ISSN 2175-6813

Revista Engenharia na Agricultura

Viçosa, MG, DEA/UFV - DOI: 10.13083/reveng.v29i1.11236 v.29, p.236-244, 2021

PRODUCTION OF EUCALYPTUS SEEDLINGS USING ALTERNATIVE SUBSTRATES

Paulo Henrique Frata Ferreira[1], Vitor Corrêa de Mattos Barretto[1], Renato Nallin Montagnolli[2] & Paulo Renato Matos Lopes*[1]

1 - São Paulo State University, College of Agricultural and Technological Sciences, Department of Crop Production, Dracena, São Paulo, Brazil

2 - Federal University of São Carlos, Agricultural Sciences Center, Department of Natural Sciences, Mathematics and Education, Araras, São Paulo, Brazil

Keywords:
Coconut fiber
Corymbia citriodora
Fertilization
Sustainability
Vermicompost

ABSTRACT

The efficiency of forest species production is associated with the seedlings quality. Hence, the substrate used is a determining factor in crop productivity, such as eucalyptus. Thus, the physical and chemical parameters of alternative and sustainable substrates were evaluated using coconut fiber and vermicompost in the production of *Corymbia citriodora* seedlings. Plants performance and quality were also evaluated by determining plant biomass and Dickson's quality index, with or without mineral supplementation during cultivation. Results revealed that the proposed substrates obtained good physical and chemical characteristics when compared to a commercial substrate. The fertilization of seedlings showed to be essential in the production of more vigorous and better quality plants. The best quality *C. citriodora* seedlings was produced in the commercial substrate. However, it is worth highlighting the seedlings performance using alternative substrates such as coconut fiber and vermicompost, which represent a great potential for improvement, mainly due to its low cost and the observed result regarding the possible availability of nutrients in a gradual and constant way during the plants development.

Palavras-chave:
Adubação
Corymbia citriodora
Fibra de coco
Vermicomposto

PRODUÇÃO DE MUDAS DE EUCALIPTO UTILIZANDO SUBSTRATOS ALTERNATIVOS

RESUMO

A eficiência da produção de espécies florestais está intimamente associada à qualidade das mudas. Neste contexto, o substrato utilizado na produção das mudas é um fator determinante na produtividade da cultura, como o eucalipto. Assim, foram avaliados os parâmetros físicos e químicos de substratos alternativos e sustentáveis, fibra de coco e vermicomposto, na produção de mudas de *Corymbia citriodora*. O desempenho e a qualidade das plantas também foram avaliados pela determinação da biomassa vegetal e do índice de qualidade de Dickson, com presença ou não de suplementação mineral durante seu cultivo. Os resultados revelaram que os substratos obtiveram boas características físico-químicas quando comparados a um substrato comercial. A adubação das mudas revelou ser essencial na produção de plantas mais vigorosas e de melhor qualidade. As mudas de *C. citriodora* de melhor qualidade foram produzidas com substrato comercial. Porém, vale destacar o desempenho vegetal nos substratos alternativos com fibra de coco e vermicomposto apresentaram um grande potencial para aperfeiçoamento, principalmente pelo baixo custo e pelo resultado observado, como possível disponibilização de nutrientes de forma gradual e constante durante o desenvolvimento das plantas.

SECTION EDITOR IN CHARGE
André Pereira Rosa

Received 07 Oct, 2020 • Accepted 16 Jun, 2021 • Published 22 Sep, 2021

Email (corresponding author)*: prm.lopes@unesp.br

INTRODUCTION

The forest sector is of great importance in the Brazilian economy. This activity generates about 3.75 million jobs in the country, with gross revenue of R$ 97.4 billion in 2019, which represents a growth of 12.6% compared to the previous year (IBÁ, 2020). In addition, the forest sector is responsible for 12.5 billion dollars in exports, equivalent to 5.2% of total Brazilian exports (RABELO *et al*., 2020).

