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Short Communication

Growth of *Eucalyptus urophylla* seedlings produced in conventional and water collection trays in degradable tube and polypropylene systems

Crescimento de mudas de *Eucalyptus urophylla* produzidas em bandejas coletoras de água e convencional nos sistemas de tubetes degradáveis e polipropileno

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ABSTRACT

The nursery revolution in the 80s occurred with polyethylene tubes, which are still widely used, even with some negative points. The demand to reduce costs in the nursery has driven the evolution of seedling production techniques and products, such as degradable tubes and water collection trays. This study aimed to evaluate under nursery conditions the growth phase of Eucalyptus urophylla clones produced in polyethylene tube systems and degradable material with different occupation levels. The occupancy of 27% and 50% of flat polyethylene trays with 176 cells and 100% of water collector trays with 40 cells were tested. The height, diameter, survival rate, Dickson's Quality Index (DQI), shoot dry matter, and root system dry matter were evaluated 70 days after the experiment implementation. According to the results obtained, the degradable tube and the water collector tray favored the development of the clones in terms of height and DQI. The tubes and trays used in the study did not statistically influence shoot dry matter, root system dry matter, and the total dry matter of the clones. The treatment that used degradable tubes and the water collection tray presented the best mean values of the evaluated growth parameters.

Keywords: Alternation of clones; Clone quality; Tray; Degradable tube degradation; Aerial and root biomass

RESUMO

A revolução dos viveiros florestais na década de 80 ocorreu com o uso dos tubetes de polietileno, sendo ainda muito utilizados, mesmo apresentando alguns pontos negativos. A busca pela redução de custos no viveiro impulsiona a evolução de novas técnicas de produção de mudas e produtos utilizados, como os tubetes degradáveis e bandejas coletoras de água. O objetivo do estudo foi avaliar em condições de viveiro a fase de crescimento de mudas de *Eucalyptus urophylla* produzidas em sistemas de tubetes de polietileno e de material degradável com diferentes níveis de ocupação. Foram testadas a ocupação de 27% e 50% de bandejas planas de polietileno com 176 células e 100% das bandejas coletoras de água com 40 células. A altura, diâmetro, taxa de sobrevivência, Índice de Qualidade de Dickson (IQD), matéria seca da parte aérea e matéria seca do sistema radicial foram avaliadas aos 70 dias após a implantação do experimento. De acordo com os resultados obtidos, o tubete degradável e a bandeja coletora de água favoreceram o desenvolvimento das mudas em relação à altura e IQD. Os tubetes e as bandejas utilizadas no estudo não influenciaram estatisticamente a matéria seca da parte aérea, matéria seca do sistema radicial e matéria seca total das mudas. O tratamento que utilizou tubetes degradáveis e bandeja coletadora de água foi o que apresentou melhores valores médios dos parâmetros de crescimento avaliados.

Palavras-chave: Alternagem de mudas; Qualidade de mudas; Bandeja; Degradação de recipiente; Biomassa aérea e radicial

1 INTRODUCTION

Introduced in Brazil in the 1980s, polyethylene tubes used in the production of forest seedlings represented an advance in forestry, allowing the mechanization of different processes in the nursery, and facilitating large-scale application (Freitas *et al*., 2009). However, with the growing demand for products from reforestation, the improvement of seedling production techniques has become increasingly demanding (Storck; Schorn; Fenilli, 2015), involving cost reduction and new technologies in an attempt to obtain seedlings with high-quality standards (Tatagiba *et al*., 2019).

The use of polyethylene tubes requires their removal at the time of planting, return for cleaning (Mendonça *et al*., 2016), and areas in the nursery for storage and disinfection until reuse. They can also cause damage to the root system when removed at the time of planting (Dias, 2011). The use of degradable tubes has become an increasingly innovative and increasingly viable alternative, as they are incorporated into the soil and assimilated by the environment, generating no residues (Conti *et al*., 2012). Furthermore, there is no need to remove it during planting, which eliminates the costs related to returning and disinfecting the container (Oliveira, 2016).

In addition to degradable tubes, the use of water collection trays has also become an option to reduce costs and meet the demands of seedling production with less environmental impact, especially in the growth phase, when seedlings demand more water and nutrients (Faria *et al*., 2019) and solar radiation (Wendling; Dutra, 2017). Collection trays are capable of improving efficiency in water use, fertilizer utilization, and alternation operational performance, as they have pre-defined locations to insert the seedlings.

Flat polyethylene trays do not have a physical barrier to direct water to the tube, causing water loss through its drainage out of the tray and, consequently, less utilization of fertilizers. Furthermore, the operational performance in the activity of alternating seedlings may be lower than that carried out in water collection trays, as they do not have pre-defined locations. Water collection trays have only been on the market for a short time and more information is required regarding their use in the growth phase of seedlings in the nursery, as well as the use of degradable tubes.

In this context, this study aimed to evaluate, under nursery conditions, the growth phase of *Eucalyptus urophylla* seedlings produced in polyethylene and degradable tube systems with different occupancy levels.

2 MATERIALS AND METHODS

The *Eucalyptus urophylla* clone was selected for implementation in the experiment due to its high productivity, adaptability to different environments, and ease of vegetative propagation, standing out in Brazilian forestry (Sereghetti, 2016).

