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Original Article

Efficiency of organomineral fertilizer and doses of *Azospirillum brasilense* on the morphophysiological quality of *Mezilaurus itauba* seedlings

Eficiência de fertilizante organomineral de resíduos de cupuaçuzeiro e doses de *Azospirillum brasilense* na qualidade morfofisiológica em mudas de *Mezilaurus itauba*

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Abstract

The present study was conducted to determine the efficiency of organomineral fertilizer from cupuaçu residues (ORFCup) and dose of maximum technical efficiency of *Azospirillum brasilense* on the initial growth and morphophysiological quality of *Mezilaurus itauba* seedlings in the northern Amazon. The variables evaluated were: shoot height (H, cm), stem diameter (SD, mm), shoot dry mass (SDM, g plant^{-1}), root dry mass (RDM, g plant^{-1}) total dry mass (TDM, g plant^{-1}), Dickson quality index (DQI), net assimilation rate (NAR, g m^{-2} day^{-1}), leaf relative growth rate (RGR, g m^{-2} day^{-1}), leaf area ratio (LAR, m^2 g^{-1}), leaf relative growth rate (RGR, g m^{-2} day^{-1}), leaf area ratio (LAR, m^2 g^{-1}), specific leaf area (SLA, cm^2 g^{-1}), and leaf mass ratio (LMR, g g^{-1}). Organomineral fertilizer from cupuaçu residues promotes better quality and robustness in *M. itauba* seedlings at the dose of maximum technical efficiency of 0.45 mL. L^{-1} of *A. brasilense*.

Keywords: Itaúba, specific leaf area, net assimilation rate, Dickson quality index, N-fixing bacteria.

Resumo

O presente estudo foi realizado com o objetivo de determinar a eficiência de fertilizante organomineral de resíduos de cupuaçuzeiro e a dose de máxima eficiência técnica de *Azospirillum brasilense* sobre o crescimento inicial e qualidade morfofisiológica em mudas de *Mezilaurus itauba* na Amazônia setentrional. As variáveis avaliadas foram: comprimento da parte aérea (H, cm), diâmetro do colo (DC, mm), massa seca da parte aérea (MSPA, g plant^{-1}), massa seca das raízes (MSR, g plant^{-1}) e massa seca total (MST, g plant^{-1}), e índice de qualidade de Dickson (IQD), taxa de assimilação líquida (E_A, g.m^{-2}.dia), taxa de crescimento relativo foliar (RA, g.m^{-2}.dia); razão de área foliar (F_A, m^2.g^{-1}), área foliar específica (S_A, cm^2.g^{-1}), razão da massa foliar (Fw, g/g^{-1}). O fertilizante organomineral de resíduos de cupuaçuzeiro (FORCup) promove melhor qualidade e robustez nas mudas de *Mezilaurus itauba* em conjunto com a aplicação de 0.45 mL. L^{-1} de *Azospirillum brasilense*.

Palavras-chave: Itaúba, área foliar específica, taxa de assimilação líquida, índice de qualidade de Dickson, bactéria fixadora de N.

1. Introduction

Itaúba, a tree native to Brazil, belonging to the Lauraceae family, known scientifically as *Mezilaurus itauba* (Meisn.) Taub. ex Mez, is among the species of the national flora threatened with extinction, as stated by Franciscon and Miranda (2018). Itaúba is a tree that produces wood with high quality and can grow up to 40 m in height and 80 cm in diameter, being highly used in forest plantations and for illegal logging.

In addition, *M. itauba* is included as an endangered species both in the red list of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (JBRJ, 2023) and in the International Union for Conservation of Nature (IUCN, 2023).

As its wood is commonly used in construction, in the manufacture of posts, sleepers, stakes and other parts, it has high economic potential to be grown in agroforestry systems or used in forest restoration areas, according to Ferreira et al. (2017). The success of reforestation projects depends on the availability and quality of seedlings, which must be produced on a large scale and acclimatized for survival in the field.

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Propagation of seedlings in a forest nursery presents itself as a viable option to meet this demand, as it offers a favorable environment of factors such as illuminance, temperature and water availability, which can promote improvement in the quality of seedlings produced (Smiderle et al., 2021).