Seeking to improve yields in the sector, more technological researches are being performed for the production of eucalyptus seedlings with good performance and quality (ROSA *et al*., 2002; STEFFEN *et al*., 2011). In this context, the substrate can represent a high-cost component in the system, beyond the possibility of generating impacts on the environment (KLEIN, 2015). Therefore, the use of alternative substrates in the production of forest seedlings has stood out for its efficiency, economy and sustainability.

The scarcity of natural resources increases the search for alternative materials for the productive sector, which must be easily obtainable, stable, low cost, homogeneous, ecologically viable, with good physical, chemical and biological characteristics, beyond to meet the needs of the vegetable to be produced (KLEIN, 2015). There are several commercial products and ecological strategies to obtain a good quality substrate, being the association of organic compounds with the soil a highly viable alternative. Therefore, agroindustrial residues available on a large scale in Brazil represent a sustainable option in the composition of sustainable substrates for the production of forest seedlings (FONSECA, 2001).

According to Steffen *et al*. (2011), the vermicompost is a material from the reuse of waste and with potential for other uses. The authors highlighted that its use has a positive effect on the production of eucalyptus seedlings in up to 50 % when compared to other substrates. Vermicompost is extremely rich in humidified organic matter and nutrients, and its use is associated with other inert material (SILVA *et al*., 2013; FERREIRA *et al*., 2020). Thus, its association with another easily obtainable residue can be possible, which highlights the sustainable application of this substrate: coconut fiber. According to Rosa *et al*. (2002), 80 to 85% of the raw weight of green coconut is discarded. The green coconut husk fiber has been used as a raw material in the production of substrates because it is an inert material and has high porosity (CARRIJO *et al*., 2002).

Thus, the aim of this study was to evaluate the physical and chemical parameters of an alternative substrate associating vermicompost and coconut fiber. Furthermore, the application of mineral supplementation on these substrates for the production of eucalyptus seedlings was evaluated.

MATERIAL AND METHODS

The experiment was performed in the seedling nursery of the municipal government of Dracena (SP) and in the Faculty of Agricultural and Technological Sciences of Unesp, campus of Dracena, coordinates 21º28’57” south latitude and 51º31’58” west longitude, with an average altitude of 400 m, in the period between January and May 2020.

Description of substrates and experimental design

The alternative substrates were composed of vermicompost (VC) and coconut fiber (FC). The vermicompost was produced from the reuse of domestic organic waste in vermicomposters containing earthworms of the species *Eisenia foetida*. For its use, this material was dried and homogenized. Coconut fiber was produced from healthy fruits of *Cocos nucifera*, being used in natura form without the need for treatment. The commercial Carolina Soil® substrate was also used for comparison purposes.

The experiment was performed in a completely randomized design with four treatments: T1 (85-15% FC-VC); T2 (75-25% FC-VC); T3 (65-35% FC-VC) and T4 (100% commercial). Fertilization was divided into two groups: with and without mineral supplementation. Thus, eight treatments were performed with 15 replicates each.

The proportions of substrate per treatment as well as the seedling production procedure were performed according to Ferreira *et al*. (2020). The sowing was performed manually and directly with six seeds of *Corymbia citriodora* in each tube. The seedlings were cultivated for 105 days (t_{105}), and the thinning was performed on the 14th day. After that, three analyses of physicochemical characterization of the proposed substrates with association between vermicompost and coconut fiber, in addition to the commercial one, were performed: total porosity, apparent density and electrical conductivity.

Substrate characterization

The determination of porosity and apparent density was performed according methodology described by Guerrini and Trigueiro (2004), with soaking and drying of the substrates. Thus, the total porosity and apparent density of substrates were obtained from Equations 1 and 2, respectively.

$$Total\ Porosity = \frac{(wet\ weight - dry\ weight)}{tube\ volume} * 100 \quad (1)$$

$$Apparent\ Density = \frac{dry\ weight}{tube\ volume} \quad (2)$$

The electrical conductivity of the substrates was measured in two stages: before planting (t_0) and at the end of the evaluation (t_{105}) with the two groups: with and without mineral supplementation. First, 2.6 g of substrate in 20.8 ml of deionized water was added (ratio 8:1). After homogenization, electrical conductivity determinations were performed in the aqueous extract using a Digimed® conductivity meter - model DM.

