

GROWTH AND NUTRITION OF *Paratecoma peroba* SEEDLINGS IN DIFFERENT TUBE VOLUMES AND CONTROLLED-RELEASE FERTILIZERS

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Resumo

Crescimento e nutrição de mudas de Paratecoma peroba em função do volume do tubete e fertilizante de liberação controlada. A *Paratecoma peroba* é espécie florestal nativa de grande interesse econômico e ecológico, atualmente está em risco de extinção pela exploração seletiva e ilegal, entretanto não há parâmetros estabelecidos para a produção de mudas da espécie. Desta forma, objetivou-se com este trabalho analisar o crescimento e balanço nutricional de mudas de *P. peroba* cultivadas em diferentes volumes de tubetes e doses de fertilizante de liberação controlada. Foram testados três volumes de tubetes (120, 180 e 280 cm³) e quatro doses FLC (0, 2,5; 5 e 7,5 kg m⁻³) mais uma adubação mineral convencional (AC), conforme indicação na literatura para espécies florestais nativas, dispostos em delineamento inteiramente casualisado em esquema fatorial de 3 x 5, com quatro repetições compostas por 16 mudas. Após 180 dias foi analisada a porcentagem de sobrevivência, as variáveis de crescimento, índices do sistema integrado de diagnose e recomendação e do índice de balanço nutricional médio das mudas. Com base na matéria seca total e no índice de balanço nutricional médio, a combinação, tubete de 280 cm³ associada a dose 7,5 kg m⁻³ de FLC mostrou-se a mais adequada na produção de mudas de *P. peroba*.

Palavras-chave: peroba-amarela; viveiros florestais; recipientes; adubação; DRIS.

Abstract

Paratecoma peroba is a native forest species of great economic and ecological interest, currently at risk of extinction from selective and illegal exploitation; however, there are no established parameters for the production of seedlings of this species. The objective of this study was to analyze the growth and nutritional balance of *P. peroba* seedlings grown in polypropylene tubes of different sizes with variable doses of controlled-release fertilizer (CRF). Three volumes of tubes (120, 180, and 280 cm³), four CRF doses (0, 2.5, 5, and 7.5 kg m⁻³), and a conventional mineral fertilizer (CF) were tested as indicated in the literature for native forest species: arranged in a completely randomized design in a 3 × 5 factorial scheme, with four replicates composed of 16 seedlings. After 180 days, the percentage of survival, growth variables, indices of the diagnosis and recommendation integrated system, and the average nutrient balance index of the seedlings were analyzed. Based on the total dry matter and the mean nutritional balance index, the combination of a 280 cm³ tube with a 7.5 kg m⁻³ CRF dose was the most effective in the production of *P. peroba* seedlings.

Keywords: peroba-amarela; forest nurseries; containers; fertilizing; DRIS.

INTRODUCTION

Paratecoma peroba (Record and Mell) Kuhlm, popularly known as peroba-amarela, peroba-do-campo e ipê-peroba is a tree species belonging to the family Bignoniaceae. These large trees can reach up to 30 m in height and are endemic to the Cerrado region of the states of Bahia, Espírito Santo, and north of Rio de Janeiro. Currently endangered due to intense exploitation, the species has great ecological and economic importance because of its natural beauty and wood quality. There are an estimated 8,500 adult individuals of *P. peroba* in nature (CNCFLORA, 2012).

In addition to the difficulty in finding matrices, the species has irregular seed production, with years of intense production followed by years of scarcity (LINS; NASCIMENTO, 2010). The seeds are recalcitrant, and the plants grow slowly in the nursery phase, taking around 6 to 8 months for seedling production (LORENZI, 2009). Therefore, there is a need to develop alternative and/or improved *P. peroba* propagation techniques to increase the availability of seedlings for species conservation projects.

Modern nurseries have gradually adopted the use of commercial substrates and polypropylene tubes, including biodegradable tubes such as Ellepot, in place of substrates composed of subsurface soil

samples and organic matter (ARAÚJO et al., 2016), and plastic bags (GASPARIN et al., 2015), respectively.