In addition, to ensure the growth and development of plants and, at the same time, protect the environment, it is of paramount importance to employ a judicious combination of mineral fertilizers, organic fertilizers and organomineral fertilizers (Sousa et al., 2021; Menegatti et al., 2020; Leal et al., 2020; Magalhães et al., 2017). Organomineral fertilizers, which are a mixture of organic matter derived from plants and animals and mineral fertilizers, represent the ideal solution (Leal et al., 2020).

Organomineral fertilizers constitute a promising alternative for soil fertility (Leal et al., 2020), as they have the potential to partially or totally replace industrialized mineral fertilizers (Holík et al., 2019). In addition, organomineral compounds have advantageous attributes for the soil, including soil biota activation, nutrient supply, moisture preservation, and enhancement of soil physical properties (Dueñas et al., 2020).

The same is true for the use of technological packages, for instance, the use of microorganisms such as atmospheric nitrogen-fixing bacteria, which involves the incorporation of atmospheric N_2 (Ferraro et al., 2023), which is then fixed by bacteria and allows nutrients in the form of ammonium (NH_4^+) and nitrate (NO_3^-) to be released and become available to the root system of plants according to their nutritional need, resulting in balanced growth (Bashan 1999; Souza et al., 2023).

Souza et al. (2023), in a study with production of *Cordia alliodora* seedlings, observed that the use of *Azospirillum brasilense* with foliar and soil application promoted increments in biomass production and in the photosynthetic parameters of the leaves, including chlorophyll content, stomatal conductance and leaf area.

However, there are few studies that prove the efficiency of using these technological packages for the production of *M. itauba* seedlings and they need to be reported. In this context, the present study aimed to determine the efficiency of the organomineral fertilizer from cupuaçu and the dose of maximum technical efficiency of *A. brasilense* on the initial growth and morphophysiological quality of *M. itauba* seedlings in the northern Amazon.

2. Material and Methods

2.1. Plant materials

The present study was conducted in a seedling nursery belonging to Embrapa Roraima. To produce seedlings of itaúba (*M. itauba*), the fruits were harvested from trees located in a region of Submontane Dense Ombrophilous Forest, with emerging canopy. This area is located at the geographical coordinates of 1°38’29” N latitude and 60°58’11” W longitude, in the municipality of Caracaraí, RR, Brazil. After obtaining the fruits, the seeds were processed and sown in a bed with sand of medium particle size.

Moisture in the sand substrate was maintained by manual irrigation, with four daily irrigation events. Approximately 30 days after sowing, the seedlings reached a homogeneous height of approximately 5.0 cm and were then transplanted into polyethylene bags (15 × 35 cm) containing sand + soil + carbonized rice husk + organic compost (1:1:1:1). Chemical and physical analyses (Table 1) of the substrate were performed using the methodology described by the Official Network of Soil and Plant Tissue Analysis Laboratories of RS and SC - ROLAS (SBCS, 2016).

2.2. Illuminance

The experiment was conducted in a greenhouse, and the average daily temperature recorded in the growing period of itaúba (*M. itauba*) seedlings was 28 ± 3 °C, with relative air humidity from 60% to 80%. Illuminance was recorded days after transplantation (DAT), as expressed in Figure 1.

The plants were kept in a greenhouse for 120 days after transplantation (DAT) and manually irrigated as needed, with one irrigation every 15 days with 50 mL of the organomineral fertilizer from cupuaçu (*Theobroma grandiflorum*) residues (ORFCup) per plant, applied using a beaker at 4:30 p.m. ORFCup was obtained from the composting process of crop remains of cupuaçu orchard, in an area of a family farmer, in the municipality of Pacaraima, RR, using leaves, twigs and branches with witch’s broom symptoms resulting from phytosanitary pruning, as well as cupuaçu fruit peels and seeds that were discarded after fruit processing. Such residues were crushed and arranged

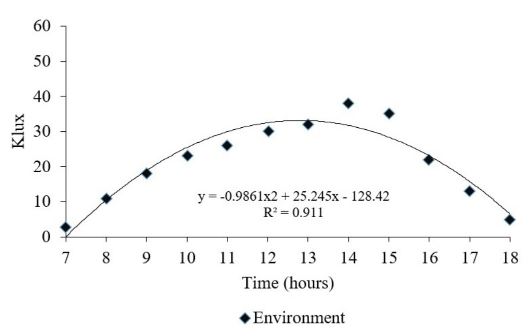

Figure 1. Illuminance recorded in the environments along the total period of production of itaúba (*M. itauba*) seedlings.

