Irrigation Management in the Paricá Seedlings Development in Amazon Region

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ABSTRACT

Paricá is a native tree to the Amazon region recognized for several socioeconomic applications. However, there are few studies on the influence of irrigation regime in the seedling stage. Thus, the objective of the research was to evaluate the effect of water depths and irrigation frequency on the development of Paricá seedlings in the edaphoclimatic conditions of the Amazon region. The experiment was conducted in a greenhouse at the Federal Rural University of the Amazon (UFRA), Capitão Poço Campus, located in Capitão Poço, Pará, Brazil. The experimental design was randomized blocks, in 5x2 factorial arrangements, consisting of five irrigation depths and two irrigation frequencies, with four replications. The highest irrigation depth (725 mL) at daily frequency resulted in lowest biomass production maybe due to hypoxia in the root zone. In contrast the every three day irrigation promoted high biomass production with the highest irrigation depth (725 mL). Contrarily, 435 mL depth produces high quality seedlings at daily irrigation frequency. Regarding the rational use of water, producers may use 725 mL at 3-day frequency, given that it has promoted high seedling quality and provides savings of 580 mL compared to the best water depth on the daily irrigation (435 mL).

Keywords: Water availability, silviculture, *Schizolobium amazonicum* Huber ex Ducke

INTRODUCTION

Knowledge of the optimal water supply in the formation of forest seedlings is extremely important, as the lack or excess of water can therefore limit or develop the seedlings (Hart *et al.,* 2020). The lack of water leads to water stress, in addition to the decrease in nutrient absorption; the excess can lead to leaching and provide a microclimate favorable to the development of diseases, resulting in low quality seedlings (Du *et al.,* 2019). Thus, irrigation management is fundamental to produce Paricá seedlings, both from a quantitative and qualitative point of view. Water is an important resource in the development of seedlings in the nursery as it is directly linked in all stages of the plant's morphological, physiological and biochemical development (Souza *et al.,* 2017).

Paricá (*Schizolobium amazonicum* Huber ex Ducke) is native to the Amazonian ecosystem, it stands out among the reforested species in Brazil because it has increases in height and diameter that allows a short-term use. According to Silva *et al.* (2020), Paricá wood has an easy peel removal, lamination, drying, pressing, excellent finish and is used

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in the manufacture of laminates and plywood. Paricá is by far the wood species with the greatest planted area in the Amazon region, covering about 90,000 hectares (Mascarenhas *et al.,* 2021).

For this reason, it is essential to obtain information on the production system of native forest species with potential for this sector. Given the wide demand, research must be developed to maximize the production of forest tools, considering the efficiency of the use of the resources needed for production and minimizing production costs. Despite the great economic, ecological and social importance of Paricá, the success of its implementation still requires research related to the management of seedling production, especially on water management, since water is one of the fundamental elements for increasing the productivity (Borma & Nobre, 2013). The objective was to evaluate the influence of water depths and irrigation frequencies on the development of Paricá seedlings in the edaphoclimatic conditions of the Amazon region.

MATERIALS AND METHODS

Field Sites and Material Description

The experiment was conducted in a greenhouse at the Federal Rural University of the Amazon (UFRA), Capitão Poço Campus, in Capitão Poço (01º 44' 47" S 47º03'34" W, 73 m a.s.l.), Pará, Brazil. The experimental time was from November 11, 2015 to March 12, 2016. Air temperature and relative air humidity were monitored during the experiment through the digital thermo-hygrometer (1566-1, J.Porlab, São José dos Pinhais, Paraná, Brazil) (Figure 1).

Soil is classified as a Latossolo Amarelo (Oxisol). The physical and chemical analyses of the soil used in the experiment were performed according to Santos *et al.* (2013) and the results are shown in Tables 1 and 2.

