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Scientific Article

GROWTH OF *Didymopanax morototoni* SEEDLINGS AS A FUNCTION OF DOSES OF CONTROLLED-RELEASE FERTILIZER

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ABSTRACT

The species *Didymopanax morototoni*, commonly known as morototó, presents great potential for the timber industry and the recovery of degraded areas, but the absence of adequate technical standards for seedling production limits its success in the field. The use of controlled-release fertilizers (CRF) is an alternative to conventional fertilizers, as it reduces costs and losses. The authors of this study aimed to evaluate the effect of different doses of Osmocote® fertilizer on the growth characteristics and seedling quality of *D. morototoni*. The experiment was conducted in a nursery, using a randomized block design, testing five doses of Osmocote® (0, 2, 4, 6, and 8 g dm^{-3}), with an NPK 18-5-9 formulation and a release period of five months. After 150 days, height, collar diameter, number of leaves, root length, leaf area, chlorophyll content, dry mass, and Dickson Quality Index were evaluated. The data were subjected to ANOVA and regression analysis ($\alpha = 0.05$), and the dose of maximum technical efficiency (DMTE) was calculated using the derivative of the fitted equations. The results showed that the controlled-release fertilizer significantly influenced on the increase of all analyzed variables compared to the control. The most effective dose was 3 2 g dm^{-3} of Osmocote® 5M 18-5-9 mini prill, which provided the highest DQI for the production of *D. morototoni* seedlings.

Keywords: Morototó; Osmocote; Reforestation

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CRESCIMENTO DE MUDAS DE *Didymopanax morototoni* EM FUNÇÃO DE DOSES DE FERTILIZANTE DE LIBERAÇÃO CONTROLADA

RESUMO A espécie *Didymopanax morototoni*, conhecida como morototó, apresenta grande potencial para a indústria madeireira e a recuperação de áreas degradadas, mas a ausência de padrões técnicos adequados para a produção de mudas limita seu sucesso em campo. O uso de fertilizantes de liberação controlada (FLC) é uma alternativa aos fertilizantes convencionais, pois reduz custos e perdas. Os autores deste estudo tiveram como objetivo avaliar o efeito de diferentes doses do fertilizante Osmocote® nas características de crescimento e na qualidade das mudas de *D. morototoni*. O experimento foi realizado em viveiro, com delineamento em blocos casualizados, testando-se cinco doses de Osmocote® (0, 2, 4, 6 e 8 g dm^{-3}), com formulação NPK 18-5-9 e período de liberação de cinco meses. Após 150 dias, foram avaliados os parâmetros de altura, diâmetro do coleto, número de folhas, comprimento da raiz, área foliar, teor de clorofila, massa seca e Qualidade de Dickson. Os dados foram submetidos a anova e análise de regressão (α = 0,05), sendo a dose de máxima eficiência técnica (DMET) calculada através da derivada das equações ajustadas. Os resultados mostraram que o fertilizante de liberação controlada influenciou significativamente no aumento de todas as variáveis analisadas em comparação ao controle. A melhor dose foi de 3,2 g dm^{-3} de Osmocote® 5M 18-5-9 mini prill, que proporcionou maior IQD para a produção de mudas de *D. morototoni*.

Palavras-Chave: Morototó; Osmocote; Reflorestamento

1. INTRODUCTION

In Brazil, the main sources of natural vegetation change are deforestation, improper land use, and the irregular occupation of protected areas, such as springs and riparian zones, which lead to environmental degradation (Calmon, 2021; Almeida, 2016). In this context, it is clear that the process of restoring degraded ecosystems depends on improving the practices and techniques used, with special emphasis on the forest seedling production phase (Brancalion et al., 2015; Rodrigues et al., 2023).

The growing interest in the forestry field has encouraged research into the use of tree species for multiple purposes, whether commercial or ecological (Coelho Junior et al., 2020). Among these species, *Didymopanax morototoni* (Aubl.) Decne. & Planch., commonly known as "morototó," stands out. It belongs to the Araliaceae family and is a tree species with a wide geographic distribution, especially in the Amazon Biome (Macieira et al., 2014).

D. morototoni is found in various types of vegetation, including savannas, roadsides, secondary forests, and dense upland forests (Anastácio et al., 2010; Brancalion et al., 2015; Vilarinho et al., 2019). The species has economic potential due to its soft, easy-to-work wood and is considered promising for reforestation and ecological restoration programs due to its fast growth and fruits that serve as food for wildlife (Anastácio et al., 2010; Macieira et al., 2014). However, the limited knowledge of its nutritional requirements in the literature hinders the production of high-quality seedlings and, consequently, compromises its use in ecosystem restoration efforts.

Comprehensive studies on lesser-known forest species play a crucial role in the production of high-quality seedlings, as the lack of technical knowledge limits successful development in the field (Cunha et al., 2023). Therefore, factors such as nutrient availability, substrate type, propagation method, and appropriate fertilizer dose must be considered in such studies (Dutra et al., 2023).

In seedling production, it is common to use various types of fertilizers, particularly conventional ones that are readily soluble (Rajan et al., 2021). However, the nutrients in these fertilizers are easily leached during irrigation, both in the nursery and in the field, requiring split applications that lead to additional costs (Almeida et al., 2019; Rajan et al., 2021).

In this scenario, a viable alternative is the use of controlled-release fertilizers (CRFs), which stand out for their gradual and consistent release of nutrients, reducing losses through volatilization and minimizing environmental impacts (Cunha et al., 2023; Guelfi, 2017). Moreover, these fertilizers reduce the need for frequent applications, thereby lowering production costs (Almeida et al., 2019; Rajan et al., 2021).