Table 1. Chemical characteristics of the substrate used in the production of itaúba (*M. itauba*) seedlings.

	pH	K	P	Ca	Mg	Al	H+Al	CEC	SB	OM	Zn	Fe	Mn	Cu	B	S
		--------cmol/dm³-------								dag/kg	---------------mg/dm³-------------					
Subst.	6.7	0.31	0.87	11.0	0.7	0.0	1.1	13.31	12.01	3.50	16.5	13.5	88.6	0.3	0.5	17.2

(Subst.) sand + soil + carbonized rice husk + organic compost (1:1:1:1).

in piles, with layers of plant remains, interspersed with layers of manure, in a ratio of 3:1, respectively, inside wooden compost bins up to a maximum height of 1.5 m. The material was turned every 5 days over the first 15 days and, after this period, every 10 days, being watered during the first 14 days. The liquid residue obtained from the composting process was drained to a water tank connected to the composter, stored and later collected for testing. Samples of the liquid residue obtained from the composting process were sent to SOLOCRIA Laboratório Agropecuário LTDA for macronutrient and micronutrient analyses. Chemical characteristics of ORFCup are shown in Table 2.

The solution of *A. brasilense* (2x108 viable cells mL^{-1}), with a minimum concentration of 200 million viable cells mL^{-1}, as recommended by Brazilian legislation (Hungria, 2011), was deposited in four small depressions of 3 cm on the surface, 2 cm away from the plant collar, using an automatic graduated pipette. The experimental design was completely randomized in a 2 × 5 factorial scheme, representing the conditions with and without application of ORFCup and five doses (0.0, 0.2, 0.4, 0.6 and 0.8 mL L^{-1}) of *A. brasilense* with five replicates, each of which consisting of five seedlings (one in each container).

At 120 days after transplantation (DAT), the plants were evaluated for shoot height (H) with a graduated ruler and stem diameter (SD) with a digital caliper.

Then, the seedlings were divided into roots and shoots to evaluate their dry mass. Roots were washed in running water, and then shoots and roots were placed in kraft paper bags and dried in a forced air circulation oven, with temperature adjusted to 70 °C, for 72 h. Subsequently, these parts were weighed on an analytical balance (0.0001 g) to determine shoot dry mass (SDM, g $plant^{-1}$) and root dry mass (RDM, g $plant^{-1}$), and their sum was used to calculate total dry mass (TDM, g $plant^{-1}$). Dickson quality index was determined using the Formula 1:

$$DQI = TDM / \left[\left(H / SD \right) + \left(SDM / RDM \right) \right] \tag{1}$$

according to Dickson et al. (1960).

2.3. Doses of maximum technical efficiency

The doses of maximum technical efficiency (DMTE) of *A. brasilense* were calculated by deriving and equaling to zero the mean quadratic functions of production that best fitted to the data according to Equations 2 and 3 (Tiesdale et al., 1993).

$$y = cx^2 + bx + a \tag{2}$$

$$\frac{dy}{dx} = 2cx + b = 0 \tag{3}$$

2.4. Leaf area (LA)

Was obtained from the Li-Cor area meter, model LI3100C. The values of net assimilation rate (NAR, g m^{-2} day^{-1}), leaf relative growth rate (RGR, g m^{-2} day^{-1}), leaf area ratio (LAR, m^2 g^{-1}), specific leaf area (SLA, cm^2 g^{-1}) and leaf mass ratio (LMR, g g^{-1}) were determined from instantaneous values of LA, leaf dry mass (LDM) and total dry mass (TDM), used in the equations LAR=LA/TDM, SLA=LA/LDM and LMR=LDM/TDM, according to Radford (1967) and Richards (1969).

2.5. Statistical analysis

All variables were subjected to comparison of means by Tukey test, at 5% probability levels, whereas quantitative variables were subjected to regression analysis in order to assess the response of the application of ORFCup as a function of the doses of *A. brasilense*. Data analysis was performed using the Sisvar statistical package (Ferreira 2014).