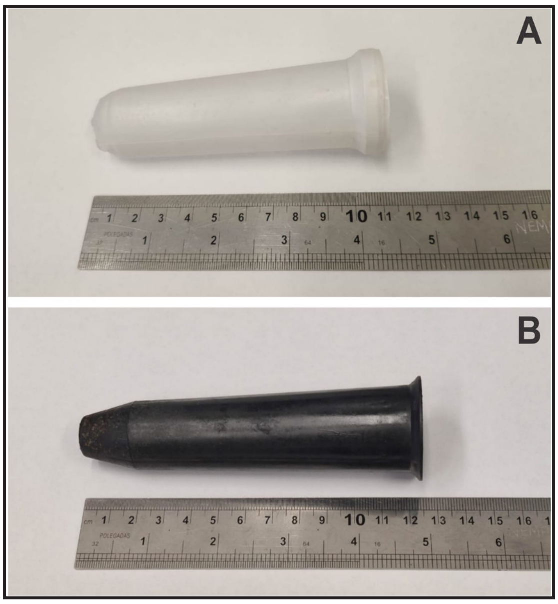
2.1 Nursery location

The experiment was conducted from May to October 2021 in the seedling production nursery of the Laboratory of Biomass and Bioenergy Agroforestry (LABB), associated with the Bioenergy Research Institute (IPBEN) (latitude 22°50'54" S and longitude 48°26'08" W), located at the School of Agricultural Sciences at UNESP, Botucatu/SP, and 825 m above sea level. The region has a mean annual temperature of 20.5 °C and a mean annual precipitation of 1696 mm year^{-1} (CLIMATE, 2022). According to the Köppen climate classification, the regional climate is considered Cfa, that is, humid subtropical with hot summers (Cunha; Martins, 2009).

2.2 Containers and trays

Seedling production was carried out in two types of containers: the polyethylene tube, with a volume of 55 cm^3 and six protruding internal grooves, and the degradable tube, composed of 75% degradable polymer (EP 103) and 27% synthetic polymer (inert vinyl), known as SIS BGC manufactured by Corrêa Neto, with a volume of 55 cm^3 and without internal grooves (Figure 1).

Figure 1 – Containers used in the production of *Eucalyptus urophylla* seedlings

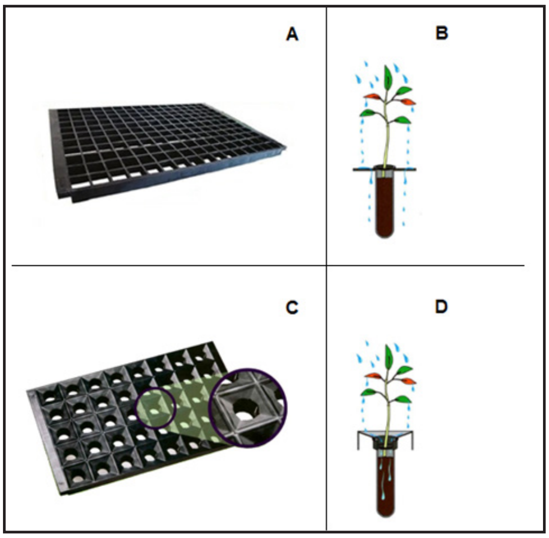


Source: Authors (2021)

In where: A – SIS BGC degradable tube; B – polyethylene tube

Flat polyethylene trays with 176 cells (59 cm x 39 cm) and water collection trays with 40 cells (59 cm x 34 cm), known as ECO E40 with higher water utilization capacity, were used as supports, being arranged in raised beds 90 cm high from the ground (Figure 2).

Figure 2 – Configuration of trays and respective utilization of water by *Eucalyptus urophylla* seedlings



Source: Authors (2021)

In where: A – flat tray with 176 cells; B – water utilization by seedlings placed in flat trays; C – water collection tray with 40 cells; D – water utilization by seedlings placed in water collection trays.

2.2.1 Greenhouse

The genetic material of *Eucalyptus urophylla* (AEC-144) was staked in May, with mini-cuttings measuring an average of 7 cm in height and with two to three pairs of leaves with half their original size. Staking occurred in degradable polyethylene tubes, placed in flat polyethylene trays with 176 cells with a plant density at 100% tray occupancy, arranged at an irrigation depth of 6 mm day^{-1}.

The substrate consisted of a commercial product composed of peat, vermiculite, and organic agroindustrial residue in a 2:1:1 ratio (volume basis). The Fort Cote fertilizer with controlled release for three months and formulation 19-06-10 (N-P-K) was used for base fertilization of the substrate.

Temperature and humidity remained in the range between 16 °C and 36 °C in the greenhouse environment, except on low-temperature days, which made it necessary for the seedlings to remain in the greenhouse for 34 days before proceeding to the shade house.

2.2.1.1 Shade house

The seedlings were taken to the shade house to undergo the acclimatization period under 50% shade coverage and an irrigation depth of 8 mm day^{-1}. Most of the seedlings had roots and sprouts after staying for 7 days and were taken to the suspended, full-sun area to begin the growth and acclimatization phase.