Polypropylene tubes have advantages over plastic bags, such as the possibility of reuse, better formation of the seedling root system, lower substrate consumption, higher number of seedlings per area, and better handling, transport, and planting of seedlings (GONÇALVES et al., 2005). Despite these advantages, using the incorrect tube volume can result in deformation of the root system due to space limitations, with possible consequences on its performance in the field (JUNIOR et al., 2013).

Fertilizer application is required when using commercial substrates, which can result in increased production costs. Controlled-release fertilizers (CRFs) are polymer-coated fertilizers that release active nutrients in a controlled manner, extend the duration of nutrient release, and meets the metabolic needs of the plant (IRFAN et al., 2018). The use of CRFs in nurseries provides several benefits, such as reduced production costs, culture cycles, and labor.

Some techniques can illuminate the relationship between nutrients applied through fertilization and their assimilation by plants. Chemical analysis of the leaves, when well-interpreted, can be a useful tool for correcting nutritional deficiencies and imbalances in plants. In this sense, the Diagnosis and Recommendation Integrated System (DRIS) is used to interpret foliar chemical analysis. In short, the DRIS uses multiple relationships between nutrients and integrates them in a series of indices, thus taking into account the relationships and interactions between nutrients instead of the absolute and isolated concentration of each. The lower the negative DRIS index, the more nutrient-deficient the plant will be, and the higher the positive DRIS index, the more nutrient-rich the plant will be (WALWORTH et al., 1986).

Thus, the aim of this study was to analyze the growth and nutrition of *P. peroba* seedlings produced in different tube volumes and CRF doses. Therefore, we tested the following hypotheses: (i) the volume of the tube influences the growth of *P. peroba* seedlings; (ii) higher CRF doses enhance the growth and nutritional quality of seedlings of this species.

MATERIAL AND METHODS

The experiment was conducted in a university forest nursery located in the experimental area of the Department of Forest and Wood Sciences belonging to the Federal University of Espírito Santo (DCFM-CCA-UFES) in Jerônimo Monteiro, south of the state of Espírito Santo, from July 2017 to November 2017. The experimental area has a latitude of 20°47'S, a longitude of 41°23'W, and an altitude of 120 m. The region's climate is classified as Cwa (dry winter and rainy summer) by Köppen (1948).

The seeds were obtained from fruits selected from 20 matrix *P. peroba* trees, harvested in Reserva Natural da Vale S.A., in the municipality of Linhares, in ES, at 19°23'S and 40°04'W with an altitude of 43 m. The project was registered in SisGen for access to the genetic heritage (A796E13). After beneficiation, the largest and most vigorous seeds were selected. No pre-germination treatments were used on the seeds.

The experimental design was completely randomized in a 3 × 5 factorial scheme, consisting of three volumes of tubes (120, 180, and 280 cm³), and four doses of CRF (Basacote® Mini 6 M (0 (control), 2.5, 5.0, and 7.5) plus a conventional mineral fertilizer (CF), with four replications. Each replicate consisted of 16 seedlings, totaling 960 experimental units and 64 units per treatment.

Conventional fertilization, proposed by Gonçalves et al. (2005), comprises soluble and non-encapsulated mineral nutrients to produce seedlings of native forest species. Initially, basic fertilization was carried out by adding nitrogen fertilizer (150 g m⁻³ N using ammonium sulfate), phosphorus fertilizer (300 g m⁻³ P₂O₅ using triple superphosphate), potassium fertilizer (100 g m⁻³ K₂O using potassium chloride), and micronutrients in the form of 150 g of FTE (Fritted Trace Elements). After 50 days of sowing, cover fertilization was started with a nutrient solution applied to the substrate closest to the stem. For this solution, 200 g N (ammonium sulfate) and 200 g K₂O (potassium chloride) were diluted in 100 L of water. Fertilizations were performed weekly. Therefore, the recommended monthly amount was divided into four parts.

Table 1 shows that the chemical-physical characterization of the CRF Basacote® Mini 6 M formulation is 13-6-16, with a release time of 5 to 6 months.

Tabela 1. Caracterização químico-física do fertilizante de liberação controlada.

Table 1. Chemical-physical characterization of controlled-release fertilizers.

N	P ₂ O ₅	K ₂ O	Mg	S	Fe	Cu	Mn	Mo	Grain diameter	Weight of 1,000 grains
-----%-----									Mm	g
13.00	6.00	16.00	1.40	10.00	0.26	0.05	0.06	0.015	1.5 – 2.5	9.58

Source: Basacote.

