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ROOT AND MORPHOLOGICAL CHARACTERISTICS OF EUCALYPTUS SEEDLINGS PRODUCED IN BIODEGRADABLE CONTAINERS

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Resumo

Crescimento e características morfológicas e radiciais de mudas de eucalipto produzidas em recipientes biodegradáveis. O objetivo deste estudo foi avaliar o desenvolvimento em viveiro e em campo de mudas de eucalipto produzidas em recipientes biodegradáveis (RB), com base em características morfológicas e radiculares, em comparação ao método convencional em tubetes de 55 cm^3. O experimento foi conduzido em delineamento experimental inteiramente casualizado, utilizando um arranjo fatorial 3×2 composto por três tipos de recipientes (tubetes de 55 cm^3; RB de 76 cm^3; e RB de 115 cm^3) e dois clones de eucalipto (CO1407 e AEC-144). Os parâmetros avaliados em viveiro foram: a) altura da parte aérea (APA); b) diâmetro de colo (DC); c) e razão entre APA e DC; d) massas fresca e seca de parte aérea, raízes e total; e e) número total de raízes. Os parâmetros avaliados em campo foram: a) APA; b) DC; e c) distribuição de raízes. Considerando as características avaliadas, o uso de RB de 115 cm^3 possibilitou o desenvolvimento de mudas de alta qualidade em todas as fases de avaliação. Mudas produzidas em RB apresentaram melhor qualidade e desempenho em campo. Mudas produzidas em tubetes de 55 cm^3 apresentaram menores valores para todos os parâmetros morfológicos avaliados em viveiro e em campo até 120 dias após o plantio.
Palavras-chave: Tubetes, clones, campo, viveiro.

Abstract

The objective of this study was to evaluate the nursery and field development of eucalyptus seedlings produced in biodegradable containers (BC), based on morphological and root characteristics, compared to the conventional method in 55-cm^3 tubes. The experiment was conducted in a completely randomized experimental design, using a 3×2 factorial arrangement consisting of three types of containers (55-cm^3 tubes; 76-cm^3 BC; and 115-cm^3 BC) and two eucalyptus clones (CO-1407 and AEC-144). The parameters evaluated in the nursery were: shoot height (SH); stem base diameter (SBD); SH-to-SBD ratio; shoot, root, and total fresh and dry weights; and total number of roots. The parameters evaluated in the field were: SH; SBD; and root distribution. Considering the evaluated characteristics, the use of 115-cm^3 BC enabled the development of high-quality seedlings in all evaluation phases. BC-produced seedlings presented better quality and performance in the field. Seedlings produced in 55-cm^3 tubes presented lower values for all morphological parameters evaluated in the nursery, as well as in the field up to 120 days after planting.
Keywords: Tubes, clones, field, nursery.

INTRODUCTION

The forest sector is important for the economic development in Brazil and has raised attention due to its high yields, innovative technology, management practices, modern and productive facilities, and social responsibility (IBA, 2020). Seedling survival and initial growth are among characteristics connected to implementation of new agricultural areas, mainly in sites under unfavorable climate conditions, as high-quality seedlings are essential for reducing mortality rates and avoid replanting, thus decreasing the implementation costs (CARNEIRO, 1995).

Several factors affect the forest seedling production quality, including the choice of growth containers, which is decisive for obtaining viable seedlings for planting (GOMES; PAIVA, 2013). Freitas et al. (2013) reported that the use of containers with adequate volumetric capacity for a good root development considerably improves seedling production cycles, whereas inadequate containers may compromise the root system formation by hindering water, light, and nutrient absorption, mainly under field conditions.