One CRF that has been successfully used in forest seedling production is Osmocote® (Jardim et al., 2023). Several authors report that the use of this fertilizer has proven effective in improving seedling growth of various forest species, such as *Lecythis lurida* (Jardim et al., 2024), *Calophyllum brasiliense* (Jardim et al., 2023), *Parkia gigantocarpa* (Oliveira et al., 2021), *Dinizia excelsa* (Sousa et al., 2023), *Schizolobium amazonicum* (Santiago et al., 2021), and *Handroanthus heptaphyllus* (Souza et al., 2020). However, there is still a lack of technical information in the scientific literature regarding its use in fertilization to produce *D. morototoni* seedlings.

Based on the positive results reported for various forest species, it is believed that the use of controlled-release fertilizer (Osmocote®) promotes significant improvements in the growth characteristics of *D. morototoni*. Therefore, this study aimed to determine the optimal dose of controlled-release fertilizer to produce *D. morototoni* seedlings.

2. MATERIAL AND METHODS

2.1 Study Area

The study was conducted at the Federal Rural University of the Amazon, Belém campus, at the Institute of Agricultural Sciences (ICA), in a 50% shade greenhouse, for 150 days. According to the Köppen classification, Belém has an Af (humid tropical) climate, with high average annual temperatures ranging from 26°C to 28°C and little variation throughout the year. The average annual rainfall exceeds 2,800 mm, with the greatest precipitation occurring between January and May, and relative humidity generally remains high, usually above 80%.

2.2 Experimental Design

The plant material used consisted of *D. morototoni* seeds, collected from ten mother trees located at the Germplasm Island of Eletrobrás, in the municipality of Tucuruí, Pará. After collection, the seeds were stored for six months at approximately ±20°C in polyethylene plastic bags (0.07 mm thickness) in the ICA Seed Laboratory.

The experimental design was a completely randomized block design (CRBD) with five treatments (doses) and four replicates of six plants each, totaling 20 experimental units. The evaluated doses were 0 g dm^{-3} (control), 2 g dm^{-3}, 4 g dm^{-3}, 6 g dm^{-3}, and 8 g dm^{-3}. The controlled-release fertilizer (CRF) used was Osmocote® Mini Prill, with an NPK formulation of 18-5-9 and a nutrient release period of five months.

Seeds were sown in 5 L plastic trays (34.9 cm x 28.9 cm x 7.5 cm), containing 4 L of vermiculite substrate, in which the seedlings remained until they reached a height of six centimeters. During this period, maintenance consisted of daily moistening of the substrate with distilled water. At the end of this period, seedlings were transplanted into 280 mL tubes containing a 1:1 commercial Tropstrato® + vermiculite substrate.

After mixing the substrate components, the fertilizer doses for each treatment were gradually incorporated with frequent stirring until a homogeneous mixture was obtained. The seedlings were maintained in a 50% shaded greenhouse for 150 days to match the nutrient release period of the controlled-release fertilizer. Cultural practices included irrigation via conventional sprinkler, twice a day (once in the morning and once in the late afternoon) for a duration of 10 minutes. Manual weed control was done as needed.

Evaluations were conducted at 150 days, including measurements of height (H), stem diameter (SD), number of leaves (NL), root length (RL), leaf area (LA), chlorophyll content, root dry mass (RDM), and shoot dry mass (SDM). Plant height was measured from the base to the apical bud using a ruler graduated in centimeters. A digital caliper with 0.01 mm precision was used to measure the stem diameter at the base of the stem. Leaf number was determined by counting the compound leaves on each plant. Chlorophyll content (CC) was measured using a SPAD-502 Plus chlorophyll meter on three middle-third leaves of five randomly selected plants per treatment.

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Next, the plants were removed from the tubes and washed under running water to remove substrate adhering to the roots. The main root length was measured using a ruler graduated in centimeters. Leaf area was measured using a leaf area meter (model LI-3100C, Area Meter, LI-COR®), with individual leaves being detached for assessment. For dry mass measurement, the shoot and root portions of the seedlings were separated and placed in kraft paper bags for drying in an oven at 65°C until reaching constant weight (72 hours). The dry material was then stored in a desiccator with silica to prevent moisture reabsorption and weighed using a digital scale with 0.001 g precision. The robustness index was calculated as the ratio between plant height and stem diameter. Finally, the Dickson Quality Index (DQI) was calculated using the equation proposed by Dickson et al. (1960) (Equation 1).

$$DQI = TDM/((H/SD)+(SDM/RDM)) \quad \text{(Eq. 1)}$$

Where: TDM = Total Dry Mass (g); H = Height (cm); SD = Stem diameter (mm); SDM = Shoot Dry Mass (g); RDM = Root Dry Mass (g).

2.3 Statistical Analysis

The normality of residuals and homogeneity of variances were assessed using the Shapiro-Wilk and O'Neil and Matthews tests. Once the assumptions were met, analysis of variance (ANOVA) was performed, and when significant differences among treatments were detected, regression models were fitted. For all tests and analyses, a significance level of 5% ($\alpha = 0.05$) was adopted. The coefficients of the fitted regression models were also evaluated using the t-test ($\alpha = 0.05$ and 0.01). The dose of maximum technical efficiency (DMTE) was determined using the derivatives of the fitted equations (Banzatto & Kronka, 2006). All procedures, including graphical outputs, were performed in RStudio® version 4.3.2, using the "ExpDes.pt" and "ggplot2" packages.

3. RESULTS

Significant differences ($p < 0.05$) were observed among treatment means for all evaluated variables in *D. morototoni* seedlings (Table 1). Additionally, coefficients of variation (CV) above 10% were observed for all variables, except for height (H), chlorophyll content (CC), and Dickson Quality Index (DQI).