Different doses of fertilizers were added to the commercial substrate (composed of *Pinus* bark, vermiculite, agro-industrial organic waste (Class A), wood sawdust, horse bed manure, and NPK, at 55% humidity) before filling the tubes, ensuring that each treatment received equal amounts of substrate. Samples of the substrate were collected for chemical characterization before implementing the experiment (Table 2), following the methodology of Silva (2009).

Tabela 2. Caracterização químico-física do substrato.
Table 2. Chemical-physical characterization of the substrate.

pH	N	P	K	Ca	Mg	S	CE	Density
(H ₂ O)	g kg ⁻¹					mS cm ⁻¹		g cm ⁻³
6.2	11.5	9.0	5.2	15.0	7.2	4.5	0.4	0.35

Sowing was carried out directly in the tubes filled with substrate and their respective doses of fertilizer. Each tube received two seeds, and was covered with a thin layer of the substrate. The tubes were placed in a polypropylene tray on raised beds under a screen with a 50% reduction in luminous intensity. Irrigation was carried out four times a day, for 7 min, through an automatic irrigation system with micro-sprinklers with flow rates from 31 to 152 lph. After 100 days of sowing, all seedlings were transferred to another area under full sun, receiving daily irrigation four times a day for 10 min.

After 180 days of sowing, the following variables were determined: survival (S, %); the height of the aerial part (H, cm), measured from the seedling neck to the insertion of the last leaf with the aid of a graduated ruler; diameter at root collar (DRC, mm), measured at the level of the tube edge using a digital caliper; number of leaves (NL), determined by counting the number of visible leaves; leaf chlorophyll content (LCC, µg cm⁻²), carried out on samples of intermediate seedling leaves through a portable chlorophyll meter SPAD-502; and the root volume (RV, cm³), obtained using a 500 mL beaker.

To determine the dry matter of the aerial part (DMAP, g plant⁻¹), dry matter of the leaves (DML, g plant⁻¹), and root dry matter (RDM, g plant⁻¹), four seedlings per repetition were collected randomly, and each was divided into two parts: the aerial part and the root. The root system was separated from the soil by washing it with running water. Next, the material was packed in Kraft paper bags and placed in an oven with forced air circulation at 65 °C until constant weight, at which point it was weighed on an analytical balance (with a precision of 0.0001 g). The total dry matter (TDM, g plant⁻¹) was the sum of the DMAP and the RDM. After obtaining these values, the Dickson Quality Index (DQI) was determined.

The DML was sent to the laboratory to determine the leaf content of the nutrients N, P, K, Ca, Mg, S, B, Zn, Mn, Fe, and Cu, according to Silva (2009). The Diagnosis and Recommendation Integrated System (DRIS) indices and the average nutritional balance indices (NBIm) were also calculated with the aid of the INAF program (Interpretation of Leaf Analysis) (GARCIA, 2013). To calculate the functions of the nutrient ratios, the method proposed by Beaufils (1973) with a k factor of 10 was used. Through the DRIS indices, it was possible to calculate the average nutritional balance index (NBIm), which is the sum of the DRIS indices in the module divided by the number of nutrients involved. The closer the value is to zero, the lower the nutritional imbalance of the plants and, potentially, the higher the production (MALAVOLTA *et al.*, 1997; ARAÚJO *et al.*, 2016).

For the variable S (%), the data were subjected to variance analysis, and when checking for significant differences, using the F-test at 5%, the doses were subjected to regression analysis to verify the optimal dose of the CRF through the first derivative estimators β₀ and β₁. The generalized mortality of seedlings grown at a CRF dose of 0 kg m⁻³ (control) made it impossible to continue the growth and nutrition assessments of this treatment. For the growth variables, principal component analysis (PCA) was applied to avoid the use of redundant and identical information contained in two or more correlated variables. The most important variable from the data set extracted through multivariate analysis was subjected to univariate analysis of variance. When checking for significant differences, using the 5% F-test, the treatments were compared by Tukey's test at the 5% and 1% probability. The analyses were performed using R Core Team (2018) version 3.5.0. Regression curves between seedling growth and NBIm were also fitted.