3. Results

Analysis of variance revealed a significant effect ($p<0.01$) for the interaction between the factors with and without ORFCup (F) and doses (D) of *A. brasilense* on for shoot, root and total dry mass of *M. itauba* seedlings (Table 3), suggesting that the application or not of F and D can have a direct influence on the biomass accumulation of *M. itauba* seedlings. There were also significant individual effects of the F factor on SDM, RDM, TDM and DQI, and individual effects of the D factor on all variables of the present study (Table 3)

The results obtained in the present study showed increase in the height of *M. itauba* seedlings with the increment in the doses of *A. brasilense*, with and without the application of ORFCup (Figure 2A). However, to obtain maximum height (34.19 cm) of *M. itauba* seedlings, the estimated dose of maximum technical efficiency (DMTE) was 0.38 mL L^{-1} with the addition of ORFCup (Figure 2A). In addition, the plants showed a 23.95% gain in height when compared to the zero dose (control).

For the height of *M. itauba* seedlings without addition of ORFCup, the DMTE of *A. brasilense* was 0.41 mL L^{-1}, which led to an average height of 32.01 cm (Figure 2A), with a 26.58% gain compared to the zero dose.

In general, for the stem diameter of *M. itauba* seedlings with the addition of ORFCup the DMTE was 0.39 mL L^{-1} of *A. brasilense*, which led to an average stem diameter of 6.09 mm (Figure 2B), with an average increment of 5.9% compared to the zero dose, while without the addition of ORFCup the DMTE was 0.58 mL L^{-1}, resulting in an average diameter of 5.87 mm (Figure 2B), with an average increment of 9.7% compared to the control treatment.

Table 2. Chemical analysis of organomineral fertilizer from cupuaçu residues (ORFCup) in the production of itaúba (*M. itauba*) seedlings.

	N	P	K	Ca	Mg	S	Na	Cu	Zn	Fe	Mn	B
ORFCup				%						%		
	0.024	0.031	1.89	0.014	0.015	0.011	-	0.250	0.60	8.800	3.88	0.03

N, P, K, Ca and Mg: Digestion with H_2O_2 and H_2SO_4; S, Fe, Cu, Mn, Zn and Na: Digestion with HNO_3 $HClO_4$; B: Extraction by dry combustion.

Table 3. Analysis of variance for height (H), stem diameter (SD), shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM) and Dickson quality index (DQI) of *M. itauba* seedlings without and with ORFCup as function of doses of *A. brasilense* (0, 0.2, 0.4, 0.6 and 0.8 g L^{-1}).

Variable	Sources of variation			CV (%)
	ORFCup (F)	Dose (D)	F × D interaction	
	(df = 1)[1]	(df = 4)	(df =4)	
Height (cm)	42.0250^{ns}	116.4125*	4.7125^{ns}	9.93
Stem diameter (mm)	0.7840^{ns}	1.1106**	0.1908^{ns}	8.01
Shoot dry mass (g $plant^{-1}$)	8.8360**	16.4946**	1.3853**	8.41
Root dry mass (g $plant^{-1}$)	78.4000**	118.6715**	3.6100**	7.60
Total dry mass (g $plant^{-1}$)	139.8760**	222.7091**	8.6766**	7.54
Dickson Quality Index	0.4069**	0.4551**	0.0192^{ns}	9.99

*Significant at 5%; **Significant at 1%; ^{ns}not significant at 1% probability level (p<0.01) by the F test; df: degrees of freedom; CV: Coefficient of variation.