Table 1. Summary of the analysis of variance, based on the mean square, for the parameters evaluated in *D. morototoni* seedlings produced with increasing doses of controlled-release fertilizer (Osmocote®) at 150 days under greenhouse conditions
Tabela 1. Resumo da análise de variância, pelo quadrado médio, referentes aos parâmetros avaliados de mudas de *D. morototoni* produzidas com crescentes doses de fertilizante de liberação controlada (Osmocote®) aos 150 dias em condições de casa de vegetação

Variable	Mean Square			Coefficient of Variation (%)
	Treatment	Block	Error	
Degrees of Freedom	4	3	12	
H	105.4749*	7.2296*	1.2741	7,55
SD	28.4390*	0.6110^{ns}	0.5847	11,75
NL	7.0097*	1.2382^{ns}	0.8281	19,33
LA	235252.883*	1681.233^{ns}	5128.247	15,79
CC	216.7856*	1.8982^{ns}	0.8519	3,99
RL	52.5571*	0.9323^{ns}	3.5669	12,85
TDM	18.7024*	0.3764^{ns}	0.4560	17,05
SDM	9.6256*	0.3806^{ns}	0.1995	15,58
RDM	1.6158*	0.0272^{ns}	0.0266	14,90
H/SD	1.1728*	0.1607*	0.0274	6.66
DQI	0.8823*	0.0044^{ns}	0.0032	6,94

Significant at 1% probability; Significant at 5% probability according to the F-test; ns: Not significant.

The controlled-release fertilizer (CRF) had a positive impact on seedling growth when compared to the control treatment. Seedling height varied according to the applied Osmocote® dose, following a cubic polynomial pattern. The dose of maximum technical efficiency (DMTE) was calculated as 4.6 g dm^{-3}, resulting in a seedling height of 18.31 cm (Figure 1A), which represents an increase of over 100% compared to the control.

Similarly, a trend of increasing stem diameter (SD) was observed, also following a cubic polynomial model. The DMTE was 3.9 g dm^{-3}, yielding a maximum value of 8.48 mm, which corresponds to an increase of 6.58 mm over the control (Figure 1B). Compared to the unfertilized treatment, an increase of over 300% in SD was recorded with doses ranging from 2 to 8 g dm^{-3}.

For the variable number of leaves (NL), significant differences were observed among

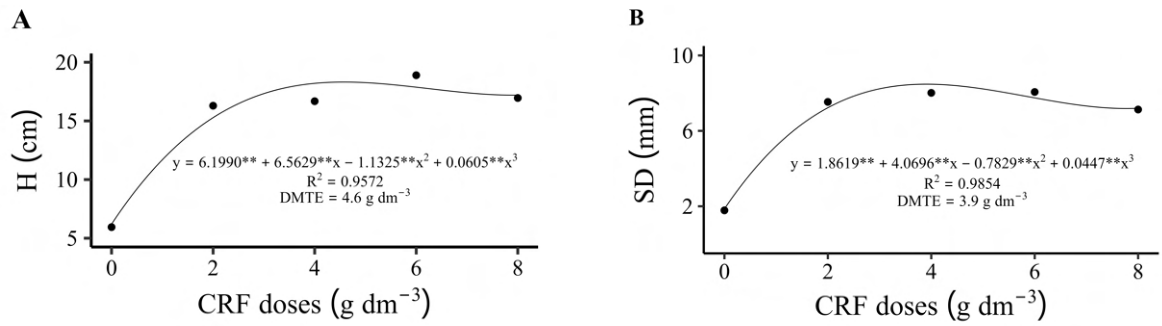

Figure 1. Average height (A) and stem diameter (B) of *D. morototoni* seedlings produced with increasing doses of controlled-release fertilizer (Osmocote®) at 150 days in greenhouse conditions
Figura 1. Valores médios de altura (A) e diâmetro do coleto (B) de mudas de *D. morototoni* produzidas com crescentes doses de fertilizante de liberação controlada (Osmocote®) aos 150 dias em condições de casa de vegetação

treatments. The best means, according to the regression model, were recorded at 2, 6, and 4 g dm^{-3}, with values of 4.93, 5.60, and 5.83, respectively (Figure 2). Furthermore, the DMTE was calculated as 4.6 g dm^{-3}, which would result in an estimated mean of 5.93 leaves.

An increase in leaf area (LA) of *D. morototoni* seedlings was also observed with CRF application, reaching approximately

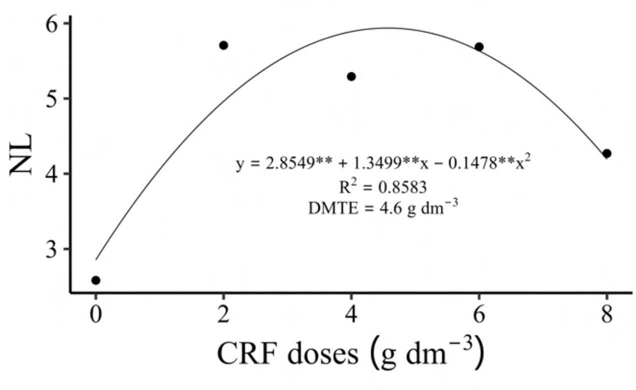

Figure 2. Average values of leaf number of *D. morototoni* seedlings produced with increasing doses of controlled-release fertilizer (Osmocote®) at 150 days in greenhouse conditions
Figura 2. Valores médios de número de folhas de mudas de *D. morototoni* produzidas com crescentes doses de fertilizante de liberação controlada (Osmocote®) aos 150 dias em condições de casa de vegetação

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614 cm² at the 4 g dm^{-3} dose, representing an increase of over 500% compared to the unfertilized treatment (Figure 3A). At 8 g dm^{-3}, LA decreased (565 cm²), accompanied by reductions in both seedling height and stem diameter under this condition.

In addition, increasing CRF doses positively influenced chlorophyll content, reaching a peak of 33.02 mg·cm^{-2} at 8 g dm^{-3} (Figure 3B), which corresponds to an increase of 19.60 mg·cm^{-2} compared to the control. This dose resulted in the highest mean among all fertilized treatments.