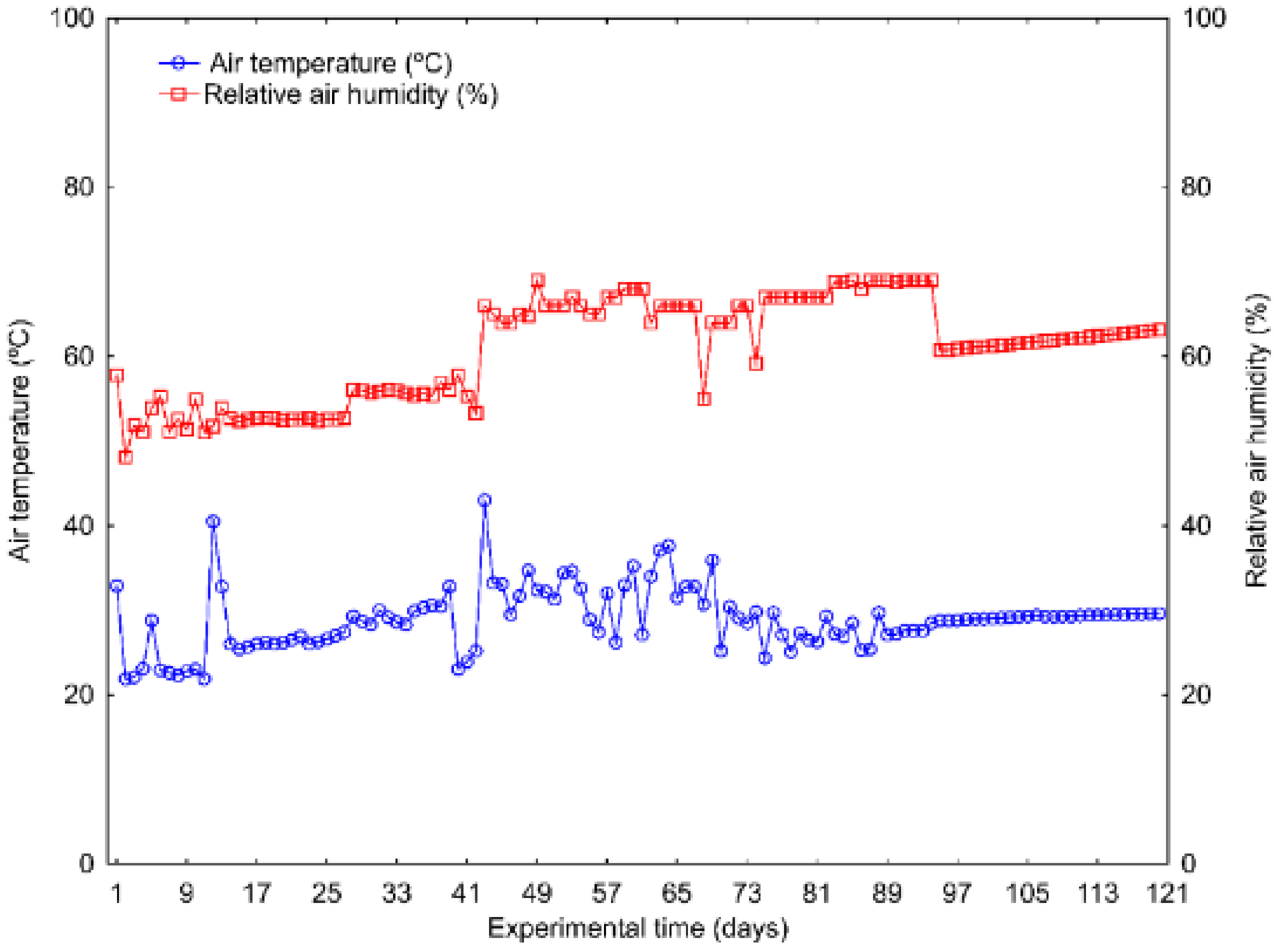


Figure 1: Meteorological data of average air temperature (ºC) and relative humidity (%) using a thermo-hygrometers.

Table 1: Results of soil chemical properties

Nutri-ent	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	H^{+} + Al^{3+}	Al^{3+}	S	CEC	T	N	C	C/N	OM	V	m	P-ass
0_20	-	ds m^{-1}	---------------(cmolc kg^{-1})--------------									----------- (g kg^{-1})-----------				(%)		(mg kg^{-1})
Con-tent	4.5	0.25	0.7	0.6	0.05	0.09	4.46	0.8	1.4	2.19	5.9	0.86	8.52	10.0	14.69	24.0	36.0	8.0

Note: pH = hydrogenation potential in water, 1:2.5 v/v; EC = Electrical Conductivity; Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; Al = aluminum; S = sulfur; CEC = cation exchange capacity, T = CEC total; N = nitrogen; C = carbon; C/N = carbon/nitrogen; OM = organic matter (Walkley-Black method); V = base saturation; m = saturation by aluminum; P-ass = phosphorus assimilable.

Table 2: Results of soil physical properties

Physical	θ_{FC} (100 kPa)	θ_{WP} (1500 kPa)	TP	MICRO	MACRO	δ_{bd}	dp
0_20	--------------------------------------- % ---------------------------------					--------- g cm^{-3} --------	
Result	17.82	7.13	46.81	36.44	10.98	1.93	2.85

Note: θ_{FC} = soil water content at field capacity at 100 kPa; θ_{WP} = soil water content at wilting point at 1500 kPa; TP = total porosity; MICRO = microporosity; MACRO = macroporosity; δ_{bd} = soil bulk density; dp = density of particles.

Paricá (*Schizolobuim amazonicum* Huber ex Ducke) seeds were acquired at the Company Sementes Caiçara Ltda. The seeds passed through the dormancy breaking process by manual scarification method for deterioration of the integument until the appearance of the embryo (Martins *et al.,* 2012). For sowing, polyethylene containers with a capacity of 5.5 L were filled with local soil, they had a spacing of 0.7 m between rows and 0.5 m between plants, three seeds were sown in each container. The fertilization was given as recommended by Vieira *et al.* (2006) with the following amounts: 100 N, 60 P_2O_5 and 25 K_2O mg^{-1} kg^{-1} of soil, in urea formulations (45% N), triple superphosphate (45% P_2O_5) and potassium chloride (60% KCl), respectively. Although liming was not carried out in this experiment, Paricá is adapted for soils under conditions where the pH is more acidic, this is proven in the studies by Carvalho (2007).

Experimental Design

In the experimental design, a completely randomized design (CRD) was used, in a 5 x 2 factorial arrangement consisting of five irrigation depths and two irrigation frequencies (Table 3), with four replications, totaling 40 experimental units. For the determination of water depths corresponding to the readily available soil water (RAW) and the frequency of irrigation, equation 1 was used, which was described by Bernardo *et al.* (2019).

$$\text{RAW} = \frac{\left(\theta_{FC} - \theta_{WP}\right)}{10} * \delta_a * h_R * f \qquad \text{Eq. (1)}$$

Where: RAW= water depth stored in the soil that will be used as a crop supply (mm); θ_{FC} = soil water content at field capacity (100 kPa); θ_{WP} = soil water content at wilting point (1500 kPa); δ_{bd} = soil bulk density; h_R = effective root depth (cm); f = soil water depletion coefficient (dimensionless quantity, 0 < f < 1).

Through the results of soil physical properties, the values of field capacity and wilting point were applied to determine water depths and irrigation frequencies (Table 3). The optimal water depth found was 20.63 mm that corresponds a volume of 725 mL for pot dimensions and 19.5 width and 21.5 height, based on these values, water depths below the field capacity were applied in an interval of 20%. The parameters f and h_R to determine the real water capacity of the soil were 0.5 and 20 cm, respectively. The amount of water of each treatment was applied at once.

Variables analyzed

The biometric variables were analyzed at 30, 60, 90 and 120 days after emergence, in order to monitor the growth and development of seedlings, the procedures performed were: plant height (PH, cm $plant^{-1}$), with the aid of the millimeter ruler, the height of the plant was measured, from which it left the soil surface to the highest part of the plant; number of leaves (NL), was performed by manually counting the number of leaves, considering all the leaves of the plant; and stem diameter (SD, mm $plant^{-1}$), was measured at five centimeters above the substrate level with the aid of a digital caliper (accuracy of 0.05 mm).

Table 3: Amount of water corresponding to RAW (%) and applied to the containers (mL) during the experiment on the irrigation frequencies

Treatments	Irrigation frequencies	RAW	Amount of water
		%	mL
1	Every day	20	145
2	Every day	40	290
3	Every day	60	435
4	Every day	80	580
5	Every day	100	725
6	Every three day	20	145
7	Every three day	40	290
8	Every three day	60	435
9	Every three day	80	580
10	Every three day	100	725

At 120 days after seed emergence, evaluations of the variables related to the production of fresh and dry matter of the seedlings were performed according to their respective treatments. The variables analyzed were: Shoot Fresh Matter (SFM, g plant^{-1}), Roots Fresh Matter (RFMRFM, g plant^{-1}), Root Dry Matter (RDM, g plant^{-1}), Shoot Dry Matter (SDM, g plant^{-1}), Total Fresh Matter (TFM, g plant^{-1}) and Total Dry Matter (TDM, g plant^{-1}).