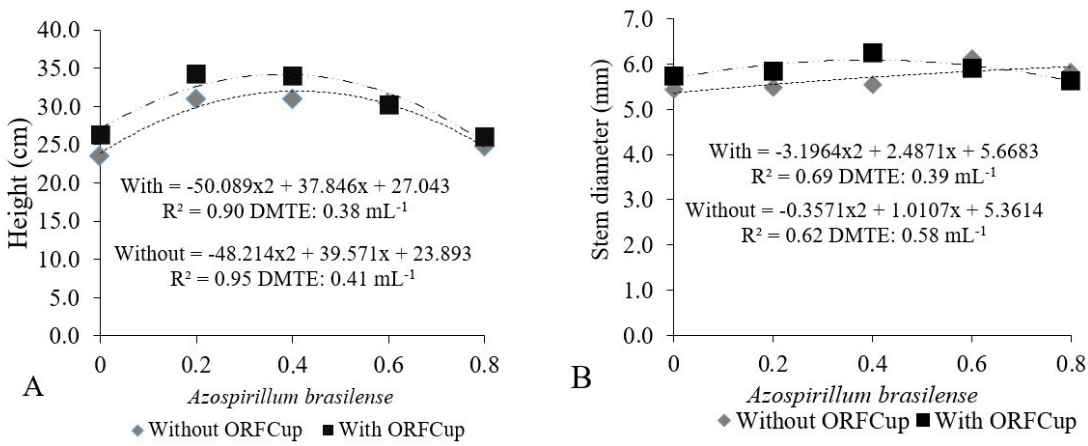

Figure 2. Mean values of height (A) and stem diameter (B) obtained with and without organomineral fertilizer from cupuaçu residues (ORFCup) as a function of doses of *A. brasilense* (0, 0.2, 0.4, 0.6 and 0.8 mL. L^{-1}) in itaúba (*M. itauba*) seedlings at 120 days after transplantation.

This suggests that the response of *M. itauba* seedlings with different doses of *A. brasilense* is not only due to the N_2 fixed, but also due to the higher efficiency in the absorption of mineral N available in the substrate and in ORFCup (Table 1 and Table 2).

For SDM production in *M. itauba* seedlings with application of ORFCup, the DMTE was 0.45 mL L^{-1} of *A. brasilense*, with biomass of 6.72 g $plant^{-1}$ (Figure 3A). In *M. itauba* seedlings without application of ORFCup, the DMTE for SDM was 0.50 mL L^{-1} of *A. brasilense*, with biomass of 5.62 g $plant^{-1}$ (Figure 3A).

In addition, the DMTE of 0.45 mL L^{-1} of *Azospirillum brasilense* with ORFCup application promoted a gain of 16.3% in shoot biomass (SDM) compared to the DMTE of 0.50 mL L^{-1} of *A. brasilense* without ORFCup application (Figure 3A).

In turn, the DMTE of 0.45 mL L^{-1} of *A. brasilense* with application of ORFCup led to SDM gain of 64.78% compared to the control (Figure 3A), exhibiting a significant and positive effect, indispensable for the maintenance of the physiological processes that culminate in biomass production and plant growth.

In addition, for RDM the DMTE was 0.45 mL L^{-1} of *A. brasilense* with the application of ORFCup, leading to a value of 17.21 g $plant^{-1}$ (Figure 3B), whereas without application of ORFCup the DMTE was 0.46 mL L^{-1} of *A. brasilense*, leading to RDM of 14.36 g $plant^{-1}$. When comparing the treatments with and without application of ORFCup at their respective DMTE, the gain in RDM was 16.46% (Figure 3B).

Regarding the TDM of *M. itauba* seedlings (Figure 4A), there were gradual increments up to the DMTE of 0.45 mL L^{-1} of the inoculant *A. brasilense* with application of ORFCup.

According to the results obtained, the highest DQI achieved was 4.63 with the DMTE of 0.46 mL L^{-1} of *A. brasilense* with application of ORFCup, whereas without application of ORFCup the estimated DMTE was 0.52 mL L^{-1} of *A. brasilense*, resulting in a DQI of 3.40 (Figure 4B), both