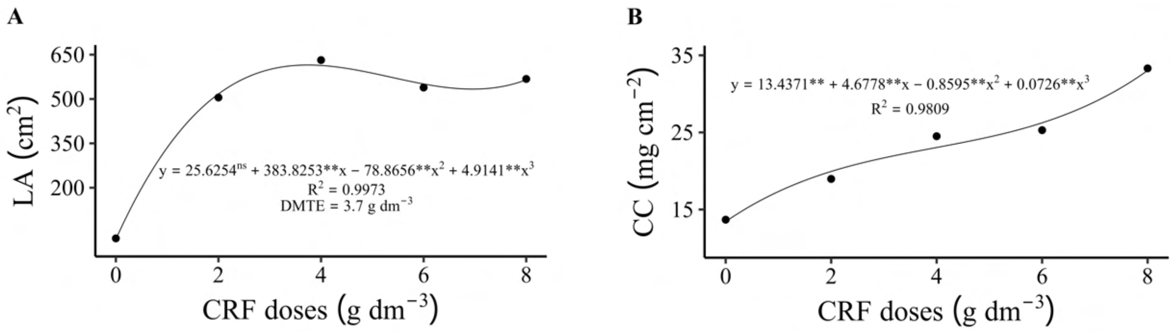

Figure 3. Average values of leaf area (A) and chlorophyll content (B) of *D. morototoni* seedlings produced with increasing doses of controlled-release fertilizer (Osmocote®) at 150 days in greenhouse conditions

Figura 3. Valores médios de área foliar (A) e teor de clorofila (B) de mudas de *D. morototoni* produzidas com crescentes doses de fertilizante de liberação controlada (Osmocote®) aos 150 dias em condições de casa de vegetação

Concerning root length (RL), the application of different CRF doses significantly improved this variable in comparison to the control. The recommended DMTE for RL was 4.8 g dm^{-3}, with the best performance observed at 4 g dm^{-3}, reaching an average of 17.62 cm (Figure 4A).

For root dry mass (RDM), significant variations among treatments were observed, and the DMTE was 3.2 g dm^{-3}, corresponding to a mean of 1.65 g (Figure 4B). Regarding shoot dry mass (SDM), a significant variation was observed between the control and fertilized treatments, although no significant differences were found among the fertilized treatments. The DMTE for SDM was 3.7 g dm^{-3} (Figure 4C), resulting in a mean of 3.98 g. For total dry mass (TDM), significant differences were observed between CRF treatments and the control, but not among the different CRF doses. The DMTE for TDM was 3.5 g dm^{-3} (Figure 4D). Among all evaluated variables, the 4 g dm^{-3} dose produced mean values closest to the optimal dose, with 1.60 g (RDM), 3.97 g (SDM), and 5.59 g (TDM), respectively.

The robustness index indicated that only seedlings from the control treatment differed significantly from the fertilized treatments, with a mean value of 3.28 (Figure 5A). DQI values showed significant differences among all treatments, with the highest efficiency recorded at 3.2 g dm^{-3}, corresponding to a mean of 1.24 (Figure 5B). A reduction in RDM was observed with increasing CRF doses, which contributed to a lower DQI. Therefore, lower CRF doses proved more effective in promoting seedling quality.

4. DISCUSSION

The significant effect of CRF on the growth variables of *D. morototoni* seedlings indicates that its use is appropriate for the production of this species, as it promotes plant development, reduces nursery time, lowers production costs, and results in more vigorous and healthier seedlings. The coefficients of variation (CV) observed indicate adequate experimental control of external variables in the greenhouse environment, being considered of medium magnitude (Pimentel-Gomes, 2009).

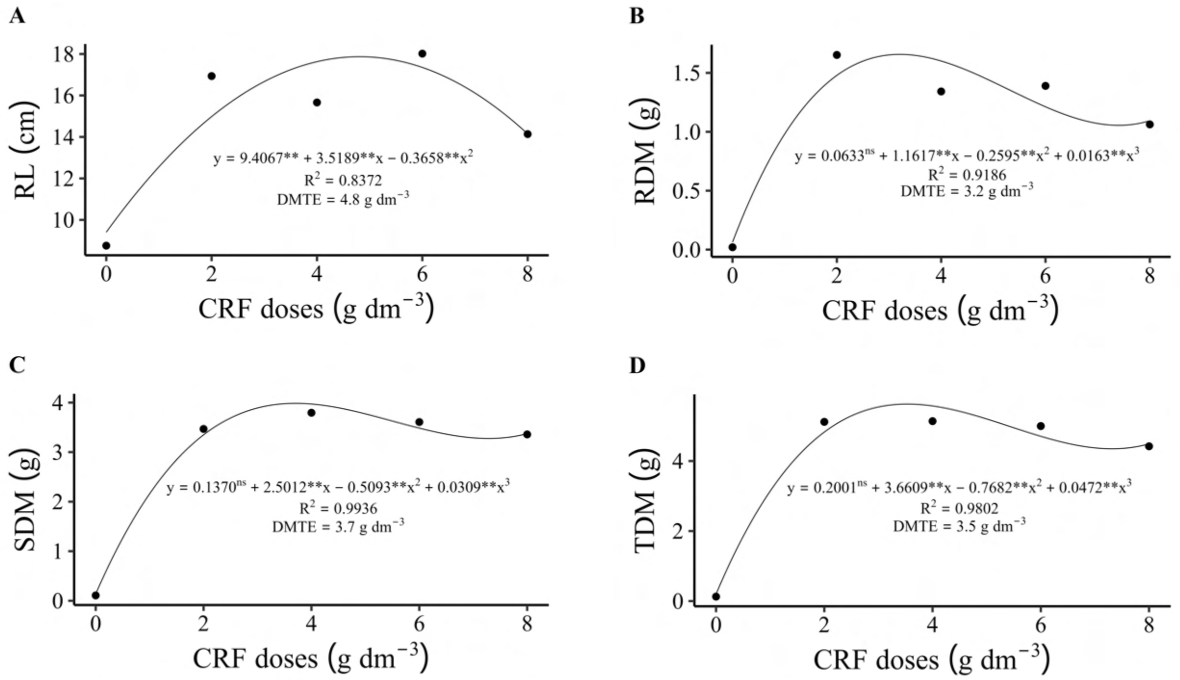

Figure 4. Average values of root length (A), root dry mass (B), shoot dry mass (C) and total dry mass (D) of *D. morototoni* seedlings produced with increasing doses of controlled-release fertilizer (Osmocote®) at 150 days under greenhouse conditions
Figura 4. Valores médios de comprimento de raiz (A), massa seca de raiz (B), massa seca da parte aérea (C) e massa seca total (D) de mudas de *D. morototoni* produzidas com crescentes doses de fertilizante de liberação controlada (Osmocote®) aos 150 dias em condições de casa de vegetação