2.2.1.2 Full sun area

The seedlings were introduced into the full sun area to begin the growth phase, followed by their acclimatization. The seedlings were classified into small (S), medium (M), and large (L), according to their size, on the seventh day of the growth phase to provide homogeneous development. This classification allowed the implementation of the experimental design, in which medium (16.03 cm) and large (19.18 cm) seedlings occupied 27% and 50% of the cells in the polyethylene trays and 100% of the cells in the collection trays. Seedlings classified as medium and large were distributed in the same quantity for each treatment. The experimental design took place for 70 days after the implementation of the experiment, that is, until the middle of the hardening off stage.

The seedlings remained in the full sun area with an irrigation depth of 15 mm day^{-1} until they completed their cycle for dispatch to the field. After 44 days in the full sun area, totaling 84 days of age of the seedlings, the hardening off process was started with potassium chloride (KCl) at a dose of 0.5 g L^{-1}, which was applied every 4 days until the end of the cycle. The seedlings were sent to the field after completing 153 days.

2.3 Statistical design

The experiment was conducted in a completely randomized statistical design consisting of six treatments 40 days after the staking date, that is, the seventh day that the seedlings were in the full sun area: (T1) polyethylene tube with 27% occupancy of the flat polyethylene tray; (T2) degradable tube with 27% occupancy of the flat polyethylene tray; (T3) polyethylene tube with 100% occupancy of the water collection tray; (T4) degradable tube with 100% occupancy of the water collection tray; (T5) polyethylene tube with 50% occupancy of the flat polyethylene tray; and (T6) degradable tube with 50% occupancy of the flat polyethylene tray. Treatments T1, T2, T3, and T4 were distributed in four replications. Treatments T5 and T6 were distributed in three replications due to the higher need for the number of seedlings for these treatments.

In total, the experiment consisted of 1232 seedlings, that is, 384 seedlings in T1 and T2 (48 seedlings * 4 replications * 2 treatments), 320 seedlings in T3 and T4 (40 seedlings * 4 replications * 2 treatments), and 528 seedlings in T5 and T6 (88 seedlings * 3 replications * 2 treatments).

The variables height, stem diameter, and dry matter were collected 70 days after the implementation of the experiment in the full sun area, that is, 127 days after the staking date. The variables height and collar diameter were collected from all seedlings. Three seedlings from each treatment were randomly collected, totaling 18 seedlings (3 seedlings for each treatment), for dry matter sampling.

2.4 Analyzed variables

Measurements of height, diameter, and survival of all plants were performed in the nursery, before determining dry matter. Height was measured from the collar to the apical meristem using a millimeter ruler. The diameter was measured with a precision caliper on the collar at the level of the substrate. Plant survival was assessed by counting dead plants.

The Dickson quality index (DQI) was calculated using the indicators of shoot dry matter, root system dry matter, total dry matter, height, and seedling collar diameter, according to Equation (1) (Dickson; Leaf; Hosner, 1960):

$$DQI = \frac{TDM}{\left(\frac{H}{CD}\right) + \left(\frac{SDM}{RDM}\right)} \tag{1}$$

where: *TDM* = Total dry matter (*SDM* + *RDM*) (g); *SDM* = Shoot dry matter (g); *RDM* = Root dry matter (g); *H* = Height (cm); *CD* = Collar diameter (mm).

After measuring height, collar diameter, and survival, the selected seedlings from each treatment were removed from the full sun area to determine dry mass. The shoot was separated from the roots to quantify dry matter. The roots were washed in a sieve (1.18 mm). The shoot and roots were dried in an oven at 65 °C (±3 °C) until constant weight, determined on a precision analytical balance.

2.5 Statistical analysis

The data were initially analyzed descriptively using means, standard deviation, and, in some cases, median, minimum, and maximum values. Analysis of variance (ANOVA) was used for inferential procedures, considering two factors ($p<0.05$), complemented by Tukey's multiple comparison test at a 5% significance level ($p<0.05$). The normality, homoscedasticity, and independence of residuals were evaluated ($p<0.05$) and, when necessary, a transformation in the original data was performed to apply the inferential procedure. The results of the statistical procedures used were obtained in the R computing environment (R CORE TEAM, 2022).

3 RESULTS AND DISCUSSIONS

The interactions between "Tube x Tray" and, individually, "Tube" and "Tray" were evaluated considering the statistical analysis. The type of tube described in the analyses includes "Deg" and "Poly" for degradable and polyethylene tubes, respectively. The trays consisted of "BC," "B27," and "B50" for water collection trays with 100% cell occupancy, trays with 27% cell occupancy, and trays with 50% cell occupancy, respectively.

3.1 Height, collar diameter, and survival

The height of *E. Urophylla* seedlings was significantly influenced by the tube ($p=0.030$; $p<0.05$) and tray ($p=0.002$; $p<0.05$) used in their production (Table 1). Moreover, the height of seedlings produced in the degradable tube (23.27 cm) presented a significantly higher mean compared to the seedlings produced in the polyethylene tube (19.93 cm). The same phenomenon occurred for seedlings produced in the water collection tray (25.30 cm), which presented a significantly higher mean than seedlings produced in the flat polyethylene tray with 50% cell occupancy (17.49 cm), as shown in Figure 3. Seedling production in the flat polyethylene tray with 27% cell occupancy (20.98 cm) showed similar results to the water collection tray and flat polyethylene tray with 50% occupancy (Figure 3).

