INPUTS OPTIMIZATION IN THE SEEDLINGS PRODUCTION OF *Corymbia citriodora* E *Eucalyptus dunnii*

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Resumo

Otimização no uso de insumos na produção de mudas de Corymbia citriodora e *Eucalyptus dunnii*. *Corymbia citriodora* e *Eucalyptus dunnii* são espécies de relevância econômica devido a qualidade da madeira e potencial de crescimento na região Sul do Brasil. O objetivo do estudo foi identificar recipientes e doses de fertilizante de liberação controlada, capazes de potencializar a qualidade morfofisiológica e o crescimento de mudas destas espécies em viveiro, visando o manejo adequado desses insumos. As mudas foram produzidas em dois volumes de recipientes (50 e 110 cm³), preenchidos com substrato comercial a base de turfa do tipo *Sphagnum*, misturado com diferentes doses de fertilizante de liberação controlada (FLC) NPK 15-09-12 (0, 3, 6, 9 e 12 g L^{-1} de substrato). Foram avaliados os atributos morfológicos (altura, diâmetro do coleto, área foliar, massa seca da parte aérea, radicular e total) e fisiológicos (índice de clorofila *a* e *b* e rendimento quântico do fotossistema II). Atributos morfológicos mostraram-se indicadores adequados da qualidade de mudas de *C. citriodora* e*. dunnii*, permitindo recomendar o recipiente de 50 cm³ e as doses de 9,0 g L^{-1} de fertilizante de liberação controlada NPK 15-09-12 para ambas as espécies, enquanto as variáveis fisiológicas avaliadas não foram responsivas ao efeito dos tratamentos.

Palavras-chave: espécies florestais; volume de substrato; fertilizante de liberação controlada; clorofila; atributos morfológicos e fisiológicos.

Abstract

Optimization in the use of inputs in the production of seedlings of Corymbia citriodora and Eucalyptus dunnii. Corymbia citriodora and Eucalyptus dunnii are species of relevant importance due to the quality of the wood and growth potential in Southern Brazil. Therefore, we aimed to identify containers and doses of controlled-release fertilizer capable of enhancing the morphophysiological quality and growth of these species in the nursery, aiming for the proper management of these inputs. The seedlings were produced in two volumes of containers (50 e 110 cm³), filled with Sphagnum peat-based substrate, mixed with different doses of controlled-release fertilizer (CRF) NPK 15-09-12 (0, 3, 6, 9 e 12 g L^{-1} of substrates). In addition, the morphological (height, stem diameter, leaf area, dry weight of shoot, root, and total) and physiological (chlorophyll *a* and *b* index and quantum yield of the photosystem II) attributes were evaluated. The morphological attributes proved to be suitable indicators of the quality of *C. citriodora* and *E. dunnii* seedlings, allowing to recommend the container of 50 cm³ and the doses of 9.0 g L^{-1} of controlled-release fertilizer for both species. At the same time, the physiological variables evaluated were not responsive to the effect of the treatments.

Keywords: forest species; substrate volume; controlled-release fertilizer; chlorophyll; morphological and physiological attributes.

INTRODUCTION

Brazil has about 10 million hectares of planted forests, where approximately 75% of the areas are forest stands with species of the genus Eucalyptus (IBGE, 2018), with a perspective of an increase of 2 million hectares in the next ten years (BRASIL, 2020). Reis *et al.* (2015) relate the extension of areas planted with this genus in the country due to the adaptation of species to local edaphoclimatic characteristics, growth potential, and productivity.

Corymbia citriodora (Hook.) K. D. Hill & L.S.A. Johnson and *Eucalyptus dunnii* Maiden are among the main species planted in the country, aiming to produce wood and non-wood forest products. *C. citriodora* stands out for its quality of wood (high density, 650 kg/m³), being used in the sawmill, for charcoal, for firewood, sleepers, poles, stakes, and posts (LOPES *et al.*, 2014), and the production of essential oils (ARAUJO *et al.*, 2012). In addition, this species has attracted the interest of forestry companies that produce cellulose, due to the modernization of pulp extraction processes, with high yields in the industry. In turn, *E. dunnii* can reach from 30 to 45 meters in height, show rapid growth, and tolerate colder regions, which is why states of southern Brazil widely cultivate it. In addition, wood is suitable and of good quality for the production of cellulose (LORENZI *et al.*, 2003; FLORES *et al.*, 2016).

The success in the formation of forest stands is associated with the quality of the seedlings used in planting, as they ensure high survival, initial growth, and a reduction in the need to carry out silvicultural treatments in the stand (GOMES; PAIVA, 2012; ARAUJO *et al.*, 2018). According to Gomes e Paiva (2012), the quality of the seedlings relates directly to the inputs and techniques used in their production. In this scenario, basic fertilization stands out, which provides the necessary nutrients for the initial growth of the seedlings during the nursery stage. Controlled-release fertilizers (CRF) are a basic fertilization strategy capable of nourishing the plant for periods, generally compatible with the time it remains in the nursery, reducing the loss due to leaching, as well as reducing labor. Furthermore, this practice allows providing nutrients to the plants slowly and continuously, dispensing top dressing fertilizer (AIMI *et al.*, 2016).

The influence of fertilization on the quality of seedlings in the nursery phase is perceived through morphological characteristics such as height (H), stem diameter (SD), shoot dry matter (SDM), root dry matter (RDM), and also physiological attributes such as chlorophyll *a* fluorescence emission and photosynthetic pigments (GOMES; PAIVA, 2012; ARAUJO *et al.*, 2018). Recent studies have shown that the use of controlled-release fertilizer improves the morphological attributes of several forest species, increasing height values, stem diameter, total dry matter, and leaf area, in addition to physiological attributes, such as an increase in the chlorophyll index a and b and maximum quantum yield of photosystem II (AIMI *et al.*, 2019). However, there is still a lack of research to identify the stress that basic fertilization causes in the production phase of tree species seedlings.