RESULTS

There was an effect (p≤0.05) isolated from the fertilization factor for the survival of *P. peroba* seedlings at 180 days, according to the analysis of variance. The quadratic model best explained the effect of the CRF doses, with the maximum survival value (73.47%) obtained in the 4.91 kg m⁻³ dose (Figure 1). This result was superior to that observed for the CF (44.79%) and the control dose (0 kg m⁻³), where seedling survival was not observed.

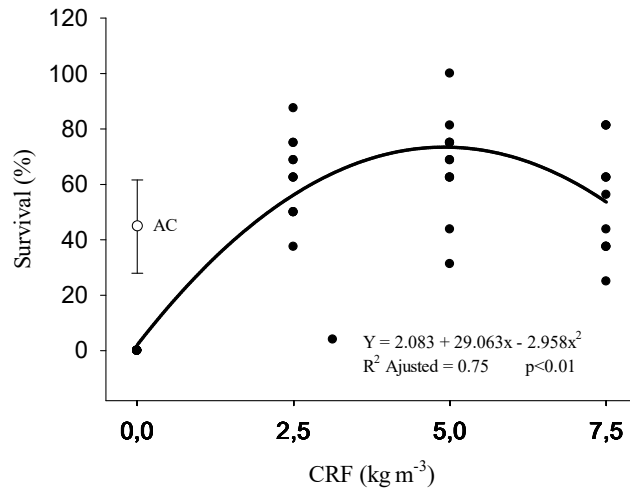


Figura 1. Sobrevivência aos 180 dias de mudas de *Paratecoma peroba* em função do volume do tubete e da adubação com fertilizante de liberação controlada e convencional. I = Adubação convencional (AC); Fertilizante de liberação controlada (FLC).

Figure 1. Survival at 180 days of *Paratecoma peroba* seedlings produced in tubes of different sizes with variable doses of controlled-release fertilizer and a conventional mineral. I = Conventional mineral fertilizer (AC); Controlled-release fertilizer (FLC).

The relationship between the growth and quality variables of *P. peroba* seedlings as a function of the tube volume and fertilizer dose is shown in Figure 2. The data variability explained on axis 1 (83.73%) and axis 2 (9.68%) totaled 93.41% of the total data variability. The variables H, DRC, RV, RDM, DMAP, TDM, and DQI were grouped and intuitively correlated. The treatments with tube volumes of 180 and 280 cm³, when associated with the 7.5 dose of CRF, were associated with high values for these variables. TDM showed a greater correlation ($r=0.993$) with the first main component, and thus it is the variable that best describes the effects of the treatments (Table 3).

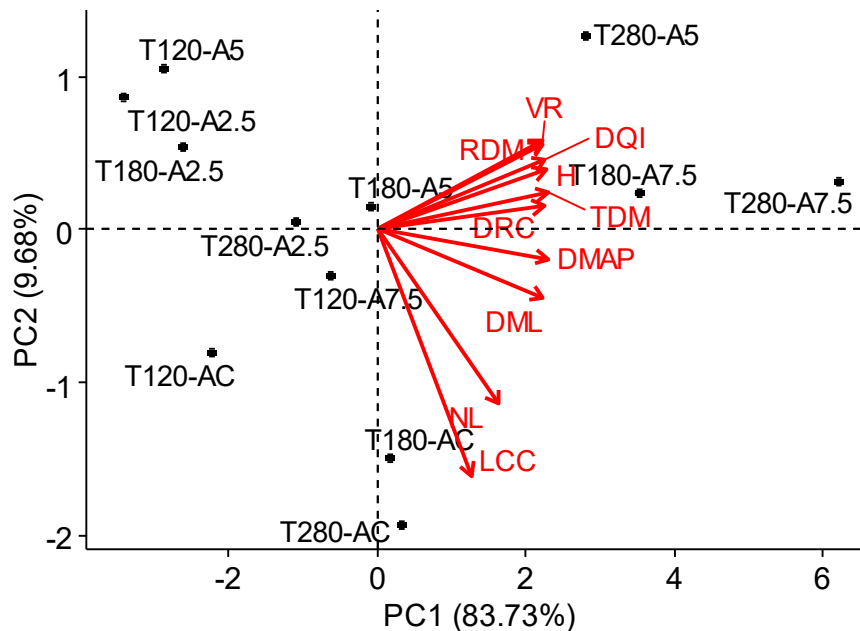


Figura 2. Biplot com as projeções das variáveis relacionadas ao crescimento e qualidade de mudas de *Paratecoma peroba* em função do volume do tubete e da adubação com fertilizante de liberação controlada e convencional. T: tubete; A: adubação; NF: número de folhas; CF: clorofila foliar; H: altura; DC: diâmetro do coleto; VR: volume da raiz; MSR: massa seca da raiz; MSF: massa seca