Eucalyptus seedlings are commonly grown in 55 cm^3 tubes that have internal grooves to restrict roots to the container's bottom, preventing root entanglement. However, the limited volumetric capacity of these tubes has disadvantages by causing other deformations, such as root bending and strangulation, hindering plant development in the field (FREITAS et al., 2013). Novaes et al. (2014) and Figueiredo et al. (2014) reported that root damage caused by using these containers during the nursery stage reduced seedling performance and survival in the field. Other disadvantages of these tubes include difficulties in removing seedlings for planting; the need for nursery areas for storage, washing, and asepsis; transportation issues; field losses; and negative environmental impact due to disposal at the end of their useful life, as they are not easily degradable (ALFENAS, et. al. 2009).

The use of biodegradable containers is an option to overcome the disadvantages of tubes (DIAS, 2011). According to Alfenas et al. (2009), these containers provide an adequate root development, as their walls allow for the passage of lateral roots, favor pruning, and significantly decrease root deformations, resulting in production gains in seedling quality, survival, and initial growth in the field. They reported that paper pots are among the most promising commercial biodegradable containers, as they are composed of a fine cellulose film, i.e., a degradable paper that enables the natural development and growth of lateral roots, resulting in seedlings with adequate root architecture.

In this context, the objective of this study was to evaluate the nursery and field development of eucalyptus seedlings produced in biodegradable containers, based on morphological and root characteristics, compared to the conventional method (55-cm³ tubes).

MATERIAL AND METHODS

The research was developed in two phases: seedling production at the Tecnoplant forest nursery, Eunápolis, state of Bahia (BA), Brazil (16°22'39"S; 39°34'49"W); and field evaluation in a commercial eucalyptus area in Canavieiras, BA, Brazil (15°47'44"S; 39°12'55"W; and altitude of 103 meters). Eunápolis has a mean annual rainfall depth of 1,743 mm and a mean annual temperature of 24.1 °C. The soil texture of the study area was analyzed and classified as loamy sandy. The predominant vegetation in the region is lowland dense ombrophilous forest (NASCIMENTO and DOMINGUEZ, 2010).

Containers, genetic material, and substrate

Two seedling production methods were evaluated. The first method consisted of using biodegradable containers (Ellepot®; Esbjerg, Denmark) in two different sizes (8.0 cm height, 35.0 mm diameter, and 76 cm³ volumetric capacity; and 12.0 cm height, 35.0 mm diameter, and 115 cm³ volumetric capacity). The second method consisted of using conical plastic tubes with dimensions of 12.0 cm height, 3.0 cm upper internal diameter, and 1.0 cm lower internal diameter, with 55 cm³ volumetric capacity, containing four internal grooves; these tubes were used as an evaluation parameter.

The substrate used for the two seedling production methods consisted of a mixture of a commercial product consisted of sphagnum peat, expanded vermiculite, dolomitic limestone, and agricultural gypsum (Carolina Soil®; Santa Cruz do Sul, Brazil) and coconut fiber at the proportion of 1:1. The fertilizers applied consisted of a mixture of approximately 2.0 kg of a 19-06-10 N-P-K formulation (Osmocote® Mini Prill; ICL Specialty Fertilizers, São José dos Campos, Brazil) and 1.5 kg of a 14-16-18 N-P-K formulation (PG Mix; Yara, Porto Alegre, Brazil) per cubic meter of substrate. The seedlings were produced using the following two eucalyptus genetic materials: clones CO-1407 (*Eucalyptus urophylla* × *E. grandis*) and AEC-144 (*E. urophylla*).

Seedling production

The seedlings used in the experiments were produced from minicuttings obtained from the clones CO1407 and AEC-144. The containers were mechanically filled with substrate, and staking was carried out directly into the containers, which were then placed in trays. The trays with containers were taken to a rooting chamber with a temperature of approximately 35 °C and relative humidity of approximately 86%, where they remained for 20 days. The seedlings were then transferred to growth areas and subsequently to the acclimation area, where they remained for more than 10 and 30 days, respectively. Thinning was carried out, removing 50% of the plants. After this growth stage, the seedlings were transferred to the hardening area, where they remained for more than 40 days, totaling 100 days after staking.