The containers used for production directly influence the quality of seedlings, which is generally related to the volume of the substrate. Polypropylene tubes stand among the most used containers for forest species in nurseries (GOMES; PAIVA, 2012). These containers stood out in relation to others due to the presence of internal longitudinal streaks that direct root growth and the hole in the base that facilitates the pruning of the roots naturally, providing better formation of the root system, lower incidence of pests and diseases, reuse of material and ergonomics during seedling management (GOMES; PAIVA, 2012; ARAUJO *et al.*, 2018). Thus, these containers provide the production of high-quality seedlings.

In this sense, the study's objective was to identify containers and doses of controlled-release fertilizers capable of enhancing the development and growth of *C. citriodora* and *E. dunnii* seedlings in nurseries, aiming at the proper management of these inputs.

MATERIAL AND METHODS

Location and conduct of experiments

The research was carried out in a greenhouse at the Forest Nursery of the Department of Forest Sciences (29º43'13" S and 53º43'17" W) at the Federal University of Santa Maria, the municipality of Santa Maria, Rio Grande do Sul, Brazil. According to Köppen's classification, the region has a humid subtropical climate (Cfa), with an average temperature in the coldest months of -3 to 18 ºC (June to August) and in the warmer months, temperatures above 22 ºC (December to February), with mean annual precipitation ranging from 1,600 to 1,900 mm (ALVARES *et al.*, 2013).

The experimental design used was completely randomized, in a 2 x 5 factorial scheme, for each species (*C. citriodora* and *E. dunnii*) considering two volumes of containers (polypropylene tubes of 50 and 110 cm^3) and five doses of controlled-release fertilizer (CRF 15-09-12) (0, 3, 6, 9 and 12 g L^{-1} substrate). Each treatment consisted of three replicates containing 24 seedlings, measuring eight central seedlings of each repetition.

The seeds used to produce seedlings came from the Institute of Forestry Research, with a germination percentage of approximately 90%. Carolina Soil® commercial substrate based on *Sphagnum* peat and vermiculite filled the containers. A concrete mixer moistened the CRF doses to the substrate during the mixing procedure. According to the manufacturer's technical specifications, the fertilizer used in the base fertilization had a semipermeable organic layer, release time of six months and the following chemical composition: macronutrients 15% of nitrogen (N); 9% superphosphate (P_2O_5); 12% potassium chloride (K_2O); 1% magnesium (Mg) and the micronutrients 2.3% sulfur (S); 0.05% copper (Cu); 0.06% manganese (Mn); 0.45% iron (Fe) and 0.2% molybdenum (Mo).

Sowing happened in July (end of winter), placing two to three seeds per container, and 30 days after sowing, thinning was carried out, with the seedling remaining more vigorous and central. Finally, a greenhouse received the trays with micro-sprinkler irrigation (5 mm day^{-1}). The 10 and 50 cm^3 containers used 96 and 140 cells trays, respectively, with 50% alternation.

Assessment of morphophysiological attributes

The seedlings evaluation took place 120 days after sowing, and the following morphophysiological attributes were determined: shoot height (H), stem diameter (SD), leaf area (LA), shoot dry matter (SDM), root dry matter (RDM), and total dry matter (TDM), chlorophyll index and chlorophyll *a* fluorescence. First, a ruler and a digital caliper measured the H and SD. Subsequently, three plants per repetition were sectioned in the stem region, separating the aerial and root parts. For the quantification of LA, the sheets were detached and placed on a white A4 sheet containing the scale reference. Then, the ImageJ® software processed the images obtained with a digital camera. Next, running water over a sieve washed the roots (0.84 mm mesh). Afterward, the aerial and root samples were placed in identified paper bags and conditioned in an oven with forced air circulation regulated at 65 ºC until constant weight and weighed on an analytical scale to obtain the SDM and RDM. The MST results from adding the SDM and RDM.

A non-destructive reading through a portable optical chlorophyllometer (ClorofiLOG, CF 1030, Falker Automação Agrícola, Brazil) obtained the Falker Chlorophyll Index for chlorophyll *a* (FCI*a*) and chlorophyll *b* (FCI*b*) of the seedlings. The evaluation happened at two points in the fifth leaf's middle third, considering three seedlings per repetition.

The fluorescence emission of chlorophyll *a* was analyzed with a portable light-modulated fluorometer (Junior-Pam Chlorophyll Fluorometer Walz Mess-und-Regeltechnik, Germany). Measurements were carried out in the morning (8:00 - 11:00 h) on sunny days, without the presence of clouds, using fully expanded leaves of four plants with average H and SD per treatment. Previously, the leaves were dark-adapted for 30 minutes to measure the initial fluorescence (F_0) and, subsequently, subjected to a pulse of saturating light (10,000 µmol m^{-2} s^{-1}) for 0.6 s, still obtaining the maximum quantum yield of PSII (F_v/F_m).

Statistical Analysis

The Shapiro-Wilk and Bartlett tests, respectively, checked the data for assumptions of normality of errors and homogeneity of variances. Then, after the analysis of variance, when a difference exists between treatments, the means were compared using the t-test for the recipient factor and polynomial regression for the CRF doses factor (p<0.05). After, the maximum technical efficiency dose (MTED) determination happens in the case of a significant effect of quadratic equations. Then, the Sisvar statistical software analyses the data (FERREIRA, 2014). Finally, MTED was calculated as a function of the equation using the formula:

$$MTED = -b1/2b2$$

RESULTS

Morphological and physiological attributes *C. citriodora*

The analysis of variance showed an interaction (p<0.05) between the factors (containers x CRF doses) for the variables H, SD, and maximum PSII quantum yield. In addition, for the attributes LA, Falker chlorophyll index, SDM, RDM, and TDM, there was a significant effect (p<0.05) in isolation for the tested factors.