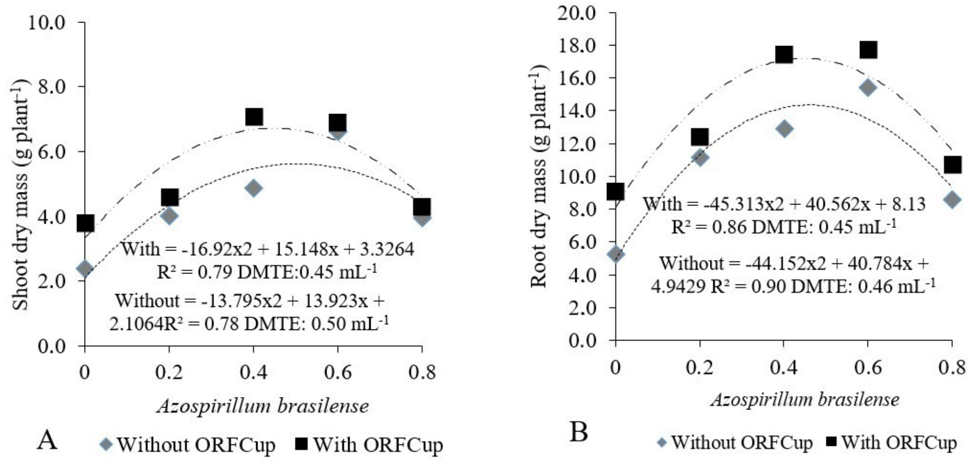

Figure 3. Mean values of shoot dry mass (A) and root dry mass (B), obtained with and without organomineral fertilizer from cupuaçu residues (ORFCup) as a function of doses of *A. brasilense* (0, 0.2, 0.4, 0.6 and 0.8 mL. L^{-1}) in itaúba (*M. itauba*) seedlings at 120 days after transplantation.

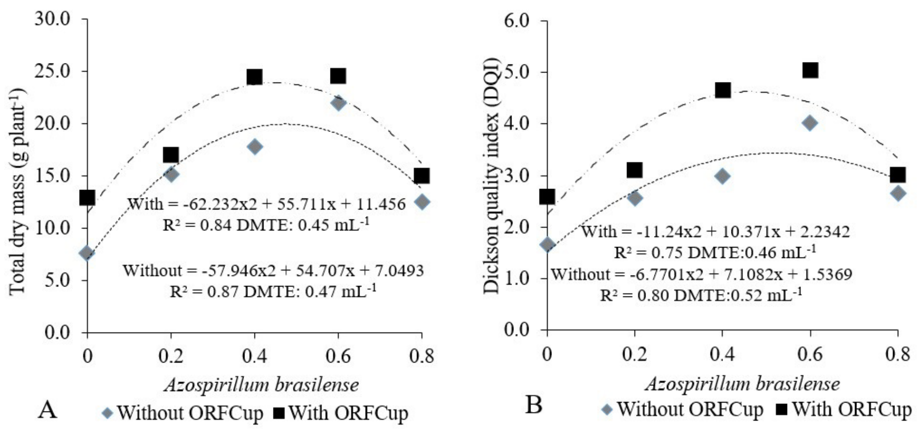

Figure 4. Mean values of total dry mass (A) and Dickson quality index (B), obtained with and without organomineral fertilizer of cupuaçu residues (ORFCup) as a function of doses of *A. brasilense* (0, 0.2, 0.4, 0.6 and 0.8 mL. L^{-1}) in itaúba (*M. itauba*) seedlings at 120 days after transplantation.

values being within the ideal range proposed by Souza et al. (2023).

In general, *M. itauba* seedlings with application of ORFCup under the different doses of *A. brasilense* showed an increase in NAR compared to those without application of ORFCup, regardless of the doses of *A. brasilense*. Thus, the application of ORFCup becomes important since it is a product that immediately makes nutrients available to plants, which can meet the nutritional demand and allow the maintenance of physiological processes.

In turn, higher values of NAR were observed at 120 DAT at the doses of 0.4 and 0.6 mL L^{-1} of *A. brasilense* with application of ORFCup (Table 4), when compared to the other doses. This result positively influenced the increase in plant biomass, as observed in the total dry mass at 120 DAT.

Leaf relative growth rate (RGR, g m^{-2} day^{-1}) can vary throughout the cycle of any plant and depends, among other factors, on the useful leaf area for photosynthesis and NAR. It can be observed (Table 4) that *M. itauba* plants that received application of ORFCup showed higher values of both NAR and RGR compared to plants that did not receive application of ORFCup, regardless of the doses of *A. brasilense* (Table 4). In general, the highest RGR values were obtained with the application of ORFCup at doses of 0.4 and 0.6 mL L^{-1} of *A. brasilense* when compared to the other doses of *A. brasilense*.