Evaluation of morphological parameters in the nursery

The nursery experiment was conducted in a completely randomized experimental design with five replications, with treatments evaluated in a 3×2 factorial arrangement consisting of three types of containers [55cm³ tubes, 76-cm³ biodegradable container (BC), and 115-cm³ BC] and two eucalyptus clones (CO-1407 and AEC144), totaling 30 plots with 20 seedlings, resulting in a total of 600 seedlings in the experiment.

Morphological parameters that determine the seedling development in the nursery were evaluated 100 days after staking. Twelve seedlings per replication were randomly collected from the containers, and the total number of roots was counted in two of them, with emphasis on the white ones, considered physiologically active. The root system of the other seedlings was separated from the substrate using running water and then distributed on filter paper sheets and kept on a bench at the laboratory for 24 hours for removal of surface water. The total number of roots was then visually counted.

Seedlings were measured and evaluated for shoot height (cm) and stem base diameter (mm), using a ruler and a digital caliper, respectively, at the Forestry Laboratory of the State University of Southwestern Bahia (UESB). Seedling shoots were separated from their root systems to determine shoot height to stem base diameter ratio and fresh and dry weights of shoots, roots, and total plant biomass.

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Two labeled paper bags, one for shoots and one for roots from the same seedling, were used for drying the seedlings in an oven at 75 °C for approximately 72 hours, until they reached a constant weight. The paper bags remained open in the oven to facilitate water loss. After cooling, the plant material was weighed on digital balance to determine the shoot, root, and total fresh and dry weights.

The results obtained were subjected to normality test and analysis of variance, and the means were compared by the Tukey's test at p<0.05, through the Statistica 7.0 software. The performance of seedlings in the field as a function of measurement times was evaluated through regression analyses using the orthogonal polynomial method.

Seedling planting and evaluation in the field

The field experiment was conducted in a randomized block design with four replications, using the same factorial arrangement as the nursery experiment, but with six seedlings per plot, totaling 144 plants. The treatments evaluated were: 55-cm³ tubes with the eucalyptus clone CO-1407; 55-cm³ tubes with the eucalyptus AEC-144; 76 BC with CO-1407; 76-cm³ BC with AEC-144; 115-cm³ BC with CO-1407; and 115-cm³ BC with AEC-144.

Before planting the seedlings in the field, the soil of the area was cleaned using a leveler and then subjected to a 90-cm subsoiling operation using a subsoiler. Soil fertilizers were applied, using a 06-30-06 N-P-K formulation at the rate of 400 kg ha^{-1}. Seedlings were planted with the aid of a manual planter, using a spacing of 4.0×3.0 meters; 400 mL of hydrogel was added to each planting hole. One-hundred grams of a 10-12-25 N-P-K formulation were manually applied as topdressing to the canopy radius of each plant 60 days after planting.

Seedling growth under field conditions was measured with 30-day intervals during four months. Shoot height and stem base diameter were measured in each evaluation, using a ruler and a digital caliper, respectively. Root distribution was evaluated four months after planting in two plants collected from each treatment, selected based on plant height and stem base diameters within their standard deviations.

RESULTS

Seedling evaluation in the nursery experiment Shoot height (SH), stem base diameter (SBD), and shoot height to stem base diameter ratio (SH/SBD)

The interaction effect between factors was not significant for SH, SBD, and SH/SBD. The means found for these variables are shown in Table 1. Seedlings produced in 76-cm³ and 115-cm³ biodegradable containers (BC) presented higher means for SH and SBD, mainly for seedlings in 115-cm³ BC, significantly differing from those produced in 55-cm³ tubes.

The use of 55-cm³ tubes to produce seedlings resulted in the highest SH/SBD, but with no significant difference from 115-cm³ BC, which resulted in means not significantly different from those obtained for 76-cm³ BC (Table 1). No significant differences were found between the evaluated eucalyptus clones for these variables.