Evaluation of the performance and quality of the produced seedlings

At the end of the period (t_{105}), the *C. citriodora* seedlings were also evaluated according to their performance and quality. Then, evaluations of fresh and dry biomass of shoot (SDB) and root (RDB) were performed. For the determination of plant biomass, the shoot was initially separated from the roots to obtain fresh biomass. Then, these materials were placed in paper packaging and dried in an oven at 65 °C until they reached a constant mass, representing the dry biomass. After its quantification, the relationship between SDB and RDB was calculated.

The final evaluation of the quality of the seedlings produced in each treatment was performed using the Dickson Quality Index – DQI (DICKSON *et al*., 1960), as described by Equation 3. Besides considering the dry biomass of the seedlings, this factor included the height (H) and the stem diameter (D) of the plants.

$$DQI = TDB/(H/D) + (SDB/RDB) \quad (3)$$

Statistical analysis

The results were analyzed by performing analysis of variance (ANOVA), simple correlation and contrasts at 5.0 % probability for the comparison of means, using the Microcal® Origin 8.0 software.

RESULTS AND DISCUSSION

Total porosity and apparent density of substrates

The determination of the total porosity and apparent density of the associations between vermicompost and coconut fiber and the commercial substrate is shown in Table 1.

In relation to total porosity, we observed that the lowest concentrations of vermicompost in the substrate had higher values, with T1 (15 %

Table 1. Total porosity and apparent density of substrates

Treatments	Parameters			
	Total porosity (%)		Apparent density (g cm-³)	
T1	69.99 ± 4.00	a	0.157 ± 0.004	a
T2	60.34 ± 2.41	ab	0.145 ± 0.003	ab
T3	55.06 ± 7.04	b	0.131 ± 0.01	b
T4	55.40 ± 3.44	b	0.137 ± 0.01	ab

*Means followed by the same letter in columns do not differ by the Tukey test (p>0.05). Treatments composition (% coconut fiber-vermicompost): T1 (85-15); T2 (75-25); T3 (65-35) and T4 (commercial substrate) of vermicompost) being statistically different from T3 and T4 (Table 1). Porosity indicators are important to evidence the presence of pores in the substrates that are responsible for gas exchange, drainage pattern and water movement (ZORZETO *et al*., 2014).

Therefore, the green coconut shell powder is able of retaining practically five times more water than its dry weight, thus presenting a great water retention capacity (ROSA *et al*., 2002). This fact highlights the quality of this material as a sustainable alternative to substrate composition, having adequate physical characteristics for the production of forest seedlings (CARRIJO *et al*., 2002).

In Table 1, we can observe similar results regarding the apparent density of the substrates. The highest value was found in T1, followed by T2 and T4 with values 7.6 % and 12.7 % lower, respectively. However, these results were not statistically different. Only the 35 % vermicompost substrate (T3), with apparent density 16.6 % lower, presented statistical significance when compared to T1 (15 % vermicompost). Although substrates with a greater presence of organic matter have lower apparent density (ZORZETO *et al*., 2014), the present work did not show any significant difference between substrates.

In general, we can observe that the alternative substrates showed similar results to the commercial substrate (Table 1). This fact highlights the good physical characteristics of the association between coconut fiber and vermicompost for the production of eucalyptus seedlings, since it can be compared to the commercial substrate used (Carolina Soil®), which represents a consolidated product in the market (FERREIRA *et al*., 2020).

Electrical conductivity of substrates

Electrical conductivity is measured by the amount of ions present in the solution. The greater the concentration of these electronic species, the greater the electrical conductivity value. Thus, this analysis indirectly provides information on the amount of salts in solution, being the most practical way to assess whether or not there is a need to add salts (HIGASHI *et al*., 2002).