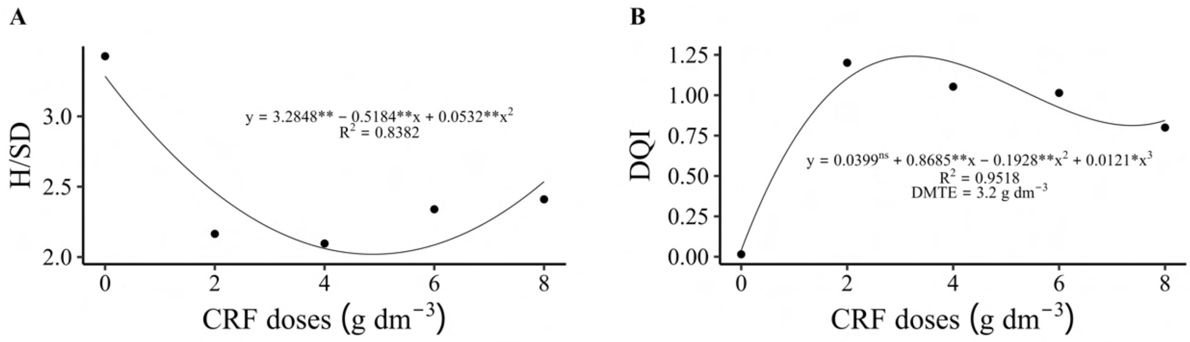

Figure 5. Average Dickson quality index values of *D. morototoni* seedlings produced with increasing doses of controlled-release fertilizer (Osmocote®) at 150 days under greenhouse conditions
Figura 5. Valores médios de Índice de robustez e índice de qualidade de Dickson de mudas de *D. morototoni* produzidas com crescentes doses de fertilizante de liberação controlada (Osmocote®) aos 150 dias em condições de casa de vegetação

According to Afonso et al. (2020), the addition of Osmocote Plus® 6M (NPK 15-09-12 + micronutrients) had a positive influence on the growth of *Tabernaemontana catharinensis* seedlings. These authors observed that plants receiving doses higher than 6 g·dm^{-3} of Osmocote Plus® performed worse than those receiving 3 and 6 g dm^{-3}. This result corroborates the findings of Jardim et al. (2023), which, in a study on the same CRF applied to *Calophyllum brasiliense* seedling development, observed reduced plant growth due to the possible excess of nitrogen resulting from the increased doses. Although nitrogen is an important nutrient for seedling vigor,

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excessive amounts can cause nutritional imbalance (Taiz et al., 2017). These results indicate that species and fertilizer dose affect seedling height response differently when using controlled-release fertilizers.

The stem diameter stands out as an excellent metric for assessing seedling quality and vigor, indicating potential field survival, in addition to being used to calculate the Dickson Quality Index (DQI) (Paiva & Gomes, 2011; Santos et al., 2010; Wendling & Dutra, 2010). There is no ideal collar diameter value, as it varies depending on the species; however, it is recommended that seedlings for dispatch have a diameter greater than 2 mm (Gomes et al., 2002).

According to Marques & Yared (1984), *D. morototoni* plants grown in a substrate composed of 60% Yellow Latosol, 20% sand, and 20% organic matter, without chemical fertilizer addition, had a collar diameter of 5.69 mm after six months in the nursery. In the present study, seedlings treated with a dose of 3.9 g dm^{-3} had a collar diameter of 8.48 mm, a value higher than that observed by these authors, indicating the potential of CRF to provide adequate nutrition for this species.

Similarly, assessing the number of leaves is essential, as leaves are the main photosynthetic organs of plants. Therefore, a higher number of leaves can result in greater light interception, increased production of photoassimilates, and consequently, a more efficient energy supply, promoting optimal plant development (Taiz et al., 2017). In the present study, *D. morototoni* seedlings performed better when treated with 4.6 $g \cdot dm^{-3}$ of CRF, a result similar to that observed by Jardim et al. (2023) in *C. brasiliense* seedlings. These data indicate that using appropriate doses contributes to morphological development, such as leaf emission, and represents an economically viable strategy by reducing input waste and production costs.

Another important variable is leaf area, which plays a fundamental role in the plant's ability to capture solar energy for photosynthesis (Souza et al., 2020). This process is essential for the production of photoassimilates, which are later translocated to various plant parts, contributing to biometric development (Taiz et al., 2017). For *D. morototoni* seedlings, adequate nutrient supply promoted significant leaf expansion up to the 3.7 g dm^{-3} CRF dose. However, higher doses did not result in additional gains in this variable, indicating that the species reaches a nutritional saturation point at relatively low fertilization levels. This behavior is operationally advantageous as it allows for optimized input use in seedling production, reducing costs without compromising physiological performance.