Table 1. Means of shoot height (SH), stem base diameter (SBD), and SH-to-SBD ratio (SH/SBD) of eucalyptus seedlings (clones CO-1407 and AEC-144 clones) produced in 76-cm³ and 115-cm³ biodegradable containers (BC) and in 55-cm³ tubes, evaluated 100 days after staking.

Tabela 1. Médias de altura da parte aérea (APA), diâmetro de colo (DC) e razão entre APA e DC (APA/DC) de mudas de eucalipto (clones CO 1407 e AEC 144) produzidas em recipientes biodegradáveis (RB) de 76 e 115 cm^3 e em tubetes de 55 cm^3, avaliadas aos 100 dias após estaqueamento.

Treatment	SH (cm)	SBD (mm)	SH/SBD
115-cm³ BC	35.41 a	3.08 a	11.53 ab
76-cm³ BC	30.48 b	2.90 a	10.60 b
55-cm³ Tubes	27.83 c	2.28 b	12.32 a
CO-1407	29.96 b	2.81 a	10.81 a
AEC-144	28.75 b	2.62 a	11.21 a

Means followed by the same letter in the columns are not significantly different from each other by the Tukey's test at p<0.05.

Root quantitative characteristics

The total number of roots and number of physiologically active roots of seedlings produced in 76-cm³ and 115-cm³ BC was higher compared to those found for seedlings produced in 55-cm³ tubes (Table 2). No significant differences were found between the evaluated eucalyptus clones for these variables.

Table 2 - Total number of roots and number of physiologically active roots in eucalyptus seedlings (clones CO1407 and AEC-144) produced in 76-cm³ and 115-cm³ biodegradable containers (BC) and 55-cm³ tubes, counted 100 days after staking.

Tabela 2 - Número total de raízes e número de raízes fisiologicamente ativas em mudas de eucalipto (clones CO1407 and AEC-144) produzidas em recipientes biodegradáveis (RB) de 76 e 115 cm^3 e em tubetes de 55 cm^3, contados aos 100 dias após estaqueamento.

Treatment	Total number of roots	Number of physiologically active roots
115-cm³ BC	16.07	7.40
76-cm³ BC	13.83	7.90
55-cm³ Tubes	07.27	2.73
CO-1407	12.97	5.63
AEC-144	12.27	4.10

Shoot, root, and total fresh and dry weights

The highest means of shoot, root, and total fresh weights were found for seedlings produced in 115-cm³ BC. Root fresh weight of seedlings produced in 115-cm³ BC was not significantly different from that found for seedlings produced in 76-cm³ BC (Table 3). However, growing seedlings in 115-cm³ and 76-cm³ BC yielded higher mean fresh weights than in 55-cm³ tubes. No significant differences were found between the evaluated eucalyptus clones for fresh weights.

Table 3. Means for shoot, root, and total fresh weights of eucalyptus seedlings (clones CO-1407 and AEC-144) produced in 76-cm³ and 115-cm³ biodegradable containers (BC) and in 55-cm³ tubes, evaluated 100 days after staking.

Tabela 3. Médias de massa fresca de partes aérea, raizes e total de mudas de eucalipto (clones CO 1407 e AEC 144) produzidas em recipientes biodegradáveis (RB) de 76 e 115 cm^3 e em tubetes de 55 cm^3, avaliadas aos 100 dias após estaqueamento.

Treatment	Fresh weight		
	Shoot (g)	Root (g)	Total (g)
115-cm³ BC	3.98 a	1.08 a	5.06 a
76-cm³ BC	3.01 b	0.90 a	3.95 b
55-cm³ Tubes	1.73 c	0.62 b	2.35 c
CO-1407	2.81 b	0.75 b	3.60 b
AEC-144	2.41 b	0.72 b	3.12 b

Means followed by the same letter in the columns are not significantly different from each other by the Tukey's test at $p<0.05$.