To determine the SFM, the seedlings were removed from the containers and the aerial parts (stem and leaves) and roots were separated. From this process, the aerial part of the seedlings were weighed individually with the aid of an analytical precision scale (AY- 220, Shimadzu, Kyoto, Japan), accurate to 0.0001 g and accommodated in kraft paper envelopes with identification of their respective treatments.

RFM was obtained from the removal of the aerial part of the seedlings leaving only the roots in the container. Therefore, the substrate that surrounded the roots was removed with running water and with the aid of a sieve, so that the thin roots would not be lost with the action of water. After this process, the roots were dried at ambient temperature and weighed individually with the aid of an analytical precision scale (AY- 220, Shimadzu, Kyoto, Japan) with an accuracy of 0.0001. After weighing, they were accommodated in kraft paper envelopes with identification of their respective treatments.

RDM and SDM were obtained from weighing the fresh mass and wrapped in kraft paper bags, taken to a forced air circulation oven with a temperature of 65 ºC, until reaching constant mass. After this procedure, they were removed and weighed with the aid of an analytical precision scale (AY- 220, Shimadzu, Kyoto, Japan) with an accuracy of 0.0001 g to measure the dry mass.

TFM was the result of the sum between the parameters SFM and RFM, as described in equation 2.

$$TFM = \sum_{i=0}^{n} \mathrm{SFM} + \mathrm{RFM} \qquad \text{Eq. (2)}$$

Similarly, TDM (g plant^{-1}) was obtained by the sum of the parameters RDM and SDM, as described in equation 3.

$$TDM = \sum_{i=0}^{n} \mathrm{RDM} + \mathrm{SDM} \qquad \text{Eq. (3)}$$

In addition, the relationship between Plant Height and Stem diameter (PH:SD) was performed based on the sum of the parameters Plant Height and Stem Diameter, as shown in equation 4.

$$PH:SD = \frac{\sum_{i=0}^{n} \mathrm{PH}}{\sum_{i=0}^{n} \mathrm{SD}} \qquad \text{Eq. (4)}$$

The relationship between SDM/SFM was performed based on the sum of the parameters SDM and SFM, as shown in equation 5.

$$\mathrm{SDM:SFM} = \frac{\sum_{i=0}^{n} \mathrm{SDM}}{\sum_{i=0}^{n} \mathrm{SFM}} \qquad \text{Eq. (5)}$$

Lastly, the Dickson quality index – DQI was estimated by Dickson *et al.* (1960).

$$DQI = \frac{\text{Seedling Total Dry Matter}(g)}{\frac{\text{Plant Height}(cm)}{\text{Stem Diameter}(mm)} + \frac{\text{Shoot Dry Matter}(g)}{\text{Root dry matter}(g)}} \qquad \text{Eq. (6)}$$

The DQI was applied as an indicator to evaluate the quality of seedlings, as its interpretation is considered reliable, and to assess the balance of biomass distribution in the seedling, combining growth and biometric variables (Bantis *et al., 2021*).

Analytical Procedures

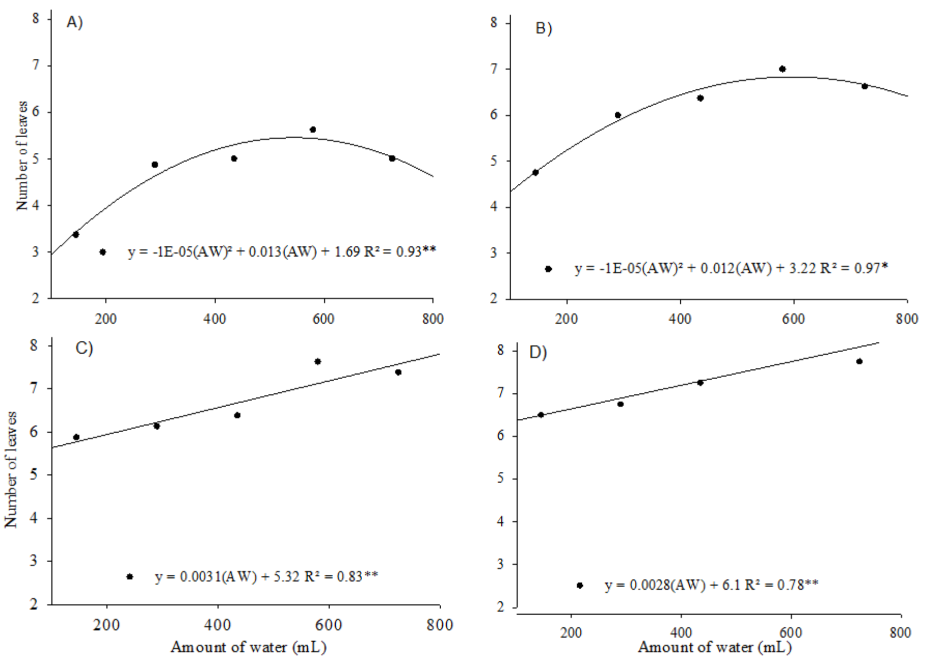
All experimental data were analyzed using the Anderson & Darling (1952) and Bartlett (1937) ($p > 0.05$) test, to verify normality and homoscedasticity, respectively. The data that did not meet the assumptions were transformed using the Box & Cox (1964) test by log-Likelihood modeling. Given the basic assumptions, the dataset was analyzed by variance using Fisher's test – Snedecor ($p < 0.05$). The variables that showed interactions were all submitted to simple regression analysis with factor A (water depths) inside factor B (irrigation frequency) to find the best model. For variables that showed no interaction, they were evaluated separately according to each treatment. Then they were separated in quantitative treatments (water depths), applying simple regression analysis, and in qualitative treatments (irrigation frequency), evaluated by the average test (t student). Both tests were evaluated considering the probability of error in ($p < 0.05$). Subsequently, Pearson correlation was applied to assess the most influential variable in Dickson quality index. Data analyzes were aided by R Core Development Team software (2021).

RESULTS AND DISCUSSION

The variables PH at 60 and 120 days after sowing (DAS), SD at 60, 90 and 120 DAS, TFM, TDM, SDM, RFM, and DQI showed significant interaction ($p \leq 0.05$) due to irrigation frequencies and water depths (Table 4). However, PH at 30 and 90 DAS, NL at 30, 60, 90 and 120 DAS, SFM and RDM showed a statistical difference between causes of variation, but there was no interaction between irrigation frequency x water depth. In addition, there was no statistical difference for SD at 30 DAS, and there were no statistical differences between PH/SD, and SDM/SFM (Table 4).