Table 1 – Mean and standard deviation for the height (cm) of *Eucalyptus urophylla* seedlings, according to the type of tube and spacing in the trays

Tube	Tray			Total
	B27	B50	BC	
Deg (cm)	23.33 (2.33)	19.06 (2.20)	26.35 (1.11)	23.27 (3.48)
Poly (cm)	18.63 (4.93)	15.93 (5.73)	24.24 (1.28)	19.93 (5.22)
Total (cm)	20.98 (4.36)	17.49 (4.24)	25.30 (1.58)	21.60 (4.65)
Interaction Tube x Tray	F=0.314 (p=0.735) *ns*			
Tube effect	F=5.650 (p=0.030) *			
Tray effect	F=9.876 (p=0.002) *			
CV (%)	15.22			

Source: Authors (2021)

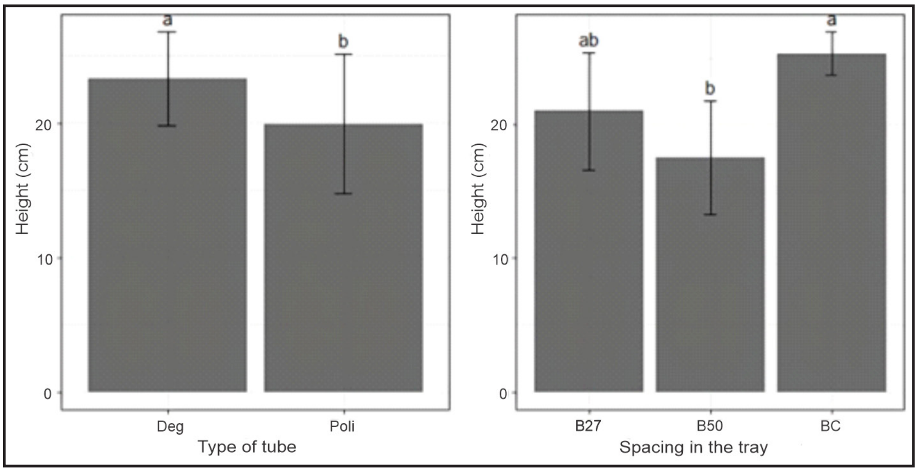
In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = Non-significant effect; *= Significant effect at 5%.

The collection tray provided superior height development in *E. urophylla* seedlings, as it presented favorable conditions relative to water use. Similarly, Gomez, Maciel, and Silva (2019) evaluated a water collection tray, a flat polyethylene tray, and four daily irrigation depths of 8, 11, 14, and 17 mm day^{-1} in the development of *Eucalyptus urophylla* x *E. grandis* (*E. urograndis*) seedlings and observed that seedling height was higher when in a water collection tray.

Plant growth patterns under optimal conditions of water and nutrient availability occur as a function of photosynthetically active radiation (PAR) intercepted by the plant, being converted into biomass (Eloy *et al*., 2013). Thus, the superior development in height of seedlings produced in degradable tubes may be related to the tube color, as the white color may favor PAR penetration into the root system, unlike the black color of the polyethylene tube, which does not allow this exchange. Also, the degradable tube may have a higher retention of irrigation water due to its higher porosity when compared to the polyethylene tube (Oliveira, 2016), which may contribute to increasing seedling height.

The height of seedlings produced in degradable tubes (23.27 cm), water collection tray (25.30 cm), and flat tray with 27% occupancy (20.98 cm) are within the quality standard for expedition seedlings (Figure 3). In fact, the height must remain between 20 and 30 cm, according to the quality parameters of companies in the cellulose sector (Alfenas *et al*., 2009).

Figure 3 – Mean effects of height (cm) of *Eucalyptus urophylla* seedlings according to the type of tube and spacing of seedlings in the tray



Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; *Distinct letters indicate significant differences by Tukey's multiple comparison test ($p<0.05$).

The diameter of *E. urophylla* seedlings was influenced by the tray ($p=0.0003$; $p<0.05$) used in its production (Table 2). Seedlings produced in the water collection tray (3.50 mm) and the flat polyethylene tray with 27% cell occupancy (3.05 mm) showed a significant difference compared to seedlings produced in the flat polyethylene tray with 50% cell occupancy (2.26 mm), as shown in Figure 4.