The highest means of shoot, root, and total dry weights were found for seedlings produced in 115-cm³ BC, with significant differences from the other treatments (Table 04). Seedlings produced in 55-cm³ tubes presented the lowest means for these variables. No significant differences were found between the evaluated eucalyptus clones for dry weights.

Table 4. Means of shoot, root, and total dry weights of eucalyptus seedlings (clones CO-1407 and AEC-144 clones) produced in 76-cm³ and 115-cm³ biodegradable containers (BC) and in 55-cm³ tubes, evaluated 100 days after staking.

Tabela 4. Médias de massa seca de partes aérea, raizes e total de mudas de eucalipto (clones CO 1407 e AEC 144) produzidas em recipientes biodegradáveis (RB) de 76 e 115 cm^3 e em tubetes de 55 cm^3, avaliadas aos 100 dias após estaqueamento.

Treatment	Dry weights		
	Shoot (g)	Root (g)	Total (g)
115-cm³ BC	2.44 a	0.68 a	3.12 a
76-cm³ BC	2.01 b	0.60 a	2.61 b
55-cm³ Tubes	1.08 c	0.40 b	1.48 c
CO-1407	1.99 a	0.52 b	2.50 a
AEC-144	1.84 a	0.54 ab	2.37 a

Means followed by the same letter in the columns are not significantly different from each other by the Tukey's test at $p<0.05$.

Seedling performance in the field Initial growth (shoot height and stem base diameter)

The highest means of shoot height were found for seedlings produced in 115-cm³ BC, with significant difference from the evaluations at 30 and 60 days after planting (DAP) (Figure 01). Seedlings produced in 76-cm³ BC presented the second highest means for these variables in all evaluations, with no significant difference from those produced in 55-cm³ tubes (30 and 60 DAP) and those produced in 115-cm³ BC (90 and 120 DAP) (Figure 1).

Seedlings produced in 55-cm³ tubes resulted in the lowest mean shoot heights in both nursery and field evaluations. The highest mean stem base diameters were found for seedlings produced in 115-cm³ BC in all evaluations, with no significant difference from those produced in 76-cm³ BC and evaluated at 60, 90, and 120 DAP, and from those produced in 55-cm³ tubes and evaluated at 120 DAP (Figure 1).

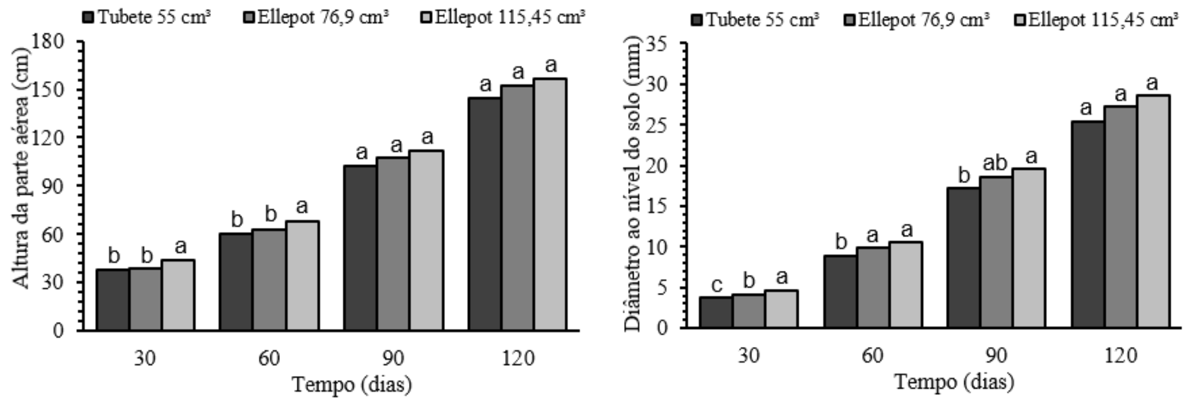

Figure 1. Means of shoot height and stem base diameter of eucalyptus seedlings produced in 76-cm³ and 115-cm³ biodegradable containers (BC) and 55-cm³ tubes, evaluated over 120 days after planting.
Figura 1. Médias de altura da parte aérea e diâmetro de colo de mudas de *Eucalyptus* spp., produzidas em recipientes biodegradáveis (RB) de 76 e 115 cm³ e em tubetes de 55 cm³, ao longo de 120 dias de plantio.