All proposed substrates were evaluated according to their electrical conductivity in two distinct stages: before sowing and after 105 days of seedling development. For this last phase, the substrates were differentiated in the groups without and with fertilization (Table 2).

The initial electrical conductivity showed to be much lower in alternative substrates (T1, T2 and T3), when compared to T4 (Table 2). At the end of the evaluation without fertilization, only T3 had a significant difference when compared to the other treatments, showing a lower value (93.01 µs cm^{-1}). Observing Table 2, it is evident that the alternative substrates increased electrical conductivity even without receiving mineral fertilizer, unlike the commercial substrate.

In the final evaluation with mineral supplementation, the results were significantly higher in the substrates that presented the highest

Table 2. Electrical conductivity of substrates at the initial and at the end of experiment (105 days) with and without fertilization

Treatments	Electrical conductivity (µs cm^{-1})					
	Initial day 0		Without fertilization 105 days		With fertilization 105 days	
T1	26.77 ± 0.95	Cb	261.05 ± 22.88	Ba	708.167 ± 62.97	Ac
T2	27.57 ± 4.27	Cb	260.75 ± 6.88	Ba	1082.00 ± 59.27	Ab
T3	34.45 ± 4.73	Cb	93.01 ± 14.22	Bb	1482.67 ± 141.71	Aa
T4	769.46 ± 14.67	Aa	257.5 ± 0.93	Ba	749.43 ± 30.56	Ac

** Different lowercase letters in columns and uppercase letters in rows indicate significant differences by the Tukey test (p<0.05).Treatments composition (% coconut fiber-vermicompost): T1 (85-15); T2 (75-25); T3 (65-35) and T4 (commercial substrate)* amount of vermicompost, T3 (1482.67 µs cm^{-1}) and T2 (1082.00 µs cm^{-1}). Furthermore, T4 did not show statistical difference compared to its initial electrical conductivity (Table 2).

According to Gonçalves and Benedetti (2000), electrical conductivity values above 1000 µs cm^{-1} can cause damage to eucalyptus seedlings, especially during initial development. In Table 2, the initial and final results for the group without fertilization revealed that all substrates were within this limit.

For alternative substrates, electrical conductivity increased significantly at the end of the evaluation period, even when the seedlings did not receive any type of mineral supplementation (Table 2). This result encourages the use of vermicompost in substrates, as plants need to be managed with this staggered availability of nutrients (DORES-SILVA *et al*., 2013).

The process of slow release of nutrient is even more evident by the results of the commercial substrate, without the presence of vermicompost. This treatment (T4), when not fertilized, decreased its electrical conductivity at the end of the evaluation. Thus, it is a more inert substrate and with nutrients readily available to vegetables.

Finally, T2 and T3 presented electrical conductivity values above those recommended at the end of the evaluation period, when there was fertilization (GONÇALVES; BENEDETTI, 2000). This is a positive result, since the alternative substrates had a lower requirement for mineral supplementation, which indicates to the producer an economy not only in obtaining the substrate, but also in the number of fertilizers needed.

Corymbia citriodora seedling biomass

The results of dry biomass of shoot (SDB) and root (RDB) of eucalyptus seedlings are shown in Table 3.

The lowest values for SDB and RDB were found in seedlings that did not receive fertilization. Still in Table 3, we can observe that the commercial substrate (T4) was the only one that showed a significant difference with higher values for dry biomass, with or without mineral supplementation.

We can verify that higher proportions of vermicompost in the substrate promote a negative effect on RDB in *Corymbia citriodora* seedlings (Table 3). This result may be associated with the high concentration of nutrients available in these substrates with earthworm humus. Thus, the development of the root system is discouraged, as already observed in the production of seedlings of other forest species (ANDREAZZA *et al*., 2013; SILVA *et al*., 2017).