Table 2 – Statistical summary (mean and standard deviation) of the variable collar diameter (mm) of *Eucalyptus urophylla* seedlings according to the type of tube and spacing in the tray

Tube	Tray			Total
	B27	B50	BC	
Deg (mm)	3.32 (0.16)	2.46 (0.22)	3.59 (0.24)	3.18 (0.51)
Poly (mm)	2.78 (0.65)	2.06 (0.70)	3.41 (0.33)	2.82 (0.76)
Total (mm)	**3.05 (0.53)**	**2.26 (0.51)**	**3.50 (0.28)**	**3.00 (0.66)**
Interaction Tube x Tray	F=0.363 (p=0.701) *ns*			
Tube effect	F=4.081 (p=0.060) *ns*			
Tray effect	F=14.587 (p=0.0003) *			
CV (%)	14.22			

Source: Authors (2022)

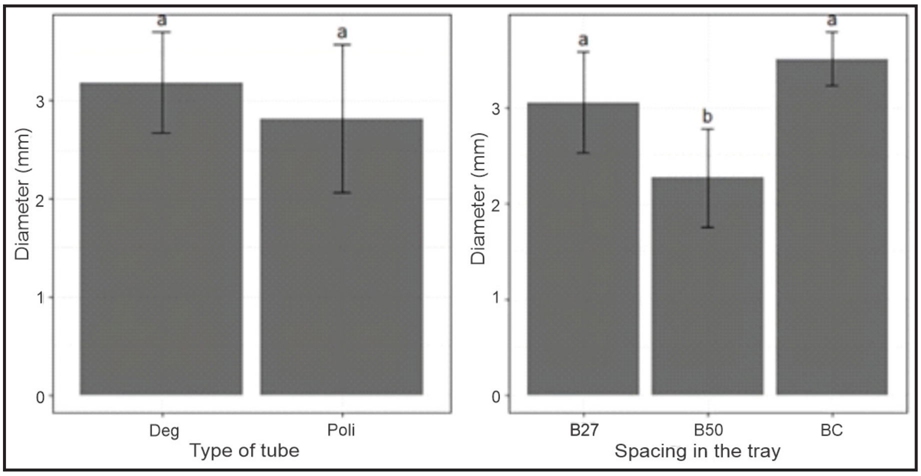
In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = Non-significant effect; *= Significant effect at 5%.

The water collection tray has a capacity of 40 cells with pre-defined locations and the flat polyethylene tray with 27% occupancy has 48 cells occupied with seedlings. Thus, competition between plants ends up becoming less, contributing to the increase and amount of energy captured per unit area when compared to the flat polyethylene tray with 50% occupancy, that is, 88 cells occupied with seedlings.

According to Sanquetta *et al*. (2014), plant biomass production depends on the amount of photosynthetically active solar radiation absorbed by the leaves and the efficiency with which the plant converts this energy into photoassimilates through photosynthesis. The light incidence on the leaves of seedlings in the water collection tray and flat polyethylene tray with 27% occupancy is higher because there is less competition for solar radiation between the seedlings, increasing biomass gain and, consequently, collar diameter.

Collar diameter is considered a morphological trait that indicates the survival capacity of seedlings in the field and must be higher than 2 mm for seedlings produced in 55 cm^3 tubes (Wendling; Dutra, 2017). Therefore, seedling diameter is within the quality standard for shipping even with a significant difference between trays.

Figure 4 – Mean effects of collar diameter (mm) of *Eucalyptus urophylla* seedlings according to the type of tube and seedling spacing in the tray



Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube.

The survival rate of *E. urophylla* seedlings was significantly influenced by the tray ($p=0.00002$; $p<0.05$) used in its production (Table 3). The collection tray showed a significant difference compared to the flat polyethylene tray with 27% occupancy and the flat polyethylene tray with 50% occupancy, consolidating survival rates of 0.99, 0.91, and 0.74, respectively (Table 3 and Figure 5).

The better utilization of irrigation water by seedlings in BC provided a higher number of live plants when compared to the seedlings in B27 and B50. The survival rate of seedlings is related to water availability (Manzato, 2022). Thus, BC presents conditions of less competition between seedlings and better utilization of irrigation water, and its use can provide positive conditions for the survival of seedlings in the nursery (Figure 5).

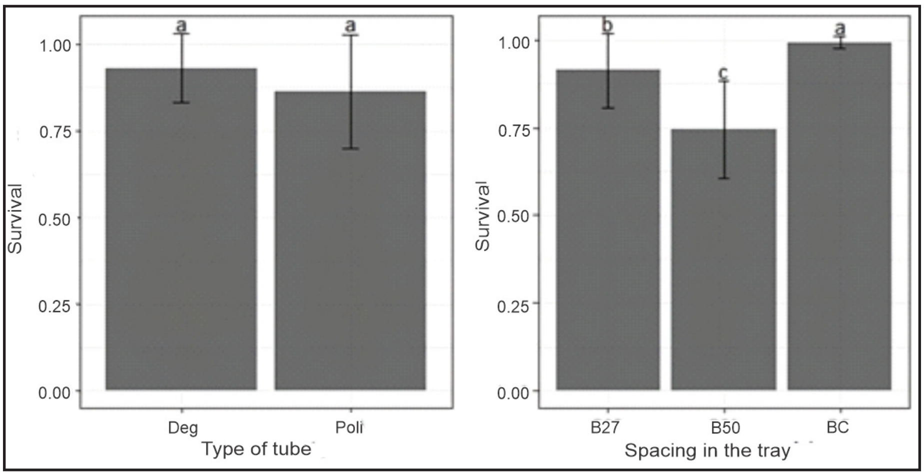
Table 3 – Survival rate (mean and standard deviation) of *Eucalyptus urophylla* seedlings according to the type of tube and spacing in the trays

Tube	Tray			Total
	B27	**B50**	**BC**	
Deg	0.96 (0.03)	0.79 (0.09)	1.00 (0.00)	0.93 (0.10)
Poly	0.87 (0.14)	0.70 (0.18)	0.99 (0.03)	0.86 (0.16)
Total	**0.91 (0.11)**	**0.74 (0.14)**	**0.99 (0.02)**	**0.900 (0.14)**
Interaction Tube x Tray	F=0.407 (p=0.672) *ns*			
Tube effect	F= 3.872 (p=0.067) *ns*			
Tray effect	F=22.110 (p=0.00002)			
CV (%)	10.33			

Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = Non-significant effect; * = Significant effect at 5%; *Statistical summaries are presented in the original scale of the variable (survival proportion), but the arcsine transformation of the square root of the respective proportions was applied for inferential analysis (ANOVA).