It was verified through the coefficient of variation (CV) that the variables analyzed presented CVs that ranged from medium ($10\% < CV \leq 20\%$) to very high ($> 30\%$), according to Pimentel-Gomes (2009). And the biomass variables (TFM, TDM, SFM, SDM, RFM, RDM, SDM:SFM) were those with the highest CV ($> 30\%$) (Table 4).

The number of leaves at 30 and 60 DAS showed polynomial adjustment of the second degree with $R^2 = 0.93$ and $R^2 = 0.9$, respectively. However, at 90 and 120 DAS, the variable behaved linearly with $R^2 = 0.83$ and 0.78, respectively (Figure 2).



**Significant at the 0.01 probability.

*Significant at the 0.05 probability e NS, not significant.

Figure 2: Number of leaves at 30 (A), 60 (B), 90 (C) and 120 (D) days after sowing (DAS) of Paricá seedlings submitted to different amount of water.

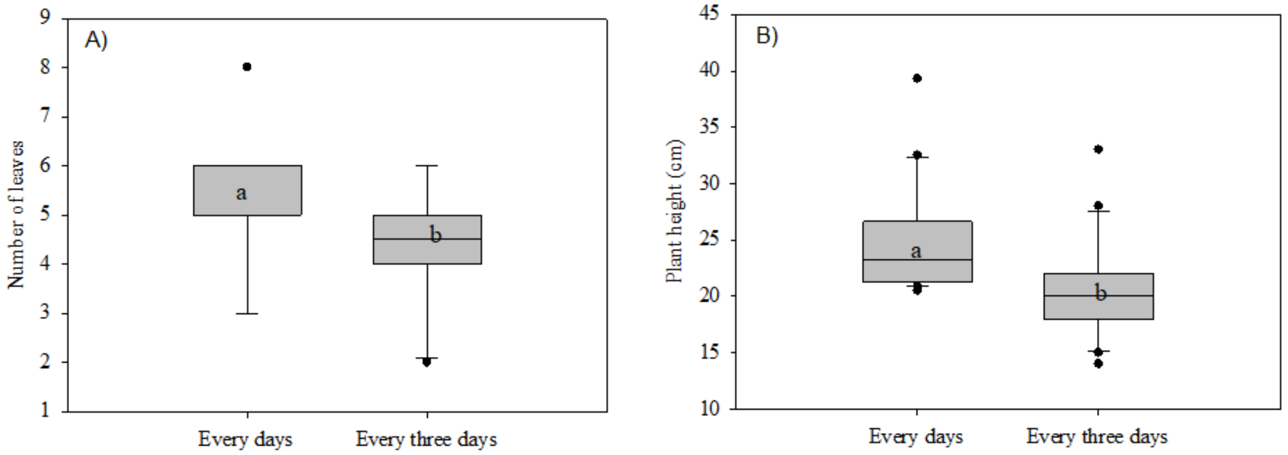
Table 4: Summary of variance analysis for Plant Height at 30 (PH30DAS), 60 (PH60DAS), 90 (PH90DAS) and 120 days after sowing (PH120DAS), Number of Leaves at 30 (NL30DAS), 60 (NL60DAS), 90 (NL90DAS) and 120 days after sowing (NL120DAS), Stem Diameter at 30 (SD30DAS), 60 (SD60DAS), 90 (SD90DAS) and 120 days after sowing (SD120DAS), Total Fresh Matter (TFM), Total Dry Matter (TDM), Shoot Fresh Matter (SFM), Shoot Dry Matter (SDM), Roots fresh matter (RFM), Root dry matter (RDM), Stem Diameter/Plant Height (SD:PH), Shoot Dry Matter/Shoot Fresh Matter (SDM:SFM) and Dickson quality index (DQI), submitted to different Irrigation Frequencies (IF) and Amount of Water (AW)

Variables	IF	AW	IF X AW	CV (%)
PH30DAS	192.28**	39.48^{ns}	17.31^{ns}	19.07
PH60DAS	11.55^{ns}	121.82**	102.19*	21.8
PH90DAS	12.25^{ns}	215.10**	87.52^{ns}	19.95
PH120DAS	110.72^{ns}	398.16**	284.01*	22.67
NL30DAS	4.22*	5.58**	1.28^{ns}	19.96
NL60DAS	0.40^{ns}	5.96**	2.33^{ns}	17.69
NL90DAS	1.22^{ns}	4.85*	2.85^{ns}	20.6
NL120DAS	2.50^{ns}	4.10*	3.25^{ns}	16.3
SD30DAS	0.00^{ns}	0.467^{ns}	0.143^{ns}	12.73
SD60DAS	2.37*	3.48**	1.43*	13.44
SD90DAS	1.68^{ns}	10.58**	6.78**	12.7
SD120DAS	4.00^{ns}	20.60**	11.78**	15.24
TFM	1753.37**	881.80**	440.83*	32.76
TDM	435.79*	645.51**	311.62**	32.57
SFM	378.22*	374.48**	205.55^{ns}	43.98
SDM	111.48^{ns}	253.72**	183.97*	41.82
RFM	502.89**	114.50**	66.06*	35.12
RDM	106.43**	94.35**	29.32^{ns}	35.06
SD/PH	0.00^{ns}	0.0002^{ns}	0.00^{ns}	1.98^{Ŧ}
SDM/SFM	0.41^{ns}	0.26^{ns}	0.04^{ns}	54.71^{Ŧ}
DQI	15.40*	20.54**	8.61*	33.52

**Significant at the 0.01 probability.
*Significant at the 0.05 probability e NS, not significant, by the F-test. NS, not significant (p > 0.05) by the F-test. CV (%): Coefficient of variation.
ŦData processed using the Box-Cox.