The H presented a linear behavior, and the means increased as the higher doses of controlled-release fertilizer were added for the evaluated containers (Figure 1A). Similar to height, the stem diameter showed a linear trend. That is, the increase in CRF doses promoted more significant growth in SD of *C. citriodora* seedlings (Figure 1B). On the other hand, for F_v/F_m, there was a quadratic behavior, with MTED of 9.04 g L^{-1} for the 50 cm³ (0.51) container and 3.4 g L^{-1} for the 110 cm³ (0.57) (Figure 1C).

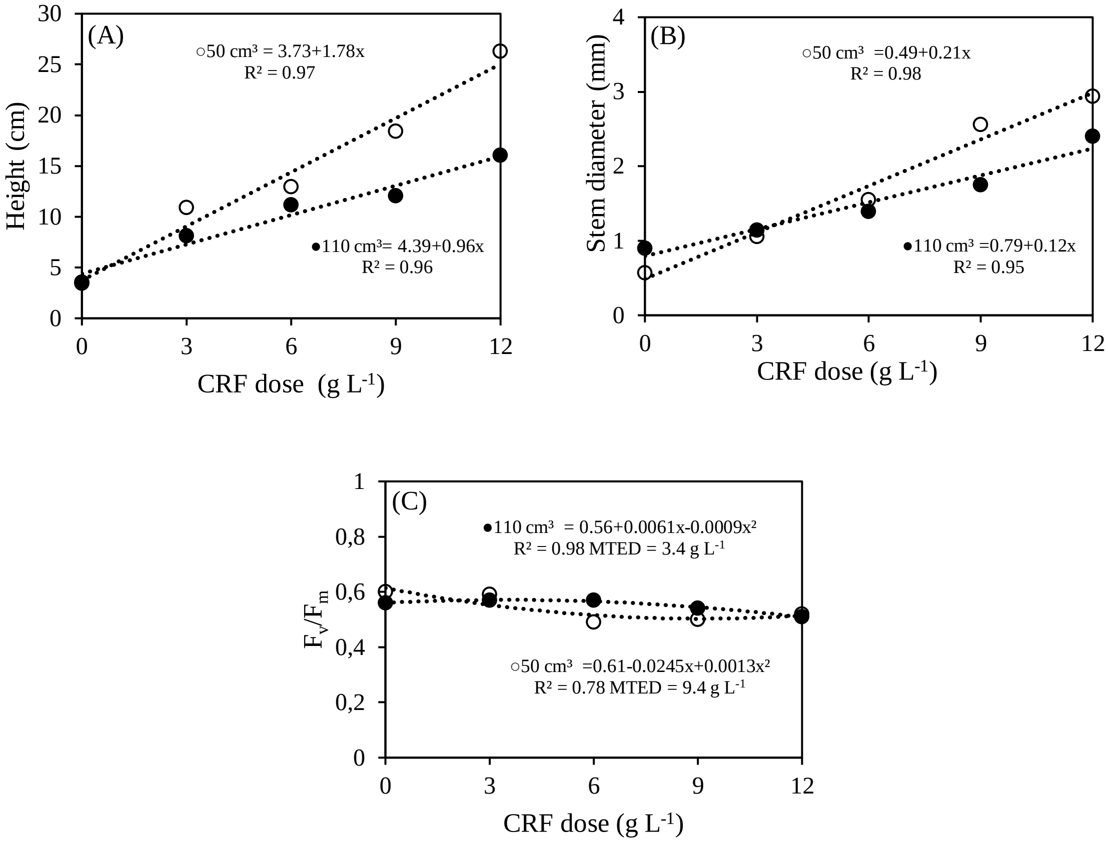

Figure 1. Height (A), stem diameter (B), and maximum quantum yield (F_v/F_m) (C) of *Corymbia citriodora* seedlings produced in different volumes of tubes and doses of controlled-release fertilizer (NPK15-09-12), at 120 days after sowing, in the nursery phase.

Figura 2. Altura (A), diâmetro do coleto (B) e rendimento quântico máximo (F_v/F_m) (C) de mudas de *Corymbia citriodora* produzidas em diferentes volumes de tubetes e doses de fertilizante de liberação controlada (NPK15-09-12), aos 120 dias após a semeadura, na fase de viveiro.

The containers used in the production of seedlings influenced the LA and dry matter accumulation (DMA, RDM, and TDM) of *C. citriodora*. The seedlings cultivated in the smaller volume containers presented the highest values for these attributes. In this condition, the LA was 41.8% higher in relation to the 110 cm³ tubes (Table 1).

Table 1. Leaf area (LA), shoot dry matter (SDM), root dry matter (RDM), and total dry matter (TDM) of *Corymbia citriodora* seedlings at 120 days after sowing, as a function of the size of the container in the nursery.

Tabela 1. Área foliar (AF), massa seca da parte aérea (MSPA), massa seca radicular (MSR) e massa seca total (MST) de mudas de *Corymbia citriodora* aos 120 dias após o semeio, em função do tamanho do recipiente em viveiro.

Container (cm³)	LF (cm²)	SDM (g)	RDM (g)	TDM (g)
50	101.3 a*	3.4 a	2.94 a	639 a
110	59.0 b	3.2 b	2.79 b	6.04 b
Mean	80.15	33.00	2.86	6.21
CV (%)	41.26	5.93	4.30	4.87

*Means followed by the same letter do not differ by the t-test (p<0.05); CV: Coefficient of variation.

Regarding the Falker chlorophyll index, there was no difference between the sizes of containers used to produce seedlings. The mean values were 25.66 and 5.92 for FCI*a* and FCI*b*, respectively.

As for CRF doses, 10.12 g L^{-1} MTED gave the highest LA values (174.14 m² plant-1). Under this condition, the growth was 98.3% higher than the control (without CRF application) (Figure 2A). The TDM ranged from 5.44 to 5.56 g $plant^{-1}$, with the lowest average shown in seedlings cultivated with a dose of 4.38 g L^{-1} of CRF. TDM and SDM showed linear behavior, showing that with the increase in the availability of CRF, there is an increase in the biomass production of seedlings (Figure 2B). For FCI*a*, MTED was 9.7 g L^{-1}, and for FCI*b*, the chlorophyll index increased proportionally with the highest doses of controlled-release fertilizer (Figure 2C).