However, several authors have also reported lower averages of fresh and dry biomass of forest seedlings, such as eucalyptus, when the compost proportion in the substrate was higher (ARTUR *et al*., 2007; ANDREAZZA *et al*., 2013; KRATKA; CORREIA, 2015; SILVA *et al*., 2017).

According to Parviainen (1981), the SDB/RDB ratio is considered an efficient and safe factor that

Table 3. Dry biomass of shoot and root of *C. citriodora* seedlings after 105 days of development

Treatments	**Shoot dry biomass / g**			
	Without fertilization		**With fertilization**	
T1	0.02± 0.00	Bb	0.50 ± 0.01	Ab
T2	0.02 ± 0.01	Bb	0.53 ± 0.07	Ab
T3	0.02 ± 0.00	Bb	0.58 ± 0.13	Ab
T4	0.15 ± 0.03	Ba	1.07 ± 0.15	Aa
Treatments	**Root dry biomass / g**			
	Without fertilization		**With fertilization**	
T1	0.02± 0.00	Bb	0.09 ± 0.02	Ab
T2	0.01 ± 0.00	Bb	0.09 ± 0.02	Ab
T3	0.01 ± 0.01	Bb	0.10 ± 0.03	Ab
T4	0.06 ± 0.01	Ba	0.20 ± 0.03	Aa

*lowercase and uppercase letters indicate a significant difference between meanss in columns and in rows, respectively (Tukey's test $p<0.05$).
Treatments composition (% coconut fiber-vermicompost): T1 (85-15); T2 (75-25); T3 (65-35) and T4 (commercial substrate)

expresses the quality standard of seedlings. Thus, this ratio was calculated for the eight proposed systems and its results are shown in Table 4.

As shown in Table 4, the group with fertilization presented statistically higher values of the SDB/RDB ratio in relation to those without fertilizers. However, when fertilized, the plants did not differ significantly. In treatments without fertilization, the commercial substrate (T4 = 2.81) was not statistically different from T3 (1.66).

In Table 4 is shown that all alternative substrates that associated coconut fiber and vermicompost and had mineral supplementation did not differ from the commercial substrate, following the same quality standard of the seedlings. Knowing that the unfavorable balance between root and shoot may be related to the height of these seedlings (GURTH, 1976), the high values found can be explained by the low production of root biomass found.

Quality of Corymbia citriodora seedlings

The Dickson Quality Index (DQI) is also an important parameter in determining the quality of seedlings. In Table 5 is shown the observed results.

We can observe that seedlings produced without fertilizer had statistically lower values compared to those with mineral supplementation. However, treatments without fertilization did not show any significant difference between them.

Among the DQI values in treatments with fertilization, the one with commercial substrate stands out. Therefore, through the index, this result indicates that seedlings produced in T4 have higher quality, since this factor indicates the robustness and balance of plant biomass (DICKSON *et al*., 1960).

Studies on DQI threshold values that lead quality seedlings are scarce in the literature (LIMA *et al*., 2017). However, Binotto (2007) indicated the minimum value of this index at 0.05, for the eucalyptus species *Eucalyptus grandis*. Thus, only the treatment with 15 % vermicompost (T1) and fertilization was below this value, and all treatments without supplementation did not reach this threshold.

When seedlings are produced in places with greater shading, they can develop more in relation to height, but this result in worse values for the DQI (FONSECA *et al*., 2002). This result may be related to the results found for the Dickson quality index, since the seedlings remained in a shaded nursery until the 50th day of evaluation and only after that were taken to a place with a higher incidence of sunlight.