das folhas; MSPA: massa seca da parte aérea; MST: massa seca total; IQD: índice de qualidade de Dickson.

Figure 2. Biplot with the projections of the variables related to the growth and quality of *Paratecoma peroba* seedlings produced in tubes of different sizes with variable doses of controlled-release fertilizer and a conventional mineral fertilizer. T: tube; A: fertilization: NF: number of leaves; CF: leaf chlorophyll content; H: height of the aerial part; CD: diameter at root collar; RV: root volume; MSR: root dry mass; MSF: dry matter of leaf; MSPA: dry matter of the aerial part; MST: total dry mass; DQI: Dickson Quality Index.

Tabela 3. Coeficientes de correlação de Pearson entre os escores dos componentes principais e as variáveis de crescimento e qualidade de mudas de *Paratecoma peroba*.

Table 3. Pearson correlation coefficients between the scores of the main components and the growth and quality variables of *Paratecoma peroba* seedlings.

Variables	PC1	PC2
Number of leaves (NL)	0.708	0.492
Height of the aerial part (H)	0.980	-0.165
Diameter at root collar (DRC)	0.972	-0.066
Leaf chlorophyll content (LCC)	0.543	0.694
Root volume (RV)	0.959	-0.248
Dry matter of the aerial part (DMAP)	0.988	0.082
Dry matter of leaf (DML)	0.964	0.189
Root dry mass (RDM)	0.959	-0.241
Total dry mass (TDM)	0.993	-0.102
Dickson Quality Index (DQI)	0.971	-0.198

PC: Main components.

There was a significant interaction ($p < 0.01$) between tube volume and fertilization with CRF and CF for the MST of *P. peroba* seedlings (Figure 3). The joint use of the CRF at a dose of $7.5 \text{ kg} \cdot \text{m}^{-3}$ and a 280 cm^3 tube promoted the greatest production of TDM ($8.41 \text{ g plant}^{-1}$) from *P. peroba* seedlings after 180 days.

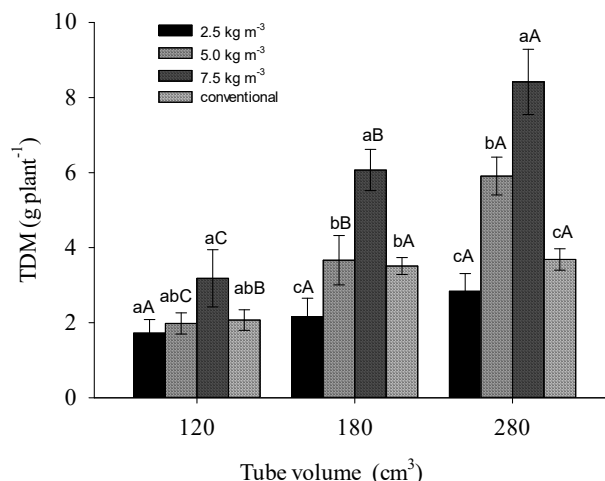


Figura 3. Massa seca total (MST) de mudas de *Paratecoma peroba*, aos 180 dias, em função do volume do tubete e da adubação com fertilizante de liberação controlada e convencional. I = Desvio padrão; Letras maiúsculas comparam os volumes de tubete dentro de cada dose, pelo teste de Tukey ($p \leq 0,05$). Letras minúsculas comparam as doses dentro de um mesmo volume.

Figure 3. Total dry mass (MST) of *Paratecoma peroba* seedlings at 180 days produced in tubes of different sizes with variable doses of controlled-release fertilizer and a conventional mineral fertilizer. I = standard deviation; Upper case letters compare the tube volumes within each dose, by the Tukey test ($p \leq 0.05$). Lowercase letters compare the doses within a same volume.