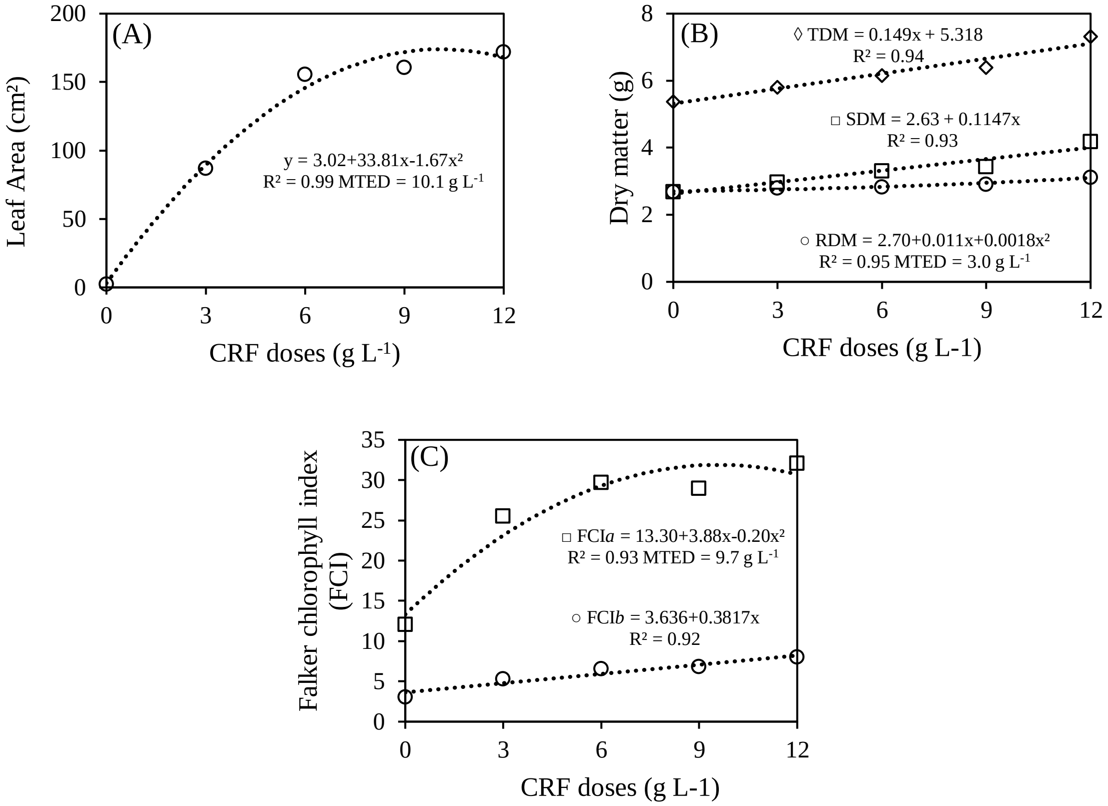

Figure 3. Growth in leaf area (LA) (A); shoot dry matter (SDM), root dry matter (RDM) and total dry matter (TDM) (B); Falker chlorophyll index chlorophyll a (FCI*a*) and b (FCI*b*) (C) evaluated 120 days after sowing *Corymbia citriodora*, as a function of controlled-release fertilizer doses (CRF, NPK15-09-12).

Figura 4. Crescimento em área foliar (A); massa seca da parte aérea (MSPA), massa seca radicular (MSR) e massa seca total (MST) (B); índice de clorofila Falker clorofila *a* (ICF*a*) e *b* (ICF*b*) (C) avaliadas aos 120 dias após a semeadura de *Corymbia citriodora*, em função das doses de fertilizante de liberação controlada (FLC, NPK15-09-12).

Morphological and physiological attributes of *E. dunnii*

In the analysis of variance for Eucalyptus dunnii, there was a significant interaction ($p<0.05$) between the factors (containers x CRF doses) for the attributes SDM, SD, and maximum quantum yield of photosystem II. However, none of the factors tested influenced the total TDM. There was only a significant effect for isolated factors for variables H, LA, RDM, FCI*a*, and FCI*b*.

In the accumulation of SDM, the highest value observed for the 50 cm³ containers was when using 9 g L^{-1} of CRF, denoting 4.21 g $plant^{-1}$. On the other hand, for the 110 cm³ containers, an increasing linear trend was observed, with the increase in CRF doses proportionally increasing the allocation of SDM in the seedlings, with the highest value at the dose of 12 g L^{-1} (Figure 3A).

The highest values of the stem diameter for the container of 50 cm³ were at the dose close to 9 g L^{-1}. For the 110 cm³ containers, the highest averages were at a higher dose than that measured in a 50 cm³ container (9.6 g L^{-1}) (Figure 3B).

Seedlings produced in 110 cm³ containers had the highest averages of F_v/F_m in the MTED of 6.1 g L^{-1}, corresponding to 0.64. For the 50 cm³ containers, this attribute expressed a linear upward trend. That is, the higher the dose of CRF applied, the greater the F_v/F_m, reaching a maximum value of 0.73 in the dose of 12 g L^{-1} of CRF (Figure 3C).