There are several studies about the Dickson quality index in the production of eucalyptus seedlings using different species and types of substrates. In Table 6 is shown a comparison of the result of substrate with 35 % vermicompost (T3)

Table 4. Shoot and root dry biomass ratio of *C. citriodora* seedlings after 105 days of development

Treatments	Ratio SDB/RDB			
	Without fertilization		With fertilization	
T1	1.49 ± 0.26	Bb	5.41 ± 0.78	Aa
T2	1.44 ± 0.41	Bb	5.91 ± 1.26	Aa
T3	1.66 ± 0.61	Bab	5.79 ± 1.46	Aa
T4	2.81 ± 0.63	Ba	5.37 ± 0.98	Aa

*lowercase and uppercase letters indicate a significant difference between means in columns and in rows, respectively (Tukey's test p<0.05). Treatments composition (% coconut fiber-vermicompost): T1 (85-15); T2 (75-25); T3 (65-35) and T4 (commercial substrate)

Table 5. Dickson quality index of *C. citriodora* seedlings after 105 days of development

Treatments	DQI			
	Without fertilization		With fertilization	
T1	0.006 ± 0.002	Ba	0.040 ± 0.006	Ab
T2	0.007 ± 0.007	Ba	0.059 ± 0.034	Ab
T3	0.011 ± 0.009	Ba	0.064 ± 0.040	Ab
T4	0.021 ± 0.004	Ba	0.107 ± 0.056	Aa

*lowercase and uppercase letters indicate a significant difference between means in columns and in rows, respectively (Tukey's test p<0.05). Treatments composition (% coconut fiber-vermicompost): T1 (85-15); T2 (75-25); T3 (65-35) and T4 (commercial substrate)

Table 6. DQI values of seedlings of different eucalyptus species produced from associations of organic residues in the substrate

Species	DQI	Substrate*	Reference
Corymbia citriodora	0.064	CF + VHW	T3 with fertilization
Corymbia citriodora	0.05-0.20	P + VCM	Steffen *et al.* (2011)
Eucalyptus grandis	0.0032-0.0497	OC + CP	Gomes *et al.* (2002)
Eucalyptus grandis	0.09-0.12	CS + VCM	Silva *et al.* (2017)

*CF – coconut fiber; CP - charcoal powder; CS - commercial substrate; OC - organic compost from fatgrass and cattle manure; P – peat; VCM - vermicompost from cattle manure; and VHW - vermicompost from household waste

with fertilization (Table 5) and other studies in the literature.

According to Table 6, the DQI values can vary greatly according to the substrate used, the eucalyptus species and the management of the crop. It is noteworthy that, despite being higher than those found in this study, the DQI values observed in the literature were measured on substrates made of costly materials (GOMES *et al*., 2002; STEFFEN *et al*., 2011; SILVA *et al*., 2017).

On the other hand, the substrates proposed in this work seek to reduce the cost of production, so that they continue to be efficient in the final quality of the produced seedlings.

In Table 6 we can observe that the DQI of the substrate with 35 % vermicompost and 65 % coconut fiber (T3), with fertilization, was higher than when using organic compost from fatgrass and cattle manure, according to Gomes *et al.* (2002). Furthermore, this result was within the range observed by Steffen *et al.* (2011), using peat and vermicompost from cattle manure of the same species. Therefore, the DQI values obtained are highlighted, since the substrate used proposed a sustainable and less costly alternative for the production of eucalyptus seedlings.

Thus, the results found show that it is possible to have a system for producing *C. citriodora* eucalyptus seedlings, with less impact on the environment, besides reusing previously discarded waste. It is noteworthy that new researches to optimize this production system are being performed, such as the supplementation of seedlings with biofertilizer.

CONCLUSION

- The substrate with 15 % vermicompost and 85 % coconut fiber presented greater total porosity of the substrate, and this parameter decreased with the greater amount of vermicompost in the substrate;
- The proposed alternative substrates showed good apparent density, with values that did not differ from the commercial substrate;
- The alternative substrates had an increase in electrical conductivity after the production of eucalyptus seedlings, showing that the presence of vermicompost can favor a constant availability of nutrients to the plants throughout their development;
- Treatments without mineral supplementation produced seedlings of much lower quality than those that received fertilization, and these results were considered insufficient for seedlings suitable for planting in the field;
- No significant differences were observed for the dry biomass of seedlings produced with alternative substrates of different proportions between coconut fiber and vermicompost;
- *Corymbia citriodora* seedlings developed on alternative substrates with fertilization reached satisfactory levels for the quality of eucalyptus seedlings. Furthermore, they stand out as a highly sustainable production model with great potential for improvement.