For SLA and LAR (Table 4), *M. itauba* seedlings also showed significant differences in the presence and absence of ORFCup and doses of *A. brasilense* evaluated at 120 DAT. In addition, the SLA at the dose of 0.4 mL L^{-1} was similar

Table 4. Means for the interaction between ORFCup (Without and With) and doses of *A. brasilense* for the physiological indices net assimilation rate (NAR, g m^{-2} day^{-1}), leaf relative growth rate (RGR, g m^{-2} day^{-1}), specific leaf area (SLA, cm^2 g^{-1}), leaf area ratio (LAR, m^2 g^{-1}), leaf mass ratio (LMR, g g^{-1}) and leaf area (LA, m^2 m^{-2}) of *M. itauba* seedlings at 120 days after transplantation.

DOSES	NAR		RGR	
	Without ORFCup	With ORFCup	WithoutORFCup	With ORFCup
0	0.000113 bB	0.000122 bA	0.003117 cB	0.003940 cA
0.2	0.000114 bB	0.000125 bA	0.006069 aB	0.006605 aA
0.4	0.000138 aB	0.000152 aA	0.006373 aB	0.006980 aA
0.6	0.000138 aB	0.000153 aA	0.006240 aB	0.007041 aA
0.8	0.000122 bB	0.000127 bA	0.004979 bB	0.005572 bA
CV	12.01		10.43	
	SLA		LAR	
	Without ORFCup	With ORFCup	Without ORFCup	With ORFCup
0	109.3 cB	172.3 cA	33.65 cB	50.65 cA
0.2	242.5 aA	249.5 abA	69.18 aA	72.89 bA
0.4	206.1 bB	267.0 aA	63.46 aB	77.57 aA
0.6	181.3 bB	262.1 aA	54.44 bB	78.50 aA
0.8	149.1 bcB	212.9 bA	47.09 bB	60.61 bcA
CV	14.98		13.65	
	LMR		LA	
	Without ORFCup	With ORFCup	WithoutORFCup	With ORFCup
0	0.30 aA	0.29 bA	246 cB	650 dA
0.2	0.26 bA	0.28 bA	1050 aB	1291 bA
0.4	0.27 bB	0.33 aA	1200 aB	1584 aA
0.6	0.30 aB	0.35 aA	1200 aB	1480 aA
0.8	0.31 aA	0.28 bB	590 bB	910 cA
CV	12.44		16.47	

Lowercase letters (a, b) compare the means for the variables between the doses of *A. brasilense*, and uppercase letters (A, B) compare the means for the variables with or without ORFCup, by Tukey test at 5% probability level.

to that obtained at the dose of 0.6 mL L^{-1} of *A. brasilense* with the application of ORFCup (Table 4).

In general, in the present study the seedlings of *M. itauba* remained for 120 DAT under light intensity ranging from 2.7 to 38 lux (Figure 1). It was observed that LAR with application of ORFCup was higher at the doses of 0.4 and 0.6 mL L^{-1} of *A. brasilense* than at the other doses (Table 4).

In addition, most forest species have high LAR at the beginning of the cycle, a period in which leaves develop for greater light capture, with a subsequent decrease due to the interference of upper leaves on lower ones, characterizing self-shading (Hönig et al., 2018), hence reducing the useful leaf area for photosynthesis.

In general, when SLA, LAR and LA increase, there is also a decrease in NAR due to the mutual shading of the leaves (Katiyar et al., 2021), which was observed in the present study (Table 4).

Among the two components of LAR, SLA is much more plastic than LMR, especially in relation to environmental factors. LMR is undoubtedly a conservative growth index with regard to environmental conditions, which was observed in the present study in *M. itauba* seedlings for *A. brasilense* mainly at doses of 0.4 and 0.6 mL L^{-1} (Table 4) due to the proportional balance between leaf dry mass and total dry mass.

4. Discussion

The practicality and benefits with the addition or not of ORFCup and the application of doses of *A. brasilense* are of fundamental importance, since both practices used in this study promoted satisfactory results for plant height.