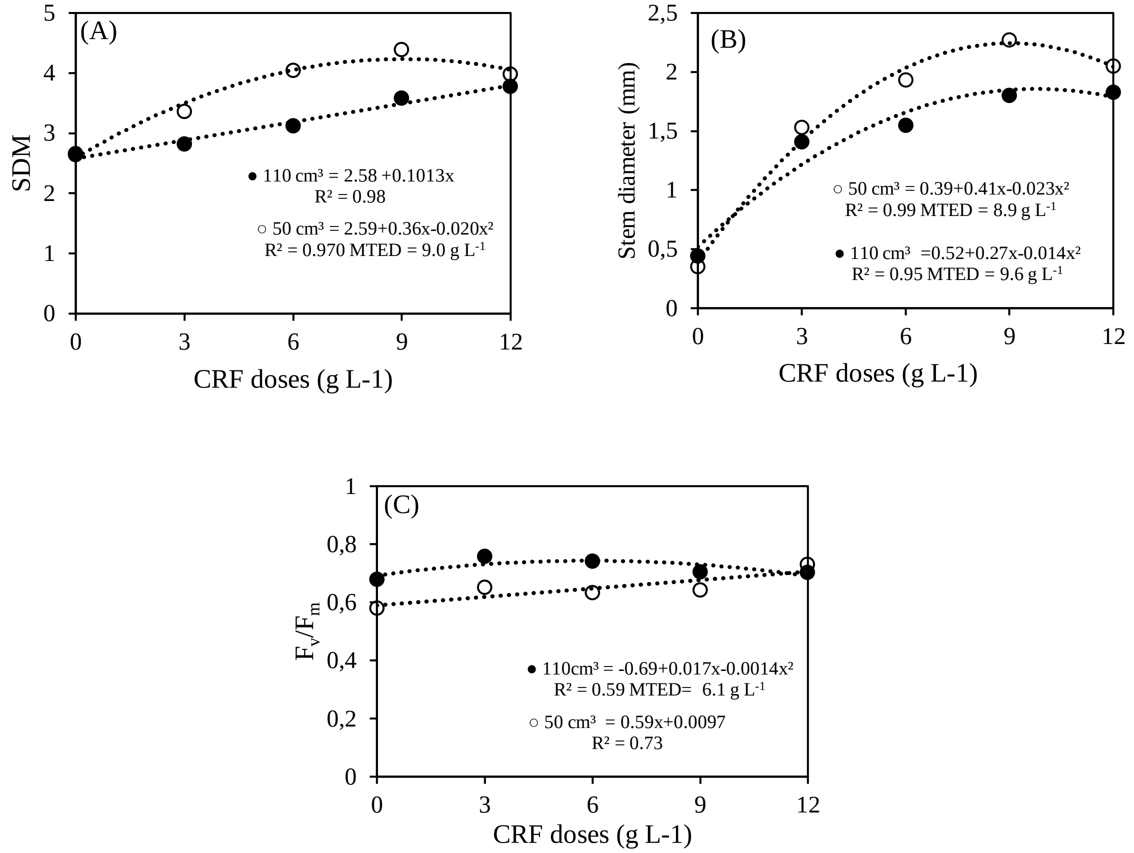

Figure 3. Shoot dry matter (SDM) (A), stem diameter (SD) (B), and maximum quantum yield (F_v/F_m) (C) of *Eucalyptus dunnii* seedlings produced in different tube volumes and controlled-release fertilizer doses (NPK15-09-12), 120 days after sowing, in the nursery stage.

Figura 3. Massa seca da parte aérea (MSPA) (A), diâmetro do coleto (B) e rendimento quântico máximo (F_v/F_m) (C) de mudas de *Eucalyptus dunnii* produzidas em diferentes volumes tubetes e doses de fertilizante de liberação controlada (NPK15-09-12), aos 120 dias após a semeadura, na fase de viveiro.

The seedlings produced in containers with smaller volumes showed the highest means for the morphological attributes H, LA, and RDM (Table 2). When cultivated in 50 cm^3 containers, *E. dunnii* seedlings increased 6.6 cm in H and 42.3 cm^2 of LA, compared to those produced in 110 cm^3 tubes, representing a gain of approximately 29 and 42%, respectively. The container used did not influence the accumulation of photosynthetic pigments, showing average values of Falker chlorophyll indices of 24.6 (FCI*a*) and 6.5 (FCI*b*) for *E. dunnii* seedlings.

Table 2. Morphological attributes of *Eucalyptus dunnii* seedlings 120 days after sowing, as a function of container size in the nursery.

Tabela 2. Atributos morfológicos de mudas de *Eucalyptus dunnii* aos 120 dias após o semeio, em função do tamanho do recipiente em viveiro.

Container (cm^3)	**H (cm)**	**LA (cm^2)**	**RDM (g)**
50	23.1 a*	101.3 a	3.01 a
110	16.5 b	59.0 b	2.93 b
Mean	19.80	80.15	2.97
CV (%)	14.56	33.23	3.50

*Means followed by the same letter do not differ by the t-test ($p<0.05$). Where: H: height of the aerial part; LA: leaf area; RDM: root dry matter; CV: Coefficient of variation

The highest values in H (28.43 cm) were at the maximum technical efficiency dose (MTED) of 10.29 g L^{-1} of CRF. In this condition, the growth was 93.7% higher than the control (without CRF application) (Figure 4A). The CO ranged from 0.45 to 1.89 mm (Figure 4B), with the lowest mean observed in seedlings cultivated with a dose of 0 g L^{-1} of CRF and the highest in MTED of 8.5 g L^{-1}. On the other hand, there was a 12.7% reduction in CO in plants grown at a dose of 12 g L^{-1} compared to that observed in MTED (Figure 4B).

Increasing doses of CRF in the substrate provided a linear increase in the LA of *E. dunnii* seedlings (Figure 4C). In addition, the increasing CRF doses resulted in a linear increase in RDM (Figure 4D). For FCI*a*, the estimated MTED was 8.83 g L-1, while for FCI*b*, the dose was 10.87 g L^{-1} (Figure 4E), corresponding to indices of 30.12 and 7.89, respectively.