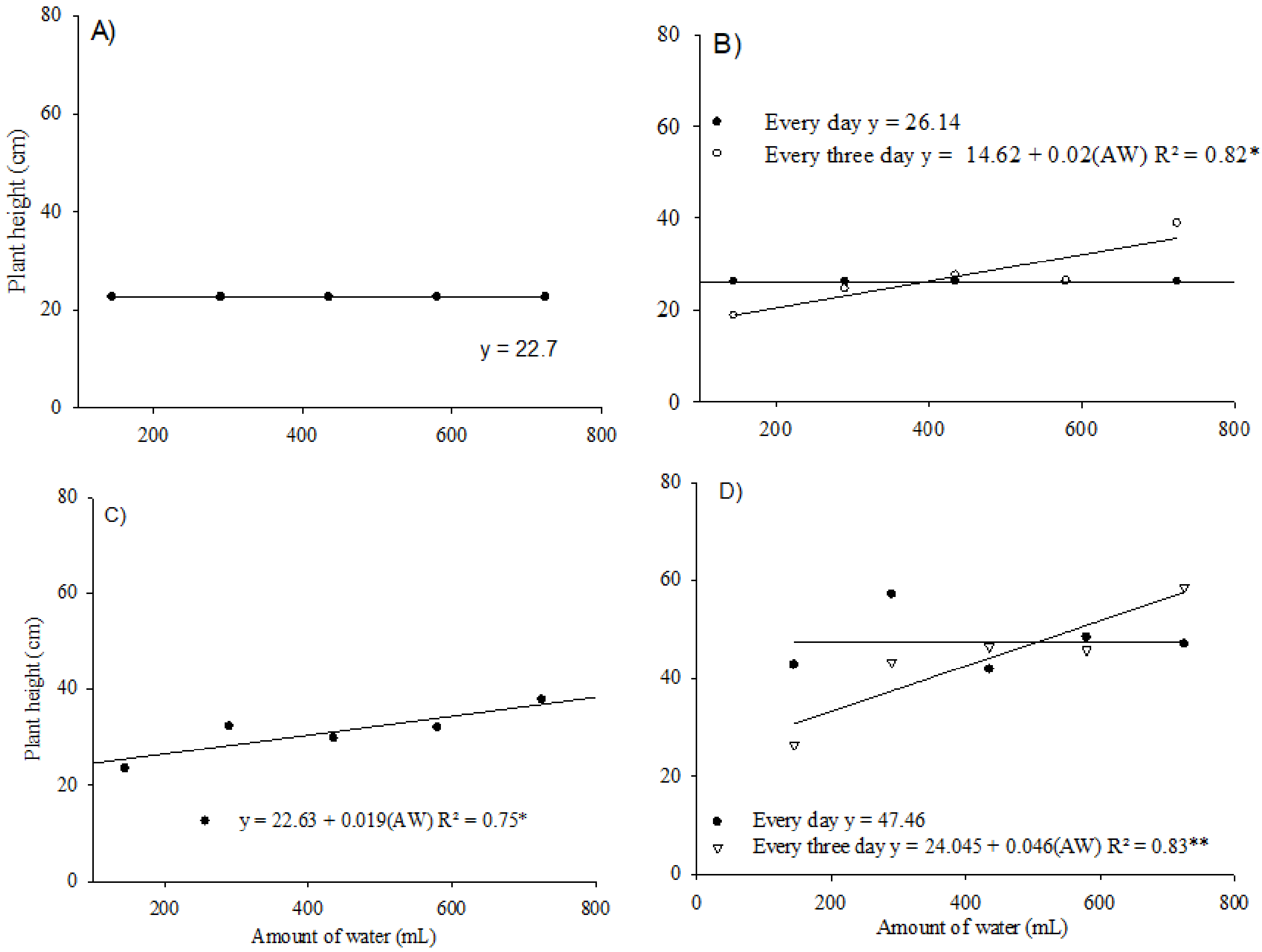
It is important to highlight that both variables only showed statistical difference at 30 DAS, and daily irrigations (every day) were the ones that showed better responses in leaf production. In the leaf count, plants with eight leaves were observed at 30 DAS, the maximum value observed for this period. However, at 120 DAS, the number of leaves increased to 10 for seedlings irrigated daily, with a growth rate of 3.3% (Figure 3).

The PH and SD were not affected by the irrigation depths at 30 DAS. However, at 60, 90 and 120 DAS there was an interaction for SD with linear growth for seedlings irrigated every three days, the coefficient of determination (R^2) was 0.97, 0.92 and 0.94, respectively. For seedlings irrigated daily, adjustment of mathematical models was not possible (Figures 4 and 5). For PH, there was interaction at 60 and 120 DAS with the linear behavior for seedlings irrigated every three days, whereas for seedlings irrigated daily, it was not possible to find an adjustment of mathematical models. At 90 DAS there was no interaction, but it was possible to adjust a linear model (Figure 5B). Both variables showed an average growth of 5.0 and 29.0% for SD and PH, respectively. It is important to note that a maximum diameter of 12.3 mm was observed for seedlings when irrigated every three days, and for PH it was 77.2 cm when irrigated every day.



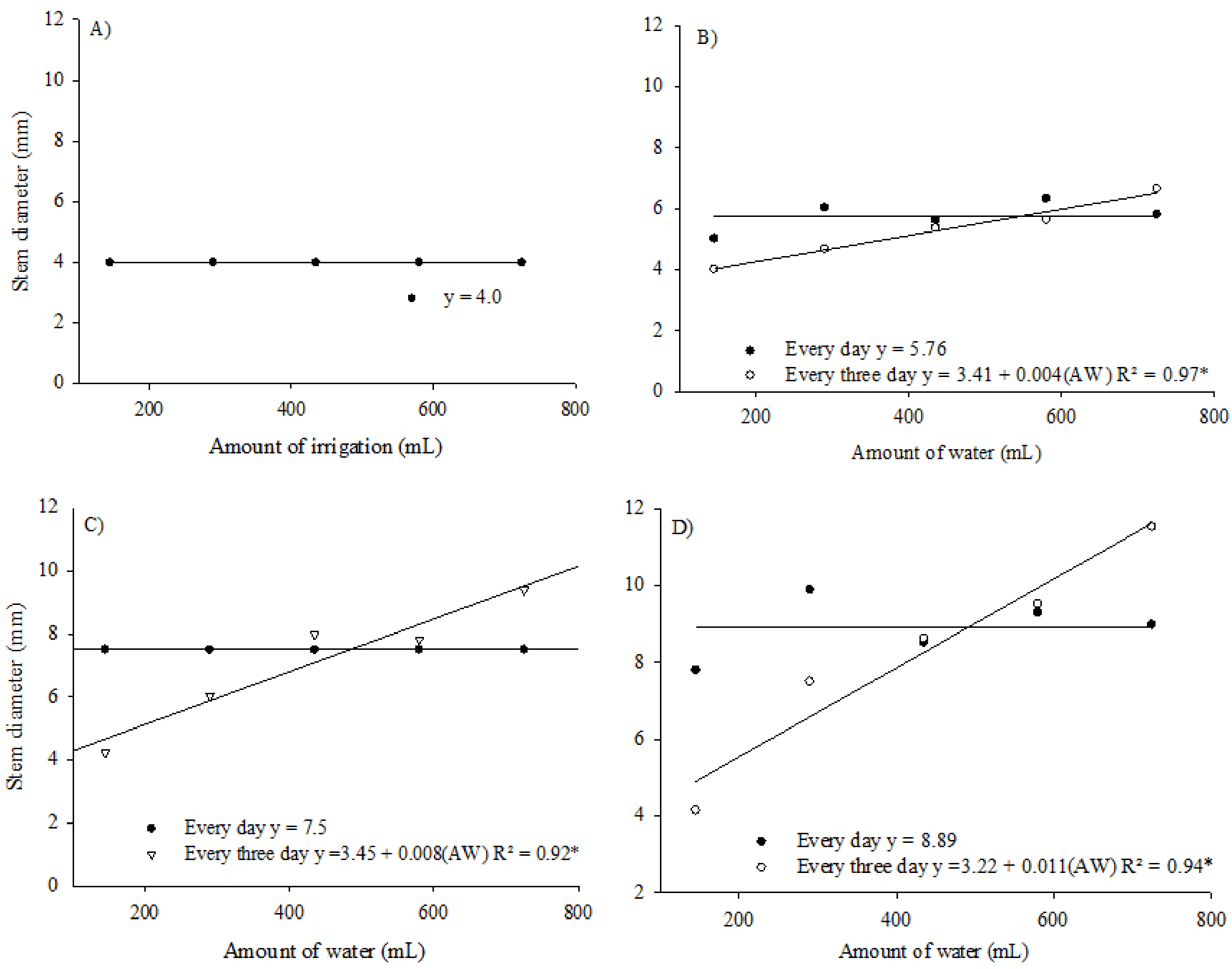
*Average followed by distinct letters differs in the column (lowercase) by the t student test at 5% probability.