Regarding chlorophyll content, Taiz et al. (2017) concluded that increased chlorophyll in leaves enhances light absorption across various photosynthetic peaks, which contributes to better photoassimilate production for plant development. Studies by Souza et al. (2020) observed similar results, highlighting the positive effect of increasing doses of Osmocote® 6M (NPK 15-09-12 + micronutrients) on the chlorophyll content of *Handroanthus heptaphyllus* seedlings. The findings of this study align with those of Damian et al. (2015), who demonstrated that increased leaf area resulted in higher chlorophyll content in *Sebastiania schottiana* leaves.

The increase in leaf number is directly linked to leaf area (LA) expansion, which also showed significant gains up to the 4 g dm^{-3} dose, reaching approximately 614 cm^2, over 500% higher than the unfertilized treatment (Figure 3A). This behavior indicates enhanced photosynthetic capacity, contributing to greater photoassimilate accumulation and, consequently, improved seedling growth performance. Moreover, the increase in chlorophyll content suggests improved photosynthetic efficiency, which, together with increased leaf area and leaf number, reflects a greater capacity for light capture and gas exchange. Thus, the proper use of CRF proves effective in enhancing the initial development of *D. morototoni*, optimizing the aboveground functional traits of the seedlings.

In this study, intermediate CRF doses promoted increased root dry mass in *D. morototoni*, highlighting the efficiency of this nutritional management strategy in stimulating root system development. Similar results were observed by Massad et al. (2016)

in *Delonix regia* and *Tecoma stans* seedlings, Nascimento et al. (2020) in *Psidium cattleianum* seedlings, and Santiago et al. (2021) in *Schizolobium parahyba* var. *amazonicum* seedlings, all reporting positive effects of moderate CRF use in the production of different forest species. For *D. morototoni*, the 3.2 g dm^{-3} dose yielded the highest root dry mass accumulation. However, further dose increases led to a decline in this variable, possibly due to nutritional imbalance.

Root length analysis is an indicator of soil conditions where the plant is growing (Damian et al., 2015). Roots of well-watered plants tend to grow less than those in non-irrigated conditions (Almeida et al., 2019; Dutra et al., 2023). Good nutrient availability in the soil solution also affects root development, as ideal nutrient levels prevent excessive root system growth (Pereira et al., 2019; Rajan et al., 2021; Taiz et al., 2017). Therefore, efficient fertilization and irrigation are vital for proper seedling growth (Pereira et al., 2019). However, the hardening process, involving sun exposure and gradual irrigation reduction, is essential to ensure seedling establishment in the field (Almeida, 2016).

The quality of forest seedlings is directly related to specific variables, such as the robustness index (H/SD) and the Dickson Quality Index (DQI) (Pimentel et al., 2021). Among morphological parameters, height and stem diameter are key variables for assessing seedling standards, as they are non-destructive, easy to measure, and together form the seedling's robustness index (Faustino et al., 2022). The DQI is the main quality indicator for forest seedlings intended for field planting, as it combines multiple variables into a single index, including the robustness index and the shoot-to-root biomass ratio, though it is a destructive measurement (Dionísio et al., 2021). The higher the DQI, the better the seedling quality (Pimentel et al., 2021). In the literature, it is recommended that DQI values for nursery-grown forest seedlings range from 0.2 to 10 to ensure adequate development (Costa et al., 2020). The highest DQI obtained in this study was 1.19, achieved with the 3.2 g dm^{-3} dose, which falls within the recommended range.

This index varies by species, growing conditions, genetic material, or plant age. Nonetheless, despite potential variations both between and within species, DQI remains the primary quality indicator for forest seedlings (Avelino et al., 2021). This knowledge allows nurseries to determine the ideal time for transplantation, ensuring seedling survival and proper field development (Dranski et al., 2019; Fortes et al., 2021). Therefore, the DQI obtained in this study can serve as a reference to define the ideal time for seedling transplantation and assist in characterizing vigorous batches with higher establishment potential in the field.

According to Paim et al. (2022), identifying the ideal fertilization dose for forest seedling production is essential, as it prevents nutritional deficiencies and salinization in the root zone, favoring the development of more vigorous seedlings. Based on this assertion and the results of the present study, the most efficient CRF dose for the initial growth of *D. morototoni* seedlings was 3.2 g dm^{-3}. This finding contributes to the establishment of a specific fertilization protocol for *D. morototoni* seedling production in greenhouse conditions during a 120-day period.

5. CONCLUSION

The use of the controlled-release fertilizer Osmocote® 18-05-09 Mini Prill had a positive influence on the growth and quality of *D. morototoni* seedlings. The dose of 3.2 g dm^{-3} resulted in the highest Dickson Quality Index and is considered adequate for the production of this species under nursery conditions.

6. ACKNOWLEDGEMENTS

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AUTHOR CONTRIBUTIONS

Borges, M.M.R.: Conceptualization, Methodology, Experiment execution, Review, Editing; Castro, P.H.C.de.: Writing; Santos, M.D.C.: Writing; Filho, D.P. da S.: Methodology; Gama, M.A.P.: Review, Editing; Araújo, D.G. de.: Methodology, Review, Editing.

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7. REFERENCES

Afonso, M. V., Paranhos, J. T., Tabaldi, L. A., Soriani, H. H. & Saldanha, C. W. (2020). *Tabernaemontana catharinensis* A. DC. seedling emergence and growth in different substrates. *Floresta e Ambiente, 27*(2). https://doi.org/10.1590/2179-8087.077017

Almeida, D. (2016). Produção de sementes e mudas florestais. (3ª ed.). Editus. http://books.scielo.org/

Almeida, U. O., Neto, R. . C. A., Araujo, J. M., Costa, D. A. & Júnior, D. L. T. (2019). Fertilizantes de liberação lenta na produção de mudas frutíferas. *South American Journal of Basic Education, Technical and Technological, 6*(1). https://periodicos.ufac.br/index.php/SAJEBTT/article/view/2188

Anastácio, M. R., Santana, D. G. de, Oliveira, R. C. de, Babata, M. M. & Oliveira, C. A. A. de. (2010). Maturação e qualidade física de frutos na germinação dos pirênios de *Schefflera morototoni* (Araliaceae). *Ciência Florestal, 20*(3), 429–437. https://doi.org/10.5902/198050982058

Avelino, N. R., Schilling, A. C., Dalmolin, Â. C., Santos, M. S. dos & Mielke, M. S. (2021). Alocação de biomassa e indicadores de crescimento para a avaliação da qualidade de mudas de espécies florestais nativas. *Ciência Florestal, 31*(4), 1733–1750. https://doi.org/10.5902/1980509843229

Banzatto, D. A. & Kronka, S. N. (2006). Experimentação Agrícola (Vol. 4). FUNEP.