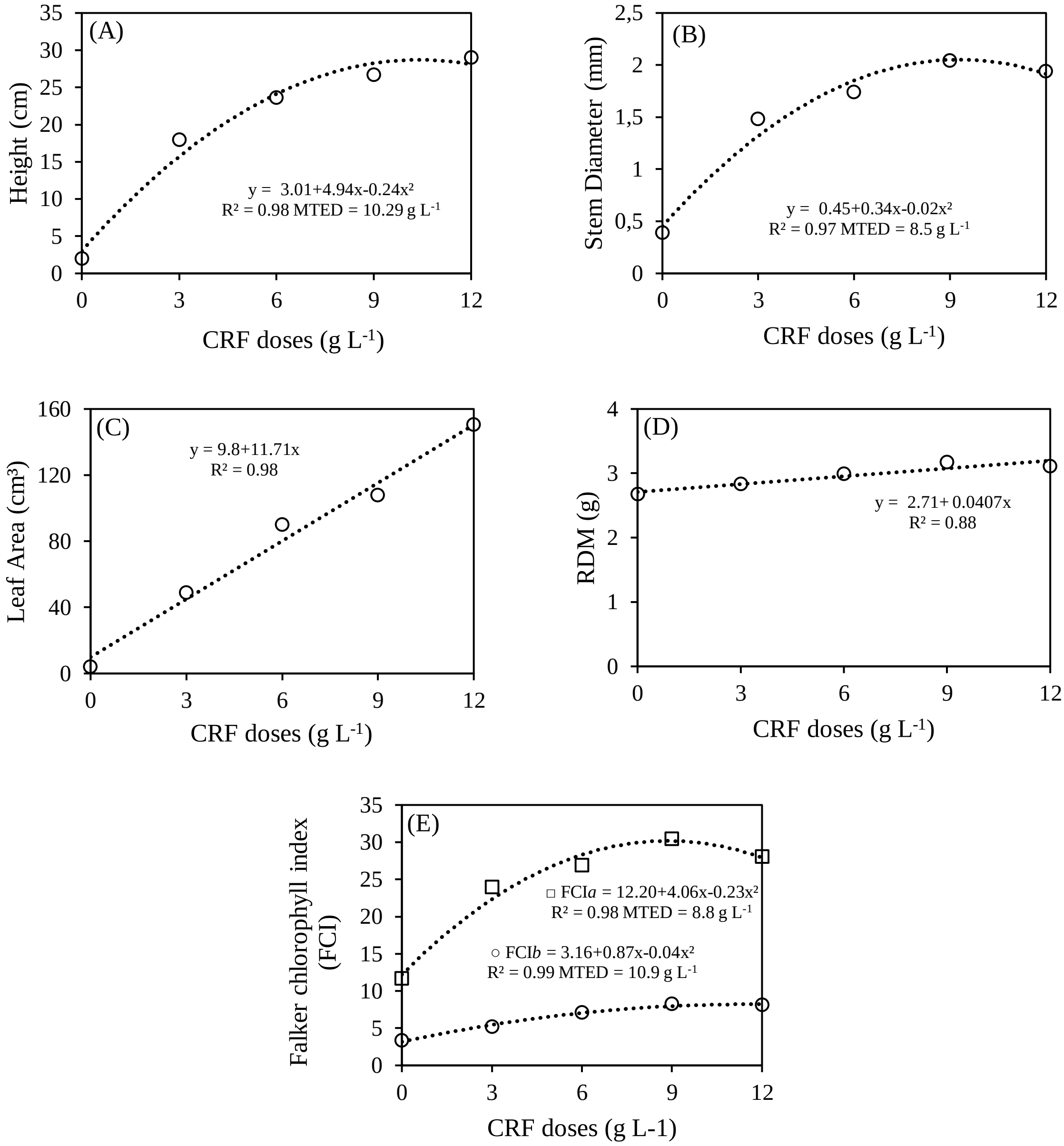

Figure 4. Mean height (A), stem diameter (B), leaf area (C), root dry matter (RDM) (D), CFI*a* and CFI*b* (E), evaluated 120 days after sowing *Eucalyptus dunnii*, in function of controlled-release fertilizer doses (NPK15-09-12) in the nursery phase.

Figura 4. Médias de altura (A), diâmetro do coleto (B), área foliar (C), massa seca radicular (MSR) (D), IFC *a* e IFC *b* (E), avaliadas aos 120 dias após a semeadura de *Eucalyptus dunnii*, em função das doses de fertilizante de liberação controlada (NPK15-09-12), na fase de viveiro.

DISCUSSION

The container with the smallest volume (50 cm³) was the most suitable for the production of seedlings of *C. citriodora* and *E. dunnii* (Tables 1 and 2), these seedlings have more significant potential to be subjected to hardening at 120 days after sowing when produced with higher doses of CRF (Figures 1A, B and 3A, B), close to 9 g L^{-1}. These results are related to the characteristics of the species, which showed rapid growth and development in the nursery stage, allowing their production with a smaller volume of substrate, reduction in base fertilization, and, consequently, in the costs with the acquisition of inputs by the nurseryman. Plants of the Corymbia and Eucalyptus genera, produced in this type and volume of the container, also developed adequately in the field, without harming their establishment (FREITAS *et al.*, 2013; LOPES *et al.*, 2014).

Given these inputs, the seedlings of the studied species reached the height and stem diameter greater than 20 cm (Figure 1A and 4A) and 2 mm (Figure 1B and 4B), being within the quality standard described by Wendling e Dutra (2010). The better performance in the face of high CRF doses indicates the plants' responsiveness and greater demand for nutrient availability, emphasizing *E. dunnii*, which in this condition also increased the SDM, RDM, and the Falker chlorophyll index. Navroski *et al.* (2016) described doses varying between 5 and 6.6 g L^{-1} promoted better results for the morphological attributes of *E. dunnii* seedlings, obtaining mean values for H and SD of 18.5 cm and 1.8 mm, respectively.