According to the data on the nutritional status of *P. peroba* seedlings described in Table 4, there was variation in the DRIS indices according to the factors analyzed. The closer the DRIS indices were to

zero, the closer to nutritional balance the *P. peroba* seedlings were. Concerning the NBI_m, it was observed that fertilization with CRF at a dose of 7.5 kg m⁻³ combined with 180 and 280 cm³ tubes promoted more nutritionally-balanced seedlings.

Tabela 4. Teor de nutrientes nas folhas (TN), índice DRIS (ID) e índice de balanço nutricional médio (IBNm) geradas a partir das normas DRIS para mudas de *Paratecoma peroba* em função do volume do tubete e da adubação com fertilizante de liberação controlada e adubação convencional.

Table 4. Leaf nutrient content (TN), DRIS index (ID) and average nutrient balance index (IBNm) generated from the DRIS standards for *Paratecoma peroba* seedlings at 180 days, produced in tubes of different sizes with variable doses of controlled-release fertilizer (CRF) and a conventional mineral fertilizer (CF).

CRF kg m ⁻³		Tubes of 120 cm ³											NBI _m
		N	P	K	Ca	Mg	S	B	Zn	Mn	Fe	Cu	
		g/kg					mg/kg						
2.5	TN	22.98	7.11	15.38	12.02	5.86	2.66	41.12	18.93	75.53	279.68	10.23	
	ID	-10.30	-4.80	-46.1	-101.3	83.39	37.95	-101.0	6.99	-13.5	132.69	16.11	50.39
5.0	TN	18.64	6.89	16.29	11.7	6.38	1.42	39.18	14.64	61.14	240	5.75	
	ID	-25.65	2.96	-12.7	-78.0	176.64	-16.4	-123.9	-37.80	-2.03	116.26	0.77	53.93
7.5	TN	19.32	5.78	17.23	12.25	5.45	1.61	40.01	17.14	60.96	164.11	4.37	
	ID	-6.42	-4.31	-0.98	-36.4	82.96	-0.38	-61.00	10.37	-4.05	25.77	-5.51	21.65
CF	TN	30.38	3.23	17.59	10.39	3.84	3.58	40.13	36.25	98.56	162.39	4.64	
	ID	57.47	-72.8	-32.5	-112.3	-147.2	74.98	-39.22	266.42	6.41	6.63	-7.71	74.89
		Tubes of 180 cm ³											
2.5	TN	19.18	10.05	16.89	12.21	7.07	1.77	41.06	17.2	57	287.18	7.04	
	ID	-40.5	21.53	-21.4	-101.0	195.53	2.49	-160.2	-23.64	-24.0	148.32	2.94	67.42
5.0	TN	17.1	7.76	18.03	13.07	6.2	1.89	43.08	14.83	60.14	168.77	5.05	
	ID	-31.88	10.53	1.67	-31.40	126.67	14.47	-62.62	-36.04	-13.8	25.90	-3.46	32.59
7.5	TN	18.36	6.88	15.64	13.38	4.5	1.39	40.39	15.78	53.32	137.16	7.08	
	ID	-3.38	6.82	-4.37	0.32	1.40	-6.82	2.83	3.96	-8.30	-1.95	9.49	4.51
CF	TN	23.1	3.85	18.06	11.13	3.85	1.86	39.46	30.06	64.82	127.91	4.26	
	ID	25.99	-37.0	1.45	-52.3	-103.5	12.00	-13.31	200.55	-4.25	-23.48	-6.10	43.64
		Tubes of 280 cm ³											
2.5	TN	20.58	7.96	17.79	12.85	6.76	2.36	47.26	20.48	61.11	459.08	8.47	
	ID	-68.43	-4.03	-38.8	-155.0	88.02	24.37	-102.5	-7.35	-39.9	297.77	5.90	75.65
5.0	TN	19.4	7.09	18.68	12.32	5.52	1.86	44.97	16.37	61.35	154.84	4.16	
	ID	-9.41	6.02	4.83	-38.77	54.94	11.71	-10.88	-8.69	-10.9	10.03	-8.86	15.91
7.5	TN	21.14	5.65	19.1	14.19	4.58	1.9	40.88	15.6	75.68	150.11	4.12	
	ID	2.80	-5.61	4.92	0.45	-1.49	5.87	-2.91	-4.72	7.43	1.16	-7.90	4.11
CF	TN	24.5	4.29	18.25	13.5	4.16	2.04	58.56	29.86	76.5	153.13	3.73	
	ID	15.85	-37.0	-10.99	-39.2	-208.9	8.78	163.09	134.03	2.32	-12.78	-15.13	58.92