Figure 5 – Mean effects on the survival rate of *Eucalyptus urophylla* seedlings according to the type of tube and spacing in the tray



Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; *Distinct letters indicate significant differences by Tukey's multiple comparison test (p<0.05).

3.2 Root system, shoot, and total dry matter

The variables root system dry matter (Table 4), shoot dry matter (Table 5), and total dry matter (Table 6) presented no significant difference between means for the evaluated parameters "tube x tray", "tube" and "tray." However, the individual analysis of the means of the variables "tube" and "tray" showed that the seedlings produced in degradable tubes and water collection trays presented a higher mean for all variables.

Table 4 – Statistical summaries (mean and standard deviation) of the variable root dry matter (RDM), in grams, of *Eucalyptus urophylla* seedlings according to the type of tubes and spacing in the trays

Tube	Tray			Total
	B27	**B50**	**BC**	
Deg (g)	0.853 (0.307)	0.537 (0.200)	0.957 (0.214)	0.782 (0.285)
Poly (g)	0.490 (0.100)	0.553 (0.421)	0.667 (0.126)	0.570 (0.238)
Total (g)	**0.672 (0.285)**	**0.545 (0.295)**	**0.812 (0.224)**	**0.676 (0.277)**
Interaction Tube x Tray	F= 0.954 (p=0.413) *ns*			
Tube effect	F=3.171 (p=0.100) *ns*			
Tray effect	F= 1.670 (p=0.229) *ns*			
CV (%)	37.39			

Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = Non-significant effect; * = Significant effect at 5%.

The means of root system dry matter, shoot dry matter, and total dry matter presented by seedlings produced in the degradable tube (0.782 g, 1.812 g, and 2.594 g, respectively) were higher than those produced in the polyethylene tube (0.570 g, 1.320 g, and 1.890 g, respectively).

Table 5 – Statistical summaries (mean and standard deviation) of the variable shoot dry matter (SDM), in grams, of *Eucalyptus urophylla* seedlings according to the type of tube and spacing in the trays

Tube	Tray			Total
	B27	B50	BC	
Deg (g)	1.82 (0.431)	1.393 (0.673)	2.223 (0.150)	1.812 (0.543)
Poly (g)	1.180 (0.185)	1.233 (0.915)	1.547 (0.231)	1.320 (0.510)
Total (g)	**1.500 (0.459)**	**1.313 (0.724)**	**1.885 (0.410)**	**1.567 (0.570)**
Interaction Tube x Tray	F= 0.472 (p0.635) *ns*			
Tube effect	F=4.126 (p=0.065) *ns*			
Tray effect	F= 1.930 (p=0.188) *ns*			
CV (%)	32.82			

Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = non-significant effect; * = Significant effect at 5%.

The means of root system dry matter, shoot dry matter, and total dry matter presented by seedlings produced in the water collection tray (0.812 g, 1.885 g, and 2.697 g, respectively) were higher than those produced in the tray polyethylene with 27% occupancy (0.672 g, 1.500 g, and 2.172 g, respectively) and polyethylene tray with 50% occupancy (0.545 g, 1.313 g, and 1.858 g, respectively).

Table 6 – Statistical summaries (mean and standard deviation) of the variable total drymatter (TDM), in grams, of *Eucalyptus urophylla* seedlings according to the type of tube and spacing in the trays

Tube	Tray			Total
	B27	B50	BC	
Deg (g)	2.673 (0.710)	1.930 (0.820)	3.180 (0.364)	2.594 (0.790)
Poly (g)	1.670 (0.269)	1.787 (1.33)	2.213 (0.340)	1.890 (0.743)
Total (g)	**2.172 (0.730)**	**1.858 (0.993)**	**2.697 (0.616)**	**2.242 (0.828)**
Interaction Tube x Tray	F=0.650 (p=0.539) ns			
Tube effect	F=4.095 (p=0.066) ns			
Tray effect	F=1.974 (p=0.182) ns			
CV (%)	32.94			

Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = Non-significant effect; * = Significant effect at 5%.

3.3 Dickson quality index (DQI)

The Dickson quality index (Equation 1) of *E. urophylla* seedlings was significantly influenced by the tube (p=0.038595; p<0.05) and tray (p=0.030829; p<0.05) used in its production (Table 7). Seedlings produced in the degradable tube showed a significant difference compared to those produced in the polyethylene tube, showing DQI values of 0.299 and 0.187, respectively. The seedlings arranged in the water collection tray (DQI: 0.338) had a significantly higher difference compared to the flat polyethylene tray with 50% cell occupancy (DQI: 0.159). The seedlings arranged in the flat polyethylene tray with 27% cell occupancy (DQI: 0.231) showed similar results to the water collection tray and flat polyethylene tray with 50% occupancy (Figure 6).