Figure 3: Number of leaves and plant height 30 days after sowing (DAS) of Paricá seedlings submitted to different irrigation frequencies.



*Significant at the 0.01 probability.
*Significant at the 0.05 probability e NS, not significant.

Figure 4: Plant height at 30, 60, 90 and 120 days after sowing (DAS) of Paricá seedlings submitted to different frequencies and amounts of water.



**Significant at the 0.01 probability.

*Significant at the 0.05 probability e NS, not significant.

Figure 5: Stem diameter at 30 (A), 60 (B), 90 (C) and 120 (D) days after sowing (DAS) due to different frequencies and amounts of water.

The NL, PH and SD were influenced by water management, mainly after 60 DAS. In addition, it can be noted that the seedlings produced with water volumes below 40% (WBC < 40%) showed a reduction in the production of biometric parameters, in some cases the effects were severe to the loss of leaves as a strategy for survival, since the water supply was lower than what was required by the plant. Facts that are directly related to the functions performed by water in the biochemical and physiological activity of vegetables, such as the transport of mineral salts (Rhythm *et al.,* 2022), leaf turgor and in photosynthesis (Ahmad *et al.,* 2016), which can result in the irreversibility of physiological dysfunction (Shao *et al.,* 2022).

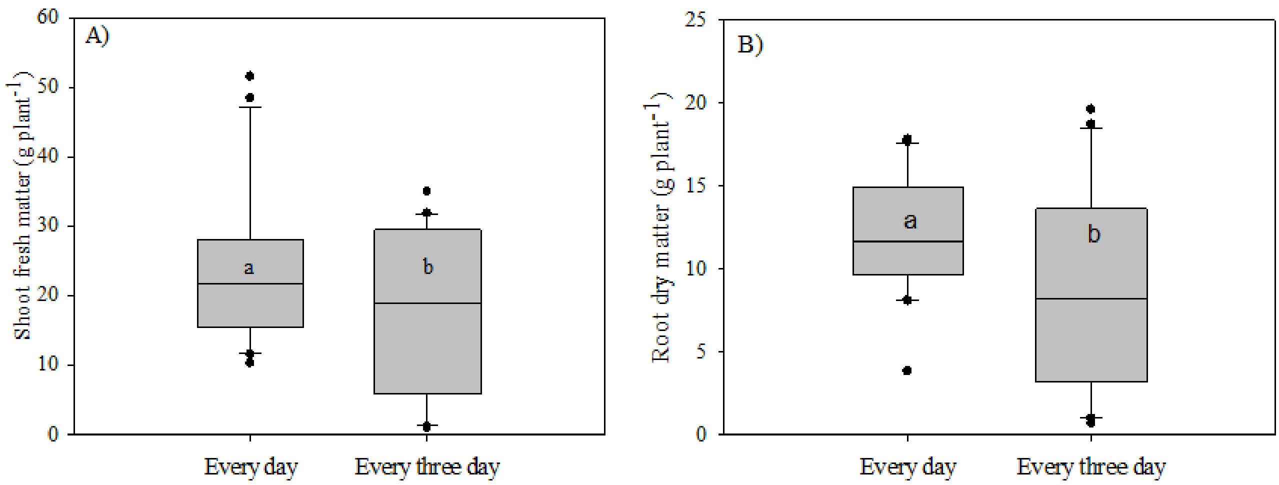
In addition, when the seedlings are under water stress, there is a reduction in the production and storage of carbohydrates (White *et al.,* 2016), a decrease in cell turgor and a lower evapotranspiration rate (Taiz *et al.,* 2017) which impairs the development of the leaf area and, consequently, affects the production and translocation of photoassimilates for the emission of new leaves (Ju *et al.,* 2018). Plants adopt internal regulation as a strategy to reduce the losses of water stress in their development through the accumulation of abscisic acid, which induces stomatal closure, resulting in water retention to delay stress (Xoconostle-Cazares *et al.,* 2010).

Nascimento *et al.* (2011) observed a negative effect of water stress on the biometric parameters (SD and PH) of *Hymenaea courbaril* L, when the depths were applied at

25% of field capacity. According to Silva *et al.* (2016), the irrigation depths influenced all the morphological parameters of the jatobazeiro (*Hymenaea courbaril* L.) seedlings (four evaluations of height of seedlings, SD and NL, leaf area, RDM, of seedlings), regardless of age.