The results of the regression analysis between NBI_m and TDM, which was the variable that best described the growth of *P. peroba* seedlings, are shown in Figure 4.

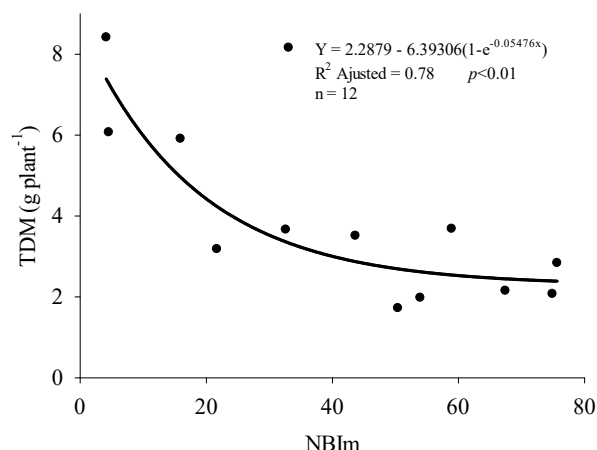


Figura 4. Relação entre o Índice de Balanço Nutricional médio (IBNm) e produção de Massa seca total (MST) de mudas de *Paratecoma peroba*.

Figure 4. Relationship between the mean Nutrient Balance Index (IBNm) and Total dry mass (MST) production of *Paratecoma peroba* seedlings.

DISCUSSION

Fertilization with CRF, among the factors tested, was crucial for the survival of seedlings of *P. peroba*, which were nutritionally demanding in the nursery phase. The high mortality rate of seedlings in the control treatment may be related to the ecophysiological characteristics of the species. Late secondary species show slower growth and a longer nursery time, requiring continuous fertilization during this period. Alternatively, the 80-day period with full sun exposure may have contributed to the increase in mortality in the poorly developed and poorly nourished seedlings from the control treatment.

Through analysis of the main components (Figure 1; Table 3), it was possible to identify that TDM acts directly with the variables H, DRC, RV, RDM, DMAP, and DQI. This is because they act with the same signal as CP1; that is, when the value of one increases, the value of the other increases (multicollinearity). TDM was the variable that presented the greatest discriminatory power in CP1, and therefore, was the most important variable to describe and select *P. peroba* seedlings with superior growth and/or morphological quality.

The growth and quality of seedlings can be better described using the dry mass production variable of the root, the aerial part, and the combined total (FERNANDES *et al.* 2019). According to Larcher (2006), the difference between carbon gains via photosynthesis and losses via respiration (CO₂ balance) results in vegetative growth; thus, the carbon not consumed in the respiratory process increases the dry mass of the plant. Therefore, it is believed that the higher the value of MST, the better the quality of the seedlings, and the better the survival and growth of plants after transplantation in the field.

In general, the cultivation of *P. peroba* seedlings were possible regardless of the size of tube used. However, among the treatments tested, the CRF combination at the dose of 7.5 kg m⁻³ with the 280 cm³ tube proved to be the most effective for production of seedlings with maximum morphological quality (Figure 2; 3). The higher production of TDM in these treatments may be attributed to the synergistic action of improving the nutritional status of the plant and using larger tubes, which may include a greater absolute amount of substrate and fertilizer, as well as a greater available space for growth and nutrient exploration of the roots.