Brancalion, P. H. S., Gandolfi, S. & Rodrigues, R. R. (2015). *Restauração florestal: Conceitos e motivações.* (1ª ed., Vol. 1). Oficina de Textos. http://www.lcb.esalq.usp.br/sites/default/files/publicacao_arq/978-85-7975-019-9.pdf

Calmon, M. (2021). Restauração de florestas e paisagens em larga escala: O Brasil na liderança global. *Ciência e Cultura, 73*(1), 44–48. https://doi.org/10.21800/2317-66602021000100009

Coelho Junior, L. M., Nunes, A. M. M., Pádua, J. F. F., Júnior, E. P. S. & Lima, P. A. F. (2020). O desenvolvimento brasileiro das florestas de rápido crescimento com fins energéticos. *Brazilian Journal of Development, 6*(5), 28111–28125. https://doi.org/10.34117/bjdv6n5-310

Costa, C. C., Almeida, L. E. & Castro, V. R. de. (2020). Evaluation of the morphological parameters of native species of the Atlantic Forest in biodegradable tubes. *Revista Ambientale, 12*(4), 44–54. https://doi.org/10.48180/ambientale.v12i4.246

Cunha, F. L., Nieri, E. M., Dias, M. G., Melo, L. A. de & Venturin, N. (2023). Uso de adubos de liberação lenta no crescimento inicial de clones de eucalipto. *Ciência Florestal, 33*(2), e69118. https://doi.org/10.5902/1980509869118

Damian, J. M., Strojaki, T. S. V., Simon, D. H., Marostega, F. & Cantarelli, E. B. (2015). Doses de Osmocote® na produção de mudas de Sarandi: Atributos morfológicos e índice de clorofila. *Revista Agrarian , 9*(33), 241–247. https://ojs.ufgd.edu.br/index.php/agrarian/article/view/3896

Dickson, A., Leaf, A. L. & Hosner, J. F. (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. *The Forestry Chronicle, 36*(1), 10–13. https://doi.org/10.5558/tfc36010-1

Dionisio, L. F. S., Schwartz, G., Rocha, M. J. S. de A. T. da S. & Corvera, R. (2021). Effects of pruning and recipient volume on seedlings' quality of *Bertholletia Excelsa* bonpl. (Lecythidaceae). *European Academic Research, 9*(2), 1198–1212. https://www.euacademic.org/ArticleDetail.aspx?id=4906

Dranski, J. A. L., Sonda, E. T. & Demarchi Junior, J. C. (2019). Tamanho de sementes e fertilizante de liberação controlada na produção de mudas de *Schizolobium parahyba* [(Vell.) S.F. Blake)]. *Biotemas, 32*(2), 23–31. https://doi.org/10.5007/2175-7925.2019v32n2p23

Dutra, T. R., Massad, M. D. & Sarmento, M. F. Q. (2023). Diferentes dosagens e formulações de Osmocote® para o crescimento inicial em viveiro de *Peltophorum dubium* (Spreng.). *Brazilian Journal of Development, 9*(1), 2740–2746. https://doi.org/10.34117/bjdv9n1-190

Faustino, I. S., Jacovine, L. A. G., Morais Júnior, V. T. M., Alves, E. B. B. M., Rocha, S. J. S. S., França, L. C. J., Oliveira, K., Oliveira, T. A., Romero, F. M. B., & Paiva, H. N. (2022). Avaliação da qualidade de mudas de espécies florestais nativas. In *Recursos hídricos: Gestão, planejamento e técnicas em pesquisa* (Vol. 2, pp. 26–39). Editora Científica Digital. https://doi.org/10.37885/220107500

Fortes, E. A., Fortes, A. R., De Almeida, L. C. & Fernandes, L. G. (2021). Inventory, colony fluctuation, and wasp nesting social habits in IFSULDEMINAS - Machado Campus. *Revista Agrogeoambiental, 12*(4). https://doi.org/10.18406/2316-1817v12n420201521

Gomes, J. M., Couto, L., Leite, H. G., Xavier, A. & Garcia, S. L. R. (2002). Parâmetros morfológicos na avaliação de qualidade de mudas de *Eucalyptus grandis*. *Revista Árvore, 26*(6), 655–664. https://doi.org/10.1590/S0100-67622002000600002

Guelfi, D. (2017). Fertilizantes nitrogenados estabilizados de liberação lenta ou controlada. Informações *Agronômicas, 157*, 1–14. http://repositorio.ufla.br/jspui/handle/1/13309

Jardim, I. N., Oliveira, J. C. de, Hamada, M. O. de S. & Oliveira, I. A. de. (2024). Osmocote® promove respostas positivas no crescimento e nutrição das mudas de *Lecythis lurida* (Lecythidaceae). *Revista de Ciências Agroveterinárias, 23*(4), 565–574. https://doi.org/10.5965/223811712342024565

Jardim, I. N., Oliveira, J. C., Hamada, M. O. S. & Oliveira, I. A. (2023). Osmocote® proporciona melhores mudas de *Calophyllum brasilienese* Cambess. *Scientia Plena, 19*(9). https://doi.org/10.14808/sci.plena.2023.090203