AUTHORSHIP CONTRIBUTION STATEMENT

FERREIRA, P.H.F.: Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft; **BARRETO, V.C.M.:** Conceptualization, Methodology, Writing – original draft; **MONTAGNOLLI, R.N.:**

Conceptualization, Validation, Visualization; **LOPES, P.R.M.:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ACKNOWLEDGMENTS

The authors thank the National Council for Scientific and Technological Development (CNPq), PROPe/Unesp and GAIA of FCAT/Unesp.

REFERENCES

ANDREAZZA, R.; ANTONIOLLI, Z. I.; SILVA, R. F.; SCHIRMER, G. K.; SCHEID, D. L.; QUADRO, M. S.; BARCELOS, A. A. Efeito do vermicomposto no crescimento inicial de ipê amarelo (*Handroanthus chrysotrichus*) e leucena (*Leucaena leucocephala*). **Nativa**, Sinop, v. 1, n. 1, p. 29-33, 2013.

ARTUR, A. G.; CRUZ, M. C. P.; FERREIRA, M. E.; BARRETTO, V. C. M.; YAGI, R. Esterco bovino e calagem para formação de mudas de guanandi. **Pesquisa Agropecuária Brasileira**, Brasília, v. 42, n. 6, p. 843-850, 2007.

BINOTTO, A. F. **Relação entre as variáveis de crescimento e o índice de qualidade de Dickson em mudas de *Eucalyptus grandis* W. Hill ex Maid e *Pinus elliottii* var. *elliottii* – Engelm.** 56 f. Dissertação de Mestrado, Universidade Federal de Santa Maria, Santa Maria, 2007.

CARRIJO, O. A.; LIZ, R. S.; NOZOMU, M. Fibra da casca do coco verde como substrato agrícola. **Horticultura Brasileira**, Vitória da Conquista, v. 20, n. 4, p. 533-535, 2002.

DICKSON, A.; LEAF, A. L.; HOSNER, J. F. Quality appraisal of white spruce and white pine seedling stock in nurseries. **The Forestry Chronicle**, Mattawa, v. 36, n. 1, p. 10-13, 1960.

DORES-SILVA, P. R.; LANDGRAF, M. D.; REZENDE, M. O. D. O. Processo de estabilização de resíduos orgânicos: vermicompostagem versus compostagem. **Química Nova**, São Paulo, v. 36, n. 5, p. 640-645, 2013.

FERREIRA, P. H. F.; BARRETTO, V. C. M.; TOMAZ, R. S.; FERRARI, S.; VIANA, R. S.; LOPES, P. R. M. Vermicomposto e fibra de coco como substratos sustentáveis na produção de mudas de *Corymbia citriodora*. **Brazilian Journal of Development**, Curitiba, n. 9, p. 70274-70286, 2020.

FONSECA, E. D. P.; VALÉRI, S. V.; MIGLIORANZA, É.; FONSECA, N. A. N.; COUTO, L. Padrão de qualidade de mudas de Trema micrantha (L.) Blume, produzidas sob diferentes períodos de sombreamento. **Revista Árvore,** Viçosa, v. 26, n. 4, p. 515-523, 2002.

FONSECA, T. G. **Produção de mudas de hortaliças em substratos de diferentes composições com adição de CO_2 na água de irrigação.** 72 f. Dissertação de Mestrado, Universidade de São Paulo, Piracicaba, 2001.

GOMES, J. M.; COUTO, L.; LEITE, H. G.; XAVIER, A.; GARCIA, S. L. R. Parâmetros morfológicos na avaliação de qualidade de mudas de *Eucalyptus grandis*. **Revista Árvore**, Viçosa, v. 26, n. 6, p. 655-664, 2002.