Previous literature suggests that forest species, independent of the ecological group, are responsive to the addition of CRF to the substrate. Navroski *et al.* (2016) demonstrated that *Cedrela fissilis* seedlings (late secondary) showed good growth when 5 kg m⁻³ of CRF was incorporated into the substrate. In seedlings of *Peltophorum dubium* (pioneer), Dutra *et al.* (2016) found growth improvement when they used CRF at doses between 5.4 and 8.2 kg m⁻³. In addition, Rossa *et al.* (2015) found that CRF led to growth gains in seedlings of *Anadenanthera peregrina* (initial secondary) at doses of 5.54 to 6.68 kg·m⁻³ and *Schinus terebinthifolius* (pioneer) at doses of 8.38 to 14.42 kg·m⁻³. Moraes Neto *et al.* (2003) experimented with 5 native species, such as *Myroxylon peruiferum* (climax), and found that doses between 3.2 and 4.8 kg m⁻³ of CRF led to the formation of quality seedlings in all 5 species. Research on the timing of seedling production indicates that the pioneer species stabilized in growth earlier (90 days) than the non-

pioneer species (150 to 180 days). Therefore, studies are needed to establish optimal CRF doses and formulations with adequate release times for each cultivated species.

In *Calophyllum brasiliense* and *Toona ciliata*, Lisboa *et al.* (2012) analyzed three tube volumes (115, 180, and 280 cm³) and concluded that the most suitable tubes for *C. brasiliense* and *T. ciliata* were 180 cm³ and 280 cm³, respectively. Gasparin *et al.* (2014) found that the use of the 280 cm³ tube provided superior growth of *Cabralea canjerana* seedlings in the field phase. Melo *et al.* (2018) analyzed the influence of tube volume (30, 55, 110, 180, and 280 cm³) on the seedling growth of *Mimosa caesalpinifolia* (pioneer) in the nursery and in the field. They found that, although the seedlings produced in the three larger volume containers showed greater growth in the nursery phase, this difference tended to disappear after implantation in the field, making it possible to produce seedlings of this species in any of the tested containers.

Thus, while larger tubes may result in larger seedlings, they require more space, substrate, and investment. By contrast, small containers are easy to handle and require less space and substrate; however, they can limit the growth of seedlings with a longer production cycle, nullifying and/or limiting the effect of fertilizers and, consequently, the nutritional balance of the seedlings. Brachtvogel and Malavasi (2010) found that the NL, DMAP, and TDM of *Peltophorum dubium* seedlings were similar under fertilization with NPK, regardless of the volume of the container, which did not occur in those under CRF, in which the growth was lower with the decrease in container volume.

Gasparin *et al.* (2015) analyzed the combined effect of CRF doses (0, 3, 6, 9, and 12 kg m⁻³) on the growth and nutrition of *Parapiptadenia rigida* seedlings in the nursery with different tube volumes (50, 110, and 180 cm³). They found that as the seedlings were exposed to higher doses of CRF, a higher N content was observed in the DMAP. However, no positive effect on seedling growth was observed on doses above 9.0 kg m⁻³. Concerning the container volume, the seedlings grown in 180 cm³ containers showed P, K, Mg, and S.

Conventional fertilization by Gonçalves *et al.* (2005) of native nursery seedlings was not effective for *P. peroba* seedlings when compared to CRF fertilization, possibly due to the absence of Mg. This can be seen in Table 4, where the Mg values and their respective DRIS indices were excessively low. It is also important to note that the Zn contents presented very high DRIS index values. The DRIS Ca and B indexes were excessively low in the treatments with 120 cm³ tubes and CRF treatments at a dose of 2.5 kg m⁻³. The levels of N in the DML of seedlings treated with conventional fertilization were slightly higher than those of seedlings cultivated with CRF, which was not reflected in gains in MST production.

Analysis of the nutritional status of *P. peroba* seedlings using NBI_m revealed that the production of TDM was significantly associated with the nutritional status of the plants (R²=0.66; p<0.01). These results are compatible with the theoretical model suggested by Beaufils (1973), in which low values of NBI_m, indicative of plants with balanced nutrition, mostly corresponded to samples with high production, confirming the importance of nutritional balance for the growth of *P. peroba* seedlings.

CONCLUSION

- The gains in growth and nutritional balance of *Paratecoma peroba* seedlings grown in higher CRF doses are limited when using tubes with volumes of 120 and 180 cm³.
- *Paratecoma peroba* seedlings produced in a 280 cm³ tube with a 7.5 kg m⁻³ dose of CRF can be considered suitable for planting in the field.

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