No significant differences were found between eucalyptus clones for the were found seedling growth variables (Figure 02). AEC-144 seedlings presented the highest mean shoot heights in all evaluations, except at 60 DAP. AEC-144 seedlings reached the highest mean stem base diameter at 120 DAP, however, with no statistical differences from the CO-1407 seedlings.

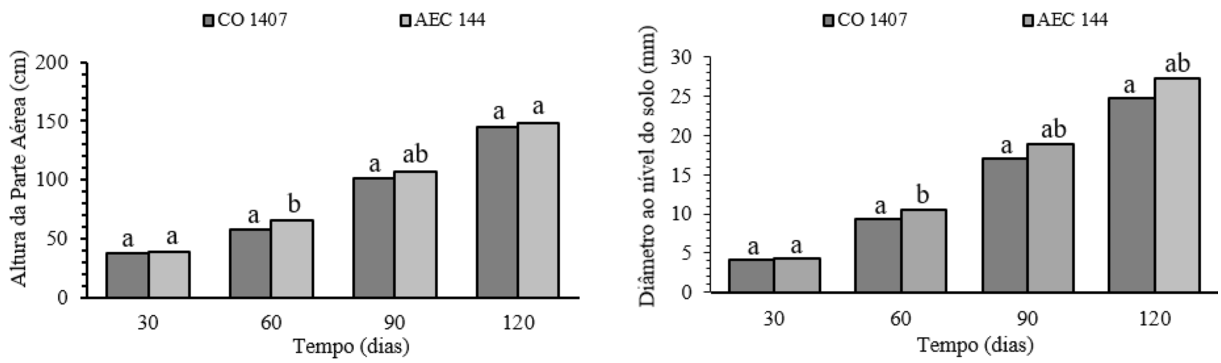

Figure 2. Means of shoot height and stem base diameter of two eucalyptus clones (CO-1407 and AEC-144) over 120 days after planting.
Figura 2. Médias de altura da parte aérea e diâmetro de colo de clones de eucalipto (CO 1407 e AEC 144) ao longo de 120 dias após o plantio.

Root distribution in the field

Seedlings produced in 76-cm³ and 115-cm³ BC presented more homogeneous root distribution compared to those produced in 55-cm³ tubes (Figure 3), mainly for 115-cm³ BC, which yielded higher number and uniformity of roots distributed in the four evaluated quadrants, mainly in the root system upper portion, when evaluating vertical root distribution.