Table 7 – Statistical summaries (mean and standard deviation) of the variable DQI of *Eucalyptus urophylla* seedlings according to the type of tube and spacing in the trays

Tube	**Tray**			**Total**
	B27	**B50**	**BC**	
Deg (g)	0.304 (0.102)	0.155 (0.056)	0.437 (0.174)	0.299 (0.161)
Poly (g)	0.158 (0.039)	0.164 (0.123)	0.240 (0.041)	0.187 (0.078)
Total (g)	**0.231 (0.105)**	**0.159 (0.085)**	**0.338 (0.156)**	**0.243 (0.135)**
Interaction Tube x Tray	F= 1.6617 (p=0.230658) *ns*			
Tube effect	F=5.3938 (p=0.038595) *			
Tray effect	F= 4.7150 (p=0.030829) *			
CV (%)	41.83			

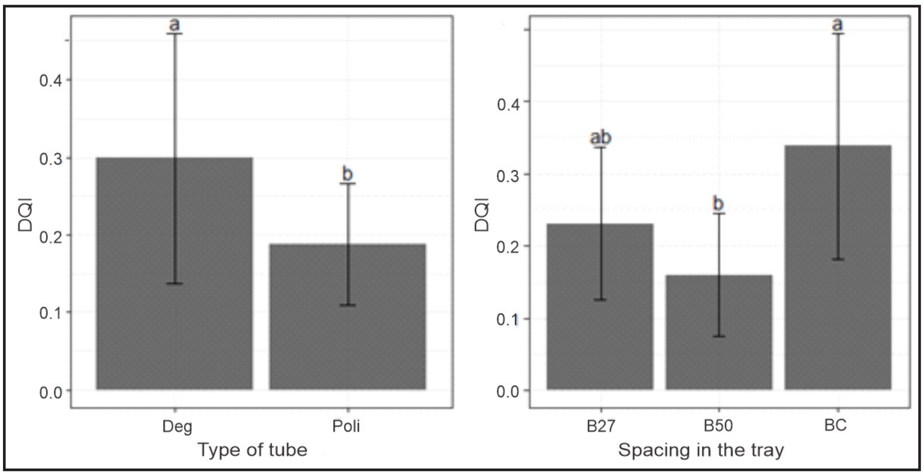
Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube; CV = Coefficient of variation; *ns* = Non-significant effect; * = Significant effect at 5%.

Statistically, seedlings grown in degradable tubes and the water collection tray presented higher height, as shown by the results obtained relative to height, stem diameter, shoot dry matter, root system dry matter, and total dry matter and considering that the DQI equation is related to these variables. Regarding collar diameter, the seedlings grown in the water collection tray and polyethylene tray with 27% occupancy had better results.

However, shoot dry matter, root system dry matter, and total dry matter showed no statistical difference, but higher means were observed in seedlings produced in degradable tubes and water collection trays. Thus, seedlings produced in the water collection tray and degradable tube presented proportionally higher values for the variables used in the equation and, consequently, helped to obtain higher values for DQI (Figure 6).

Figure 6 – Mean effects of DQI of *Eucalyptus urophylla* seedlings according to the type of tube and spacing of seedlings in the tray



Source: Authors (2022)

In where: B27 = Tray with 27% cell occupancy; B50 = Tray with 50% cell occupancy; BC = Tray with 100% cell occupancy; Deg = Degradable tube; Poly = Polyethylene tube. *Distinct letters indicate significant differences by Tukey's multiple comparison test ($p<0.05$).

4 CONCLUSIONS

The results of this research showed that the use of degradable tubes enabled better growth parameters (height, collar diameter, survival rate, dry matter, and DQI) for the clones evaluated under nursery conditions. The water collection tray presented a better performance for the growth of clones. Finally, the tray occupancy rate showed behavior inversely proportional to the growth of clones. The highest occupancy rate (B50) for the same type of tray generated lower means for the evaluated parameters than the lowest occupancy rate (B27).

In general, treatment T4 (combination of degradable tubes and water collection tray with 100% cell occupancy rate) generated the best mean results for the evaluated parameters for the experimental conditions outlined in this experiment. However, treatment T2 (degradable tube and flat tray with 27% cell occupancy) also showed good results compared to the other treatments. T2 presented mean values statistically equal to the values of T4, only showing a lower mean for the survival rate.

The results presented in this study indicate the importance of carefully choosing the cultivation system in the nursery phase to optimize the growth and survival of *Eucalyptus urophylla* seedlings.

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REFERENCES

ALFENAS, A. C.; ZAUZA, E. A. V.; MAFIA, R. G.; ASSIS, T. F. **Clonagem e doenças do eucalipto**. 2ed. Viçosa: UFV, 2009. p.442.

CLIMATE. **Botucatu Clima**. 2022. Available in: https://pt.climate-data.org/america-do-sul/brasil/sao-paulo/botucatu-4227/. Accessed in: 09 Mar. 2022.