GONÇALVES, J. L. M.; BENEDETTI, V. Nutrição e fertilização florestal. Piracicaba: IPEF, 2000.

GUERRINI, I. A.; TRIGUEIRO, R. M. Atributos físicos e químicos de substratos compostos por biossólidos e casca de arroz carbonizada. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 28, n. 6, p. 1069-1076, 2004.

GURTH, P. Forst pflanzen und kulturesfolg-eine literturubersich: Ergantzung. **Allgemeine Forest Jagdztg**, Frankfrurt, v.140, p. 240-245. 1976.

HIGASHI, E. N.; SILVEIRA, R. L. V. A.; GONÇALVES, A. N. Nutrição e adubação em minijardim clonal hidropônico de *Eucalyptus*. **Circular Técnica IPEF**, Piracicaba, n. 194, 2002.

IBÁ - Indústria Brasileira de Árvores. Relatório Anual 2020. Available: < https://iba.org/datafiles/publicacoes/relatorios/relatorio-iba-2020.pdf >. Accessed Jun. 08, 2021.

KLEIN, C. Substratos alternativos para produção de mudas. **Revista Brasileira de Energias Renováveis**, Curitiba, v. 4, n. 3, p. 1-21, 2015.

KRATKA, P. C.; CORREIA, C. R. M. A. Crescimento inicial de aroeira-do-sertão (*Myracrodruon urundeuva* allemão) em diferentes substratos. **Revista Árvore,** Viçosa, v. 39, p. 551-559, 2015.

LIMA, L. K. S; MOURA, M. C. F.; SANTOS, C. C.; NASCIMENTO, K. P. C.; DUTRA, A. S. Produção de mudas de aroeira-do-sertão (*Myracrodruon urundeuva* Allemão) em resíduos orgânicos. **Revista Ceres,** Viçosa, v. 64, n. 1, 2017.

PARVIAINEN, J. V. Qualidade e avaliação de qualidade de mudas florestais. **Seminário de Sementes e Viveiros Florestais**, Curitiba, v. 1, n. 1981, p. 59-90, 1981.

RABELO, L. K. L.; MAESTRI, M. P.; AQUINO, M. G. C.; BAUMANN, S. S. R. T.; BRIGIDA, C. A. S. Cenário das árvores plantadas no Brasil. **Biodiversidade,** Cuiabá, v. 19, n. 3, p. 170, 2020.

ROSA, M. D. F.; BEZERRA, F. C.; CORREIA, D.; SANTOS, F. D. S.; DE ABREU, F. A. P.; FURTADO, A. A. L.; NORÕES, E. R. V. Utilização da casca de coco como substrato agrícola. Documentos (INFOTECA-E). Fortaleza: Embrapa Agroindústria Tropical, 2002.

SILVA, J. M.; ALBUQUERQUE, L. S.; SANTOS, T. M. C.; OLIVEIRA, J. U. L.; GUEDES, E. L. F. Mineralização de vermicompostos estimada pela respiração microbiana. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, Mossoró, v. 8, n. 4, p. 19, 2013.

SILVA, R. F.; MARCO, R.; DA ROS, C. O.; ALMEIDA, H. S.; ANTONIOLLI, Z. I. Influência de diferentes concentrações de vermicomposto no desenvolvimento de mudas de eucalipto e pinus. **FLORAM,** Rio de Janeiro, v. 24, p. 1-10, 2017.

STEFFEN, G. P. K.; ANTONIOLLI, Z. I.; STEFFEN, R. B.; SCHIEEDECH, G. Utilização de vermicomposto como substrato na produção de mudas de *Eucalyptus grandis* e *Corymbia citriodora*. **Pesquisa Florestal Brasileira,** Colombo, v. 31, n. 66, p.75-82, 2011.

ZORZETO, T. Q.; DECHEN, S. C. F.; ABREU, M. F.; JÚNIOR, F. F. Caracterização física de substratos para plantas. **Bragantia**, Campinas, v. 73, n. 3, p.300-311, 2014.