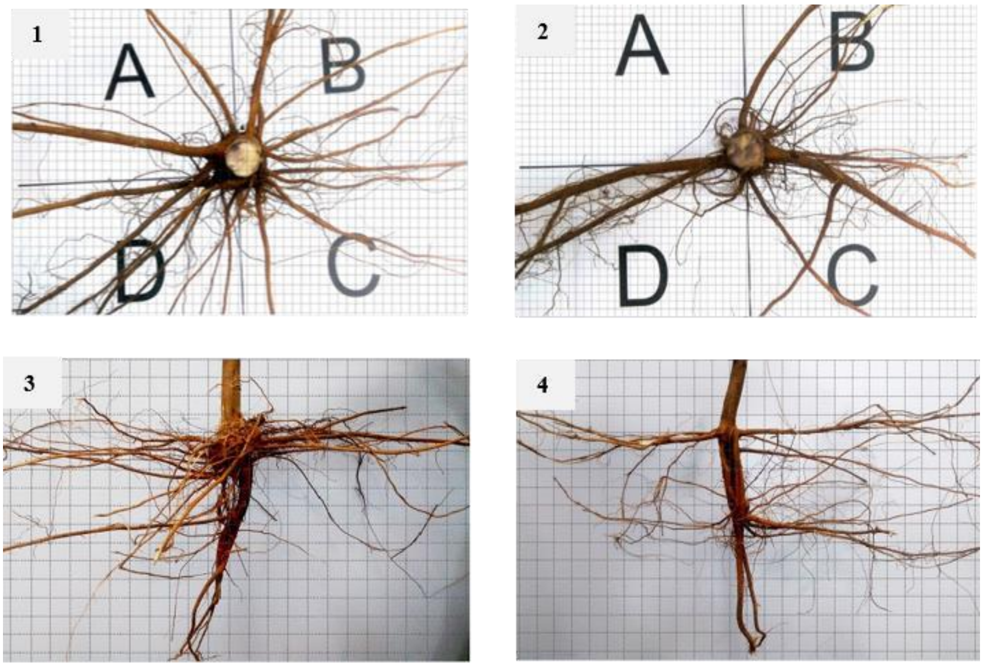

Figure 3 - Root distribution of eucalyptus seedlings produced in 115-cm³ biodegradable containers (1 and 3) and 55-cm³ tubes (2 and 4), evaluated 120 days after planting.
Figura 3 - Distribuição de raízes de mudas de *Eucalyptus* spp. produzidas em recipientes biodegradáveis de 115,0 cm³ (1 e 3) e tubetes de 55 cm^3 (2 e 4), avaliada aos 120 dias após o transplantio ao campo.

DISCUSSION

Seedling evaluation in the nursery Shoot height (SH), stem base diameter (SBD), and shoot height to stem base diameter ratio (SH/SBD)

The highest mean SH and SBD were found for seedlings produced in 115-cm³ BC (Table 1). The highest growth of seedlings produced in 76-cm³ and 115-cm³ BC is probably associated with their larger substrate volumes compared to 55-cm³ tubes, resulting in a larger area for the growth of new roots; this correlation was also found between 76-cm³ and 115-cm³ BC.

Biernaski et al. (2017) found similar results, with positive effect of larger container volume on seedling growth in terms of diameter and height. Storck et al. (2016) also found similar results, with greater water and nutrient availability in larger containers, as well as higher proportion of roots growing without restrictions compared to smaller containers, such as the 55-cm³ tube tested in the present study, which restrict root grow, resulting in lower values for these variables. Lopes et al. (2014) attributed the low development of eucalyptus seedlings produced in 55-cm³ tubes to the strong restriction to root grow due to their impermeable walls.

The lowest mean SH/SBD values were found for seedlings produced in 76-cm³ and 115-cm³ BC, denoting a higher balance between the development of shoots in height and stem base in diameter. These means were close to the ideal values recommended by Carneiro (1995). Seedlings produced in 55-cm³ tubes resulted in the highest mean SH/SBD values, probably due to the smaller container volume and higher tray densities in the early stages of seedling development in the nursery; this resulted in greater height growth at the expense of stem base diameter. Ataíde et al. (2010) found similar results and reported reduced stem base diameter in eucalyptus seedlings due to root restrictions caused by tubes and spacing in the trays.

Root qualitative and quantitative characteristics

Seedlings produced in 76-cm³ and 115-cm³ BC yielded more roots than those produced in 55-cm³ tubes, which is the most common eucalyptus seedling production method. This larger root volume may be attributed to the container sizes, which do not restrict lateral root emergence and elongation. These containers allow roots to pass through their walls and grow freely, which explains the greater initial growth of seedlings in the field after planting. This results in a higher number of active roots and greater capture and absorption of water and nutrients. The formation of new physiologically active roots and their effect on seedling survival and performance in the field was highlighted by Carneiro (1995). No significant differences were found between the evaluated eucalyptus clones for root volume, but clone CO-1407 had the highest mean total number of roots.