Biometric variables showed linear behavior as WBC increased, and irrigations performed every three days showed satisfactory development. It is important to highlight that in all evaluated periods, the morphological variables such as PH, NL and SD showed better responses when the seedlings were irrigated with WBC < 60% (< 580 mL). In the comparison of average (Student's t test) for the NL and PH in relation to the irrigation frequencies, they showed higher gains when irrigated daily (every day), this represented 6.80% (0.65 leaves plant^{-1}) and 9.64% (4.38 cm) for the NL and PH, respectively. In the last evaluation period (120DAS) the seedlings irrigated every day and every three days showed an average PH of 47.46 and 44.13 cm, respectively. Although the daily irrigation is superior to the irrigation every three days, this corresponded to only 3.14% (3.33 g) in higher gain with the daily watering. In this way, it would not be advantageous for the producer to carry out daily irrigation because the expenses will be higher and, undoubtedly, the irrigation in the interval of three days will represent a lower cost for the production, due to the savings in energy, labor and time. Also, the reduction in water consumption.

SFM and RDM, it was possible to observe that daily irrigation provided better biomass production, this behavior was also observed for number of leaves and plant height. The maximum accumulation of shoot fresh matter was 51.56 g plant^{-1}, when irrigated daily, and for root dry matter, it was 19.61 g plant^{-1}, when irrigated every three days (Figure 6A and B).

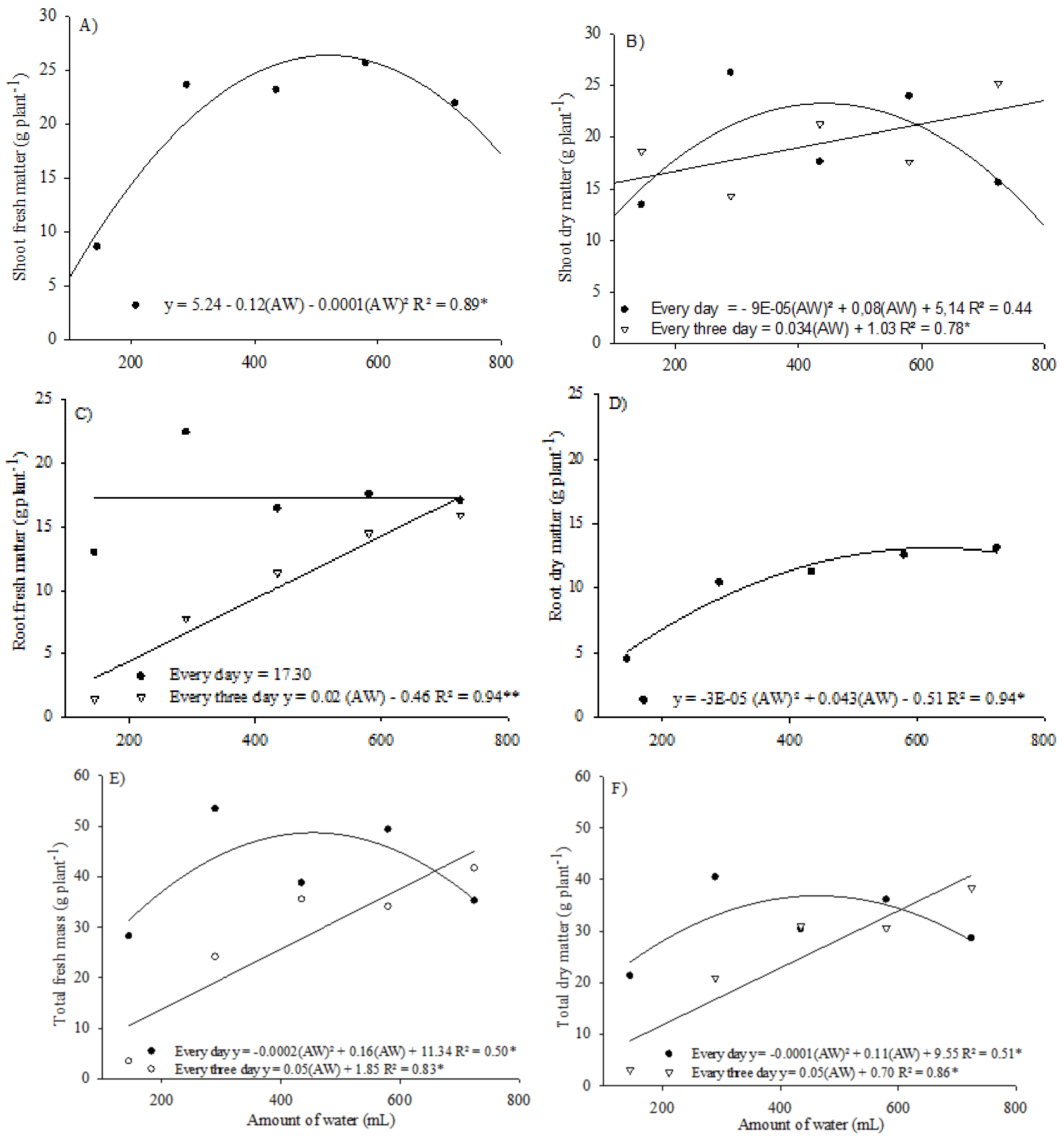


*Average followed by distinct letters differs in the column (lowercase) by the t student test at 5% probability.

Figure 6: Shoot fresh matter (A) e root dry matter (B) of Paricá seedlings submitted to different Irrigation frequencies and amount of irrigation.

For SFM, interaction between water depth and irrigation frequency can be verified, where the every day frequency showed polynomial regression of the second degree, with $R^2 = 0.44$ (Figure 7A and B). The SFM production showed a linear growth adjustment when the seedlings were irrigated every three days, while the seedlings submitted to daily irrigation frequency showed a constant value with an average fresh mass of 17.30 (g plant^{-1}) (Figure 7C). Regarding the RDM, there was a significant response only with the different irrigation depths, with quadratic adjustment with $R^2 = 0.94$ (Figure 7D).

For TFM and TDM, polynomial behavior of the second degree can be observed for seedlings irrigated daily and linear behavior when irrigated every three days. Despite this behavior with a bell-shaped tendency for daily irrigated seedlings, its coefficient of determination was low: $R^2 = 0.50$ for TFM and $R^2 = 0.51$ for dry matter. It is important to highlight that seedlings irrigated every three days showed a linear trend (Figure 7E). Regarding the accumulation of total dry biomass, a quadratic model was found for daily irrigation, in which a total fresh matter accumulation of 45.2 g plant^{-1} with a 411.5 mL depth was obtained, and when the water quantity was increased, the reduction in the accumulation of the TFM content was shown (Figure 7F).