The results obtained demonstrate that the application of doses close to 9 g L^{-1}, or even higher, maximizes the physiological attributes associated with the use of light, maximizing net photosynthesis and, consequently, the accumulation of biomass. Furthermore, this event is favored by the positive effect of nitrogen (N) and phosphorus (P) on photosynthesis and plant growth (NETZER *et al.*, 2019), since such elements participate in structures and metabolic processes of plants, as N is part of the molecular structure of chlorophyll, while the P of cofactors involved with the Calvin Cycle (TAIZ *et al.*, 2017).

The increased availability of CRF promoted greater height and diameter of the stem for both *C. citriodora* and *E. dunnii* (Figures 1 A, B), and doses close to 9 g L^{-1} CRF positively influenced these morphological attributes (Figures 4 A, B). These results corroborate those obtained by Rossa *et al.* (2015), observing a higher mean height-to-diameter ratio at doses close to 9 g L^{-1}. In addition, increasing CRF doses promoted a greater increase in leaf area (Figures 2A and 4C). This occurs because there is a stimulus in the energy metabolism of plants and provides greater cell division and expansion (TAIZ *et al.*, 2017). As a result of these processes, there is an increase in light absorption, as well as CO2 assimilation, enhancing photosynthetic rates (CROUS *et al.*, 2015), greater growth (ZAMBROSI *et al.*, 2011), and dry matter production of plants (VENEKLAAS *et al.*, 2012; NIELSEN *et al.*, 2015;).

E. dunnii delivered the most expressive results using 9.0 g L^{-1} of CRF, for SDM and RDM (Figure 3A and 4D). These observed means corroborate the dosage found by Rossa *et al.* (2015) for SDM of *Eucalyptus grandis* W. Hill ex Maiden seedlings. Lower doses were needed to increase these attributes of *C. citriodora*, between 3 and 4 g L^{-1} of CRF (Figure 2B). The SDM indicates the seedlings' rusticity, while the RDM indicates the survival and initial development of the seedlings in the field (GOMES; PAIVA, 2012).

Based on the results obtained, it is possible to say that providing adequate doses of basic fertilizer means greater absorption of nutrients, which increases the chlorophyll index, causing greater use of light energy and increased photosynthetic efficiency. As a result, there is a greater increase in the height and diameter of the plant stem. Chlorophylls are responsible for absorbing light energy (TAIZ *et al.*, 2017). The different species studied had similar values of the chlorophyll a index, and the best results were for dosages close to 9.0 g L^{-1} of CRF. Also, *E. dunnii* and *C. citriodora* delivered close means for the variable ICF b. Such values are in the range of 5 to 7, but they can vary between species. Dutra *et al.* (2012) highlight that the increase in chlorophyll b represents an essential mechanism for acclimatization and adaptation to places with lower light intensity.

The maximum quantum yield values of photosystem II found were between 0.6 and 0.8 for the species studied, demonstrating the high efficiency of the photosynthetic apparatus (FIGUEIREDO *et al.*, 2014), characteristic of pioneer and fast-growing species. Similar Fv/Fm values were found by Figueiredo *et al.* (2014), studying different clones of *Eucalyptus grandis x Eucalyptus urophylla*, a highly competitive hybrid used in forestry industries.

It is essential to consider the different factors that influence the development and growth of seedlings, such as the type of substrate, production environment, and light intensity. The CRF doses with maximum technical efficiency obtained in this research were lower than that found by Rossa *et al.* (2015) in a study with *E. grandis*. These results demonstrate that the species, despite the same genus, need different doses to present a satisfactory development, highlighting the importance of silvicultural knowledge of each species for the production of seedlings.

CONCLUSIONS

- Using polypropylene tube-type containers with a capacity of 50 cm³ is recommended for *Corymbia citriodora* and *Eucalyptus dunnii* seedlings, promoting the production of quality seedlings associated with a reduction in the use of inputs.
- For the production of *Corymbia citriodora* and *Eucalyptus dunnii* seedlings, controlled-release fertilizer (CRF) NPK 15-09-12 in doses of 9.0 g L^{-1} is recommended, as this favors the development of seedlings in the nursery stage.

REFERENCES

AIMI, S. C.; ARAUJO, M. M.; LEÓN, E. B.; OLIVEIRA, G. G.; CUNHA, F. S. Volumen de contenedores y dosis de fertilizante de liberación controlada en el crecimiento de plantas de *Cabralea canjerana* producidas en vivero. **Bosque**, Valdívia, v. 37, n. 2, p. 401–407, 2016.

AIMI, S. C.; ARAUJO, M. M.; FERMINO, M. H.; TABALDI, L. A.; ZAVISTANOVOCZ, T. C.; MIETH, P. Substrate and fertilization in the quality of *Myrocarpus frondosus* seedlings. **Floresta**, Curitiba, v. 49, n. 4, p. 831–840, 2019.

ALVARES, C. A.; STAPE, J. L; SENTELHAS, P. C.; GONÇALVES, J. L. D.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Germany, v. 22, n. 6, p. 711–728, 2013.

ARAUJO, H. J. B.; MAGALHÃES, W. L. E.; OLIVEIRA, L. C. D. Durabilidade de madeira de eucalipto citriodora (*Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson) tratada com CCA em ambiente amazônico. **Acta Amazonica**, Manaus, v. 42, n. 1, p. 49–58, 2012.

ARAUJO, M. M.; NAVROSKI, M. C.; FILHO, E. A.; SCHORN, L. A. Produção de mudas por sementes. In: ARAUJO, M. M; NAVROSKI, M. C.; SCHORN, L. A. (Org.). **Produção de sementes e mudas: um enfoque à silvicultura**. Santa Maria: Ed. UFSM, 2018, 448 p.

BRASIL. **Mapa desenvolve programa para estimular a área de florestas plantadas no território nacional**. Disponível em: <https://www.gov.br/agricultura/pt-br/assuntos/noticias/mapa-desenvolve-programa-para-estimular-a-area-de-florestas-plantadas-no-territorio-nacional>. Acesso em: 26 abr. 2020.