Shoot, root, and total fresh and dry weights

Fresh weights were higher for seedlings produced in 76-cm³ and 115-cm³ BC (Table 3) compared to those produced in 55-cm³ tubes. It is explained not only by the larger substrate volume (FREITAS et al., 2013), but mainly by the little restriction to root growth and few deformations, as these containers do not present resistance to roots to cross their walls, resulting in better root system development and, consequently, increased fresh weight and adequate and balanced shoot development. The lowest fresh weights were found for seedlings produced in 55cm³ tubes. Novaes et al. (2014) found similar results for evaluations of Indian neem seedlings (*Azadirachtha indica*).

The highest root dry weights were found for seedlings produced in 115-cm³ BC. A high root dry weight is strongly connected to survival and initial growth of seedlings in the field, as also found by Gomes and Paiva (2013). According to Carneiro (1995), the root dry weight should be analyzed together with other root systemrelated parameters, mainly physiological ones; these parameters were not assessed in the present study because the roots were very fine and, despite performing important functions, they contribute little to root dry weight.

Seedlings grown in in 55-cm³ tubes had the lowest root dry weights, denoting a root development limited by the container walls, which resulted in growth inhibition in all seedlings. Novaes et al. (2014) and Lopes et al. (2014) found similar results for Indian neem and eucalyptus seedlings, respectively, grown in containers with low volumetric capacity. No significant differences were found between the eucalyptus clones evaluated in the present study for root dry weights.

Seedling performance in the field

Seedlings of all treatments presented 100% survival over the 120 days after planting (DAP). Seedlings produced in 76-cm³ and 115-cm³ BC had the highest shoot heights and stem base diameters in all evaluations, mainly for 115-cm³ BC. This result can be attributed to the better conditions for root growth provided by these containers, among other factors.

Roots of seedlings produced in 115-cm³ BC had uniform growth in the four evaluated quadrants (Figure 3). This adequate spatial distribution of roots may have contributed to a more efficient exploration of the soil and, consequently, to a greater initial growth compared to the other treatments. Well-distributed, abundant roots explore a larger soil volume, resulting in improved seedling establishment and growth, as previously reported by Oliveira and Novaes (2020) for *Anadenanthera peregrina*.

This more efficient initial growth in the first few months after planting are important for commercial plantations, as seedlings with more vigorous initial growth tend to perform better under competition with weeds, reducing replanting and the need for weeding and, consequently, the cost of maintaining the plantation area.

Field measurements of seedlings produced in 55-cm³ tubes presented the same trend observed in the nursery, with lower increases in shoot height and stem base diameter in all evaluations. These results were may be due to root restrictions and deformations connected to the use of this container type, as already discussed in the present study. The root distribution of seedlings produced in 55-cm³ tubes was uneven, concentrating in only three quadrants (Figure 3). This irregular root distribution generates a slower initial growth in the field, as also found by Haase et al. (1993) and Novaes et al. (2002). No significant differences in growth parameters or treatments were found between seedlings of both eucalyptus clones evaluated (CO-1407 and AEC-144), regardless of nursery or field conditions.

CONCLUSIONS

- Eucalyptus seedlings produced in 76-cm³ and 115-cm³ biodegradable containers presented higher number and better quality of roots in the nursery and, consequently, better performance in the field;
- Biodegradable containers with volumetric capacity of 115 cm³ enabled the production of high-quality eucalyptus seedlings in all growth stages in the nursery and, consequently, in the field up to 120 days after planting;
- Seedlings produced in 55-cm³ tubes were morphologically inferior to those produced in biodegradable containers, both in nursery assessments and in the field up to 120 days after planting.

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