Macieira, A. P., Costa, C. C., Carvalho, L. T., Fiaschi, P., Gomes, J. I., Martins-da-Silva, R. C. V. & Margalho, L. F. P. ao C. (2014). Conhecendo espécies de plantas da Amazônia: morototó (*Schefflera morototoni* (Aubl.) Maguire, Steyerm. & Frodin - Araliaceae). https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/987447

Marques, L. C. T. & Yared, J. A. G. (1984). Crescimento de mudas de *Didymopanax morototoni* (Aublet.) Decne (morototó) em viveiro em diferentes misturas de solo. https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/383798

Massad, M. D., Dutra, T. R., Silva, C. H. S., Santos, T. B. & Sarmento, M. F. Q. (2016). Desenvolvimento de mudas de flamboyant e ipê-mirim em resposta a diferentes doses de Osmocote®. *Agropecuária Científica no Semiárido, 12*(1), 83–92. https://doi.org/10.30969/acsa.v12i1.727

Nascimento, B., Meneguzzi, A., Felippe, D., Sá, A. C. S., Pereira, M. de O. & Navroski, M. C. (2020). Doses intermediárias de Osmocote® aumentam a performance inicial de mudas de araçá. *Revista de Ciências Agroveterinárias, 18*, 13–19. https://doi.org/10.5965/2238117118e2019013

Oliveira, V. P., Mendes, R. S., Martins, W. B. R., Dos Santos, E. A., De Araújo, D. G. & Gama, M. A. P. (2021). Desenvolvimento e qualidade de mudas de *Parkia gigantocarpa* Ducke (Fabaceae) em função de fertilizante de liberação controlada. *Scientia Plena, 17*(9). https://doi.org/10.14808/sci.plena.2021.090201

Paim, L. P., Avrella, E. D., Lazarotto, M. & Fior, C. S. (2022). Fertilizante de liberação lenta no desenvolvimento inicial de *Lupinus albescens* hook. & arn. *South American Journal of Basic Education, Technical and Technological, 9*(1), 185–197. https://periodicos.ufac.br/index.php/SAJEBTT/article/view/4527

Paiva, H. N., & Gomes, J. M. (2011). *Viveiros florestais: Propagação sexuada* (1ª ed., Vol. 1) [Série Didática]. Editora UFV.

Pereira, V. G. M. de F., Lopes, A. da S., Belchior, I. B., Fanaya Júnior, E. D., Pacheco, A. & Brito, K. R. M. (2019). Irrigação e fertirrigação no desenvolvimento de eucalipto. *Ciência Florestal, 29*(3), 1100–1114. https://doi.org/10.5902/1980509823362

Pimentel, N., Gazzana, D., Spanevello, J. de F., Lencina, K. H. & Bisognin, D. A. (2021). Effect of mini-cutting size on adventitious rooting and morphophysiological quality of *Ilex paraguariensis* plantlets. *Journal of Forestry Research, 32*(2), 815–822. https://doi.org/10.1007/s11676-020-01126-6

Pimentel-Gomes, F. (2009). *Curso de Estatística Experimental* (15ª ed., Vol. 1). FEALQ.

Rajan, M., Shahena, S., Chandran, V. & Mathew, L. (2021). Controlled release of fertilizers—concept, reality, and mechanism. In: *Controlled Release Fertilizers for Sustainable Agriculture* (pp. 41–56). Elsevier. https://doi.org/10.1016/B978-0-12-819555-0.00003-0

Rodrigues, J. C. W., Campos, M. C. C., Bergamin, A. C., Silva, M. de N. S. da, Lima, R. A. & Santos, R. V. dos. (2023). A importância da produção de mudas de essências florestais na região amazônica: Uma revisão sistemática. *Revista Científica FAEMA, 14*(1), 10–24. https://doi.org/10.31072/rcf.v14i1.1144

Santiago, T. de S., Damasceno, L. J., Mariano, D. de C., Ebling, Â. A., Oliveira Neto, C. F. de & Okumura, R. S. (2021). Substratos e doses de fertilizantes de liberação lenta no crescimento e qualidade de Mudas de Paricá. *Revista Em Agronegócio e Meio Ambiente, 14*(3), 1–17. https://doi.org/10.17765/2176-9168.2021v14n3e8261

Santos, M. R., Sediyama, M. A. N., Salgado, L. T., Vidigal, S. M. & Reigado, F. R. (2010). Produção de mudas de pimentão em substratos à base de vermicomposto. *Biosci. J., 26*(4), 572–578. https://seer.ufu.br/index.php/biosciencejournal/article/view/7147

Sousa, A. C. M. de, Costa, A. L. A. da, Castro, P. H. C. de, Lima, A. da C., Silva, G. P., Araújo, D. G. de & Gama, M. A. P. (2023). Production of *Dinizia excelsa* Ducke (fabaceae) seedlings subjected to increasing doses of controlled release fertilizer. *Colloquium Agrariae, 19*(1), 182–191. https://doi.org/10.5747/ca.2023.v19.h522

Souza, A. C., Gama, M. A. P., Araújo, D. G., Silva, G. P. & Vilhena Senado, J. A. (2020). Growth and quality of *Handroanthus heptaphyllus* (Vell.) Mattos. seedlings as a function of controlled release fertilizer doses. *Revista Sustinere, 8*(1). https://doi.org/10.12957/sustinere.2020.48582

Taiz, L. & Zeiger, E. (2017). *Fisiologia e Desenvolvimento Vegetal* (6ª ed.). Artmed.

Vilarinho, M., Sales, V., Nascimento, J., Caldeira, D. & Souza, W. (2019). Quebra de dormência em sementes de *Schefflera morototoni* (Aubl.) Maguire et al. *Enciclopédia Biosfera, 16*(29), 1300–1308. https://doi.org/10.18677/EnciBio_2019A115

Wendling, I. & Dutra, L. F. (2010). *Produção de mudas de Eucalipto*. (1ª ed., Vol. 1). Embrapa Florestas.