**Significant at the 0.01 probability.
*Significant at the 0.05 probability e NS, not significant.

Figure 7: Shoot fresh matter (A), shoot dry matter (B), roots fresh matter (C), root dry matter (D), total dry matter (E) and total fresh matter (F), submitted to different Irrigation frequencies and amounts of water.

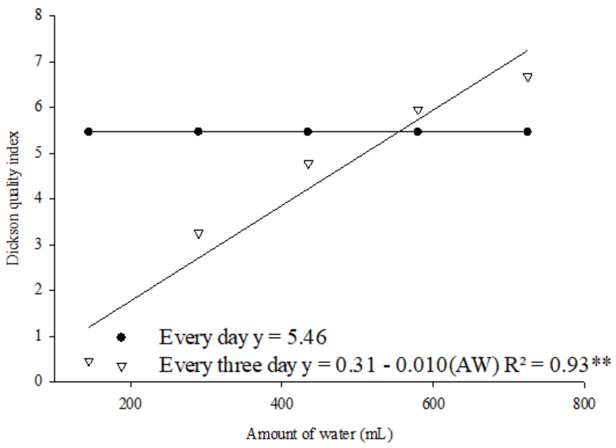
The results indicated that the maximum accumulation of SFM was 51.56 g when the seedling was irrigated daily, however the average of this variable was 23.71 g plant^{-1}, this represented 14.90% more in biomass production when compared seedlings irrigated every three days. The best production of root biomass was obtained when irrigated daily, this production was 15.70% (3.26 g) more than seedlings irrigated every three days (Figure 6A and B). The results obtained from the number of leaves and plant height corroborate with the results of SFM, considering that both variables showed better results when irrigated every day (Figure 3A and B). The dry matter production of the crops is influenced by the availability of water, especially if this water quantity represents physiological stress for the crop (Alves *et al.,* 2018). Dry matter is the most sensitive variable to water deficiency, and results observed by Nascimento *et al.* (2011) showed that irrigation depths when applied below 50% of field capacity restricted the growth of *Hymenaea couribaril*.

TFM production showed better results when water was supplied every day. According to the statements in the studies by Furtak & Nosalewicz (2022), the growth and production of phytomass are directly influenced by water availability. In addition, Taiz *et al.* (2017) clarified that the greatest production of aerial biomass occurs because water is part of the photosynthetic processes to produce photoassimilates, which consequently will provide the largest accumulation of photoassimilates in the aerial part of the seedlings. Dutra *et al.* (2018) concluded that the largest accumulations of leaf area were when the seedlings had irrigation. Silva & Silva (2015) obtained better responses in the production of *Aspidosperma polyneuron* seedlings when four daily irrigations were applied.

The seedlings irrigated every three days showed linear behavior for SDM, RFM, TFM and TDM (Figure 7B, C, E and F), in which they presented $R^2 \leq 0.78$. Thus, it is possible to observe that the seedlings irrigated daily obtained polynomial behavior of the second degree, however the coefficient of determination was lower ($R^2 \leq 0.51$), which means that the water depths showed low dependence due to the response variable (Figure 7B, E and F). It was not possible to obtain a model adjustment for RFM when the seedlings were irrigated daily, so the variable remained constant according to the water depths (Figure 7C).

The frequency of irrigation every three days significantly affected in DQI where the linear model showed the best fit, and the frequency of daily irrigation presented constant response (Figure 8). Through the notes made during the experiment, a DQI of 7.1 was observed for irrigated seedling every three days and 100% water depth (725 mL).

To analyze the biggest influences in the DQI, Pearson linear correlation analysis was applied between the variables that are part of the measurement of this index. Therefore, it can be observed that the relationship between PH:SD was the only variable that showed a significant correlation with a negative trend, which means that the lower the height / diameter ratio, the higher DQI Paricá seedlings (Table 5). TDM, SDM, SD and SDM:RDM showed a negative trend, however, they were not significant ($p > 0.05$). RDM and PH showed a positive linear correlation, however, with a low intensity and were not significant ($p > 0.05$).



**Significant at the 0.01 probability.
*Significant at the 0.05probability e NS, not significant.

Figure 8: Dickson quality index (DQI) submitted to different Irrigation frequencies and amounts of water.

Table 5: Pearson linear correlation between variables to obtain the Dickson quality index (DQI).

Variables	DQI
TDM	-0.04^{ns}
SDM	-0.13^{ns}
RDM	0.12^{ns}
SD	-0.03^{ns}
PH	0.02^{ns}
PH:SD	-0.60**
SDM:RDM	-0.01^{ns}

** Significant at the 0.01 probability ($p < 0.01$),
* Significant at the 0.05 probability ($0.01 \leq p \leq 0.05$) e NS, not significant ($p > 0.05$).

The DQI is an important morphological measure that is based on a combination of seedling height and diameter seem to offer a good guide to seedling morphological quality, they are the most common measures used for growth and classification patterns in forest nurseries (Pimentel *et al.,* 2021). These parameters associated with the production of phytomass (shoot dry and fresh matter and root) help to model the DQI, an important variable to evaluate the qualities of forest seedlings and it has been applied in several studies as a classifier of the quality of seedlings that are destined to the field. Santos *et al.* (2020) evaluated *Handroanthus serratifolius* forest seedlings, Posse *et al.* (2018) analyzed passion fruit (*Passiflora edulis Sims*) seedlings, and they observed DQI below one, Wang *et al.* (2019) *Cinnamomum burmanni* seedlings.

The phytomass balance that associates the biometric and mass parameters validates the robustness of the DQI, in which it is directly related to the development of the plant. Therefore, it was observed that the treatments with water depths that presented WBC < 40% with irrigation every three days, presented serious limitations in height and leaf area throughout the experiment, in addition to tendencies of withering of the seedlings. It is worth mentioning that the depths with WBC > 40% are the most suitable to produce Paricá seedlings with irrigation every three days.

CONCLUSION

There was a significant effect of water depths and irrigation frequency in the production of Paricá (*Schizolobium amazonicum* Huber ex Ducke) seedlings for the analyzed variables. The seedlings irrigated every three days showed better IDQ with the water depth 725 mL dm^{-3}. However, it was observed that the water depths 290; 435 and 580 mL dm^{-3} showed excellent results.

Regarding the rational use of water, producers may use amount of water corresponds to 100% of RAW at 3-day frequency (725 mL), given that it has resulted in a high DQI and provides savings of 580 mL compared to the best water depth on the daily scale (435 mL).

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