Souza et al. (2023), when determining the initial growth and morphophysiological quality of *Cordia alliodora* in the northern Amazon, established that the DMTE of 0.37 mL L^{-1} promoted the greatest gains in shoot height and stem diameter, equal to 28.8% at the DMTE of 0.40 mL L^{-1} of *A. brasilense* when applied via soil.

In addition, substances based on phytohormones, such as auxins and cytokinins, can be released by *A. brasilense*, improving the efficiency of N use by plants and consequently promoting greater gain in the biomass production of forest seedlings (Smiderle et al., 2022; Souza et al., 2023). This was observed in the present study for the variables SDM and RDM of *M. itauba* for both practices used (Figure 3A and 3B).

Thus, it is expected that the supply of *A. brasilense* + ORFCup at adequate concentration can ensure, along with micronutrients, the maintenance of the main metabolic processes that promote superior quality of native forest seedlings.

According to Souza et al. (2023), the DQI is a good indicator of seedling quality, because it considers for its calculation the robustness and balance of biomass distribution among the organs, both parameters considered important for reliable recommendation of seedling quality. For Souza et al. (2023) and Smiderle et al. (2021), the value considered ideal for the DQI of native forest seedlings of Roraima is approximately 1.00.

It is worth mentioning that SLA is a strategic measure of biomass allocation that reflects the leaf area available for light capture per unit of photoassimilates invested in biomass among plant organs (Marañon and Grubb 1993). This variable is the parameter that best explains the differences in biomass gain between plant organs and later in the quality of seedlings (Souza et al., 2023).

Smiderle et al. (2022) revealed that root mass could be another parameter of biomass allocation related to the growth rate of *Hymenaea courbaril*. In the present study, with *M. itauba* seedlings, biomass allocation was determinant for DQI, that is, for the quality of the seedlings.

According to Wright and Westoby (2000), the net assimilation rate is the increase of total dry mass as a function of leaf area, as observed in the present study (Figure 4A and Table 4).

In addition, the species *M. itauba*, evaluated in the present study, invested less biomass in shoots and more biomass in roots (Figure 3A and 3B), corroborating the findings of Souza et al. (2023), who mentioned that *C. alliodora* is a species from the Northern Amazon that is characterized by having greater dry mass accumulation in the roots of the seedlings than in their shoots.

According to Menegatti et al. (2022), species with high growth rates have high concentrations of N per unit of total DM, allocating more N to the leaves and indicating better use of this N in carbon fixation (Poorter et al., 1990);

Thus, possibly the environment with light intensity as described in Figure 1, combined with the application of ORFCup and doses of N-fixing bacteria provided the ideal amount of N and high net CO_2 assimilation rate (NAR), a determinant physiological parameter for the initial growth of *M. itauba* seedlings.

Pinzón-Torres and Schiavinato (2008) comment that plant yield depends on the use of photoassimilates, which can be employed to increase photosynthetic capacity by increasing SLA, LAR and the production of chlorophylls and biomass allocation to the different plant organs.

However, LAR varies as a function of SLA, which is the leaf area per unit of leaf dry mass, and LMR, which is the proportion of total dry mass allocated to the leaves. These parameters are relatively sensitive to environmental changes, although the increments in LAR result more from the increase in SLA than in LMR, since the values of LAR are more sensitive to changes in irradiance (Lambers and Poorter, 1992).

In this context, it can be inferred that irradiation, application of organomineral fertilizer and use of N-fixing bacteria in *M. itauba* seedlings were efficient both for plant nutrition and for the production of phytohormones that stimulate growth and development to the point of significantly increasing their biomass, robustness and quality.

These advantages allow rapid occupation in open spaces and better use of the resources available in the soil, which makes this species suitable for use in revegetation projects and restoration of degraded areas.

5. Conclusions

Organomineral fertilizer from cupuaçu residues promotes better quality and robustness in *M. itauba* seedlings at the dose of maximum technical efficiency of 0.45 mL L^{-1} of *A. brasilense*.

Presence of organomineral fertilizer from cupuaçu residues promotes positive gains in the morphological characteristics of *M. itauba* seedlings.

Presence of organomineral fertilizer from cupuaçu residues combined with doses of 0.4 and/or 0.6 mL L^{-1} has positive influence on all physiological indices studied in *M. itauba* seedlings at 120 days after transplantation.

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