CROUS, K. Y.; ÓSVALDSSON, A.; ELLSWORTH, D. S. Is phosphorus limiting in a mature Eucalyptus woodland? Phosphorus fertilisation stimulates stem growth. **Plant and Soil**, Amsterdã, v. 391, n. 1, p. 293–305, 2015.

DUTRA, T. R.; MASSAD, M. D.; SANTANA, R. C. Parâmetros fisiológicos de mudas de copaíba sob diferentes substratos e condições de sombreamento. **Ciência Rural**, Santa Maria, v. 42, n. 7, p. 1212–1218, 2012.

FIGUEIREDO, F. A. M. M. D. A.; CARNEIRO, J. G. D. A; PENCHEL, R. M.; CAMPOSTRINI, E.; THIEBAUT, J. T. L.; BARROSO, D. G. Trocas gasosas, relações hídricas e eficiência fotoquímica em mudas clonais de eucalipto com permanência prolongada em tubetes. **Scientia Forestalis**, Piracicaba, v. 42, n. 104, p. 533–542, 2014.

FERREIRA, D. F. Sisvar: a Guide for its Bootstrap procedures in multiple comparisons. **Ciência e Agrotecnologia**. Lavras, v. 38, n. 2, p. 109-112, 2014.

FLORES, T. B.; ALVARES, C. A; SOUZA, V. C.; STAPE, J. L. **Eucalyptus no Brasil: zoneamento climático e guia de identificação**. Piracicaba: Ed. Ipef, 2016, 448p.

FREITAS, T. A. S. D.; FONSECA, M. D. S.; SOUZA, S. S. M. D.; LIMA, T. M.; MENDONÇA, A. V. R.; SANTOS, A. P. D. Crescimento e ciclo de produção de mudas de Eucalyptus em recipientes. **Pesquisa Florestal Brasileira**, Colombo, v. 33, n. 76, p. 419–428, 2013.

GOMES;, J. M.; PAIVA;, H. N. **Viveiros Florestais Propagação sexuada**. Viçosa, 1 ed., 2012, 116 p .

IBGE. **Instituto Brasileiro de Geografia e Estatística**. Disponível em: <https://sidra.ibge.gov.br/tabela/5930>. Acesso em: 28 nov. 2019.

LOPES, E. D.; AMARAL, C. L. F.; DE NOVAES, A. B. Desempenho no campo de mudas de *Eucalyptus urophylla*, *Eucalyptus camaldulensis* e *Corymbia citriodora* produzidas em diferentes recipientes. **Floresta**, Curitiba, v. 44, n. 4, p. 589–596, 2014.

LORENZI, H.; SOUZA, H. M. D.; TORRES, M. A. V.; BACHER;, L. B. **Árvores exoticas no Brasil madereiras, ornamentais e aromáticas**. Nova Odessa 1. Ed. , 2003, 368 p.

NAVROSKI, M. C.; NICOLETTI, M. F.; LOVATEL, Q. C.; PEREIRA, M. D. O.; TONETT, E. L.; MAZZO, M. V.; MENEGUZZI, A.; FELIPPE, D. Efeito do volume do tubete e doses de fertilizantes no crescimento inicial de mudas de *Eucalyptus dunnii* Maiden. **Revista Agrarian**, Dourados, v. 9, n. 31, p. 26–33, 2016.

NETZER, F.; POZZI, L.; DUBBERT, D.; HERSCHBACH, C. Improved photosynthesis and growth of poplar during nitrogen fertilization is accompanied by phosphorus depletion that indicates phosphorus remobilization from older stem tissues. **Environmental and Experimental Botany**, Barcelona, v. 162, n. 3, p. 421–432, 2019.

NIELSEN, U. N.; PRIOR, S.; DELROY, B.; WALKER, J. K. M.; ELLSWORTH, D. S.; POWELL, J. R. Response of belowground communities to short-term phosphorus addition in a phosphorus-limited woodland. **Plant and Soil**, Amsterdã, v. 391, n. 1, p. 321–331, 2015.

REIS, C. F.; MORAES, A. D. C. De; PERERIRA, A. V.; AGUIAR, A. V. D.; SOUZA, V. A. D.; BORGES, H. M. D. **Diagnóstico do Setor de Florestas Plantadas no Estado de Goiás**. Brasil: Embrapa, 1 Ed. 2015, 140p.

ROSSA, Ü. B.; ANGELO, A. C.; BOGNOLA, I. A.; WESTPHALEN, D. J.; FREITAS, J. E. M. D. Fertilizante de liberação lenta no desenvolvimento de mudas de *Eucalyptus grandis*. **Floresta**, Curitiba, v. 45, n. 1, p. 85–96, 2015.

TAIZ, L. ZEIGER, E.; MOLLER, I.M.; MURPHY, A. **Fisiologia e desenvolvimento vegetal**. Porto Alegre: Ed. Artmed, 2017. p. 888.

VENEKLAAS, E. J.; LAMBERS, L.; BRANGG, J.; FINNEGAN, P. M.; LOVELOCK, C. E.; PLAXTON,W. C.; PRICE, C.A.; SCHEIBLE,W.; SHANE, M.W.; WHITE, P. J.; RAVEN, J.A. Opportunities for improving phosphurus-use efficiency in crop plants. **New Phytologist**, Reino Unido, v. 195, n. 2, p. 306–320, 2012.

WENDLING, I.; DUTRA, L. F. **Produção de mudas de eucalipto**. Colombo: Emprapa, 1. ed. 2010, 184 p.

ZAMBROSI, C. B. F.; MATTOS, D.; SYVERTSEN, J. P. Plant growth, leaf photosynthesis, and nutrient-use efficiency of citrus rootstocks decrease with phosphite supply. **Journal of Plant Nutrition and Soil Science**, v. 174, n. 3, p. 487–495, 2011.