substrates with AB did not differ from the NS, B25 and CS groups (Table 4). As the dose of AB were increased, the contents of N did not change. In relation to P, AB presented the highest content of the N element.

There was no difference in treatments AB25, AB and B for the K⁺ contents. The higher the concentration of the biochar in the substrate, consequently, the higher content of said element, due to the pyrolysis process, where there is high ash production, which are rich in K⁺. Fengel & Wegener (1984) reported that the main components of wood ash are potassium, calcium and magnesium.

CS, AB25 and AB75 presented higher Mg²⁺ contents than the other substrates. However, Ca²⁺, AB25, B25, AB50 and AB were considered the best treatments.

In the AB obtention process, the chemical composition of the AB showed that there was a reduction of phenolic

Table 4. Analysis of macronutrients of aerial part of *Eucalyptus urograndis* plants as a function of substrates at 90 days after staking.

Substrates	N	P	Macronutrients (g kg ⁻¹)		
			K ⁺	Mg ²⁺	Ca ²⁺
CS	11.92 a	3.20 b	7.18 b	4.16 a	5.81 b
NS	11.32 a	3.25 b	7.00 b	3.61 c	6.51 b
AB25	12.22 a	3.32 b	7.36 a	4.02 a	7.75 a
B25	11.00 a	3.18 b	7.03 b	3.84 b	7.41 a
AB50	11.92 a	3.37 b	7.12 b	3.86 b	7.37 a
B50	10.15 b	2.88 c	6.84 b	3.61 c	6.62 b
AB75	11.62 a	3.28 b	6.71 b	4.13 a	6.83 b
B75	9.85 b	2.60 c	6.92 b	3.91 b	6.31 b
AB	11.42 a	3.92 a	7.74 a	3.07 d	7.27 a
B	9.65 b	2.71 c	7.50 a	3.20 d	6.22 b
CV%	6.09	5.46	5.46	3.75	8.19

Means followed by the same letter do not differ by the Scott-Knott test ($p \geq 0.05$). CS – Commercial Substrate. NS- Nursery substrate. AB25; AB50; AB75 and AB - biochar activated at proportion of (25, 50, 75 and 100%). B25, B50, B75 and B - biochar without activation at doses (25, 50, 75 and 100%); CV: coefficient of variation

substances, conferring a greater lability to the substrate, which improves the nutritional availability of the said substrate, consequently gauging improvements in the biometric variables of the seedlings. The higher lability of the substrate, the higher the rate of mineralization, implying a higher cation exchange capacity. Consequently, there was an increase of specific surface, which facilitates the action of mineralizing microorganisms (Downie et al., 2009; Bruun et al., 2012).

AB presented higher porosity when compared to B (Table 2). The higher the porosity, the higher the aeration, and the values were within the optimal level (above 85%), as established by Abad et al. (1993) for seedling production.

By the analysis of apparent density, AB (0.24 g cm⁻³) presented lower value than B (0.31 g cm⁻³). The results corroborate the optimal levels determined by Abad et al. (1993), which should lie between 0.45 to 0.55 g cm⁻³, and Reis (2007), which should be a value lower than 0.4.

Substrate density is a fundamental physical property to be considered, since it is inversely proportional to porosity. As density increases, a restriction to the growth of the roots of the plants may occur (Singh & Sinju, 1998).

The principal component analysis (PCA) showed a separation by different substrates, due to the morphological parameters and the nutritional contents of the eucalyptus seedlings (Figure 1). This differentiated composition between the studied substrates can be observed in the PCA diagram (Figure 1), in which the first two axes accounted for 74% of total variance (PCA1 = 57.9% and PCA2 = 16.1%), considered appropriate, according to Cruz et al. (2004).

It was verified that the NS, AB25, AB50 and AB75 were separated from the other studied groups, composing a

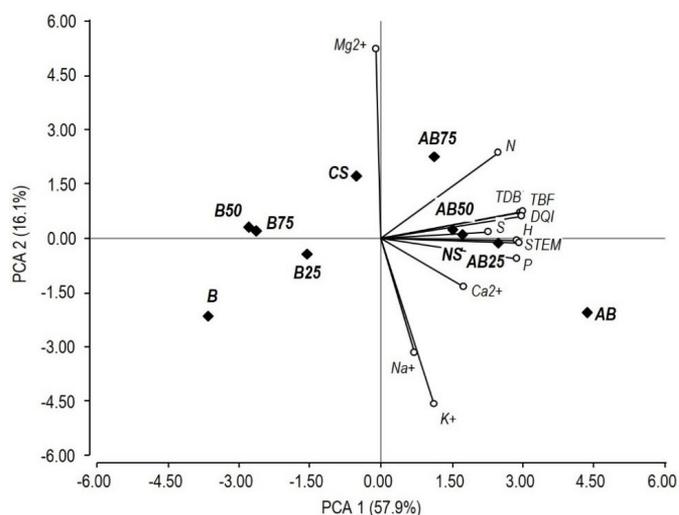


Figure 1. Ordering diagram of the Principal Component Analysis (PCA) of the 10 types of substrates used. Biochar and Activated Biochar at doses 25, 50, 75 and 100% (B25, B50, B75, B); (AB25, AB50, AB75, AB), the commercial substrate (CS) and nursery substrate (NS) with the morphological parameters of the eucalyptus plants – stem diameter, height, Dickson Quality Index (DQI) and total dry biomass (TDB), total fresh biomass and leaf analysis (N, P, K⁺, Ca²⁺, Mg²⁺, Na⁺).

grouping of analyzed parameters, mainly explained by TFB, TDB, stem diameter, height (H), DQI, P, S, Ca²⁺ and N, all close to the same quadrant.

Conclusions

The substrates with activated biochar and nursery substrate presented superior results for height, stem diameter, TFB, TDB and DQI when compared with biochar. The increase in activated biochar concentration did not influence the biometric variables.

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