CUNHA, A. R.; MARTINS, D. Classificação Climática para os municípios de Botucatu e São Manuel – SP. **Revista Irriga**, Botucatu, v. 14, n. 1, p. 1-11. 2009.

CONTI, A. C.; REIS, R. C. S.; CONTI, C.; DANIEL NETO, R. F.; ARANTES, A. K. Análise do desenvolvimento e da viabilidade econômica do plantio de mudas de árvores em tubetes biodegradáveis. **Revista de Tecnologias**, Ourinhos, v. 5, n. 1, p. 113-121, jun. 2012.

DIAS, B. A. S. **Análise comparativa de tubetes biodegradáveis e de polietileno na produção de mudas de Paratecoma Peroba (Record &Mell) Kuhlm**. 2011. 84p. Tese (Doutorado em Ciência Florestal) - Universidade Federal de Viçosa, Viçosa, 2011.

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

ELOY, E.; CARON, B. O.; SCHMIDT, D.; BEHLING, A.; SCHWERS, L.; ELLI, E. F. Avaliação da qualidade de mudas de *Eucalyptus grandis* utilizando parâmetros morfológicos. **Floresta**, Curitiba, v. 43, n. 3, p. 373-384, set. 2013.

FARIA, J. C. T.; LOPES, D. A.; LYRA, G. B.; MELO, H. C.; MELO, L. A. Manejo da densidade de plantas durante a produção de mudas em viveiro. **Ciência Florestal**, Santa Maria, v. 29, n. 3, p. 1187-1198, set. 2019. 7.

FREITAS, T. A. S.; BARROSO, D. G.; CARNEIRO, J. G. A.; PENCHEL FILHO, R. M.; SOUZA, L. S. Efeito de deformação e poda das raízes de mudas de eucalipto sobre o crescimento no campo. **Floresta**, Curitiba, v. 39, n. 2, p. 355-363, jun. 2009.

GÓMEZ, J. J. V.; MACIEL, J. L. M.; SILVA, M. R. Bandejas coletoras x bandejas tradicionais na produção de mudas de *Eucalyptus grandis* Hill ex Maiden x *Eucalyptus urophylla* S. T. Blake. Silviculture for *Eucalyptus* plantations. In: Congress Themes: C. Forests and Forest Products for a Greener Future. **Resumos**. Curitiba: 2019. p. 7.

MANZATO, C. L. **Estado hídrico de mudas de *Eucalyptus urophylla* na fase de rustificação identificado por meio de espectroscopia de infravermelho próximo e médio**. 87p. 2022. Tese (Doutorado em Ciência Florestal) – Universidade Estadual Paulista, Botucatu, 2022.

MENDONÇA, A. V. R.; RIBEIRO, L. G.; ASSUNÇÃO, J. R. A.; FREITAS, T. A. S.; SOUZA, J. S. Recipiente de fibras de *Attalea funifera* para produção de mudas de eucalipto. **Pesquisa Florestal Brasileira**. Colombo, v. 36, n. 87, p. 245-252, jul./set. 2016.

OLIVEIRA, D. P. F. **Análise técnica e econômica do uso de recipiente degradável na produção de mudas de *Eucalyptus urophylla*x *E. grandis*.** 84p. 2016. Dissertação (Mestrado em Ciência Florestal) - Faculdade de Ciências Agronômicas, Universidade Estadual Paulista, Botucatu, 2016.

R CORE TEAM. **R: A language and environment for statistical computing.** R Foundation for Statistical Computing, Vienna, Austria. Available in: https://www.R-project.org/. Accessed in: 27 Jan. 2023.

SANQUETTA, C. R.; BEHLING, A.; CORTE, A. P. D.; CADORI, G. C.; JUNIOR COSTA, S.; MACEDO, J. H. P. Eficiência de conversão da radiação fotossintética interceptada em fito massa de mudas de *Eucalyptus dunii* Maiden em função da densidade de plantas e do ambiente de cultivo. **Scientia Forestalis**, Piracicaba, v. 42, n. 104, p. 563-570, dez. 2014.

SEREGHETTI, G. C. **Qualidade do plantio manual e mecanizado para eucalipto e pinus**. 2016. Tese (Doutorado em Ciência Florestal) - Faculdade de Ciências Agronômicas, Universidade Estadual Paulista, Botucatu, 2016.

STORCK, E. B; SCHORN, L. A.; FENILLI, T. A. B. Crescimento e qualidade de mudas de *Eucalyptus urophylla x Eucalyptus grandis* em diferentes recipientes. **Floresta**, Curitiba, v. 46, n. 1, p. 39, jan. / mar. 2016.

TATAGIBA, S. D.; SILVA, A. G.; PENCHEL FILHO, R. M.; REIS, E. F.; RAMOS, K. A. Disponibilidade hídrica e doses de polímero hidrorretentor na produção de mudas clonais de eucalipto. **Revista Engenharia na Agricultura**, Viçosa, v. 27, n. 4, p. 359-369, jul. 2019.

WENDLING, I.; DUTRA, L. F. Produção de mudas de eucalipto por estaquia e miniestaquia. In: WENDLING, I.; DUTRA, L. F. **Produção de mudas de eucalipto**. 2ed. Colombo: Embrapa Florestas, 2017. p. 49-75.

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