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TECHNICAL NOTE

IRRIGATION FREQUENCIES FOR *Eucalyptus grandis* SEEDLINGS

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ABSTRACT

One of the bottlenecks in relation to the production of forest seedlings is irrigation, especially in lower-tech nurseries. The small volumes of substrate, where the seedlings develop, lead to low water storage. This can cause water deficit and significant losses in seedlings production, even leading to plant mortality. The objective of this study was to determine the best irrigation frequencies for *Eucalyptus grandis* seedling production in lower-tech nurseries. The experiment was conducted between 04/08/2013 and 07/23/2013 (106 days) in Chapadão do Sul, Mato Grosso do Sul, Brazil. The experiment was installed in a split plot scheme, with the irrigation frequencies in the plots and seven evaluations (15, 30, 45, 61, 76, 91 and 106 days after sowing) in the subplots, in a randomized complete block design, with five replicates. Four irrigation frequencies were tested: IF1 (one daily irrigation - 11:00 a.m.), IF2 (two daily irrigations - 11:00 a.m. and 7:00 p.m.), IF3 (three daily irrigations - 07:00 a.m., 11:00 a.m. and 7:00 p.m.) and IF4 (four daily irrigations - 07:00 a.m., 11:00 a.m., 3:00 p.m. and 7:00 p.m.). The sample units were composed of eight seedlings in 50 cm^3 containers with conical shape, filled with soil and vermiculite in a volume ratio of 1:1. The irrigation depth was estimated by reference evapotranspiration (Penman-Monteith) multiplied by a crop coefficient equal to two. Plant height, number of true leaves, shoot dry mass, root dry mass, total dry mass, seedling quality index, survival and water use efficiency of *Eucalyptus grandis* seedlings were evaluated. The average daily irrigation depth in the experimental period was 5.2 mm. Based on the results, for *Eucalyptus grandis* seedling producers, in lower-tech nursery, irrigation management with twice-a-day frequency (11:00 a.m. and 7:00 p.m.) is recommended.

Palavras-chave:
Evapotranspiração
silvicultura
índice de qualidade de Dickson
eficiência no uso da água

FREQUÊNCIAS DE IRRIGAÇÃO PARA MUDAS DE *Eucalyptus grandis*

RESUMO

Um dos gargalos em relação à produção de mudas florestais é a irrigação, principalmente em viveiros menos tecnificados. Os pequenos volumes de substrato, onde as mudas desenvolvem, acarretam baixo armazenamento de água. Esse fato pode acarretar déficit hídrico e perdas significativas na produção de mudas, gerando inclusive mortandade. Diante disso, objetivou-se com este estudo determinar as melhores frequências de irrigação para a produção de mudas de *Eucalyptus grandis* em viveiros de menor tecnologia. O experimento foi conduzido entre 08/04/2013 e 23/07/2013 (106 dias) e realizado no município de Chapadão do Sul, Brasil. O experimento foi montado em esquema de parcelas subdivididas, tendo nas parcelas as frequências de irrigação e nas subparcelas sete avaliações (15, 30, 45, 61, 76, 91 e 106 dias após semeadura), no delineamento de blocos ao acaso, com cinco repetições. Foram testadas quatro frequências de irrigação: IF1 (uma irrigação diária - 11:00), IF2 (duas irrigações diárias - 11:00 e 19:00), IF3 (três irrigações diárias - 07:00, 11:00) e 19:00) e IF4 (quatro irrigações diárias - 07:00, 11:00, 15:00 e 19:00). As unidades amostrais foram compostas por oito mudas em tubos cônicos de 50 cm^3 preenchidos com solo e vermiculita na proporção de volume de 1:1. A lâmina de irrigação foi estimada por evapotranspiração de referência (Penman-Monteith) multiplicada por um coeficiente de cultivo igual a dois. Foram avaliados a altura da planta, número de folhas definitivas, massa seca da parte aérea (raiz e total), índice de qualidade das sementes, sobrevivência e eficiência do uso da água pelas mudas de *Eucalyptus grandis*. A lâmina média de irrigação diária no período experimental foi de 5,2 mm. Com base nos resultados, é recomendado para produtores de mudas de *Eucalyptus grandis*, em viveiros de menor tecnologia, o manejo da irrigação duas vezes por dia. (11:00 e 19:00).

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INTRODUCTION

The Brazilian sector of cultivated forests accounts for 91% of all the wood produced for national industrial purposes in the country, with the remaining 9% coming from legally managed native forests. Cultivated forests occupy an area of 7.74 million hectares, which corresponds to 0.9% of the Brazilian territory. Among the most cultivated forest species in Brazil, *Eucalyptus genus* stands out, with a planted area in the year 2015 of 5.56 million hectares, representing 71.9% of the total cultivated area (FELIPPE *et al*., 2016).

Success in the formation of high productivity forests to produce suitable material for industrial purposes depends to a large extent on seedling quality (EHLERS; ARRUDA, 2014; KRATZ; WENDLING, 2016). For this, seedlings need to receive an adequate water supply, applied at the right moment and in the correct quantity (RUBILAR *et al*., 2017; YU *et al*., 2019). According to information collected by Silva *et al*. (2015), in eucalyptus seedling production nurseries in Brazil, the irrigation depth applied at this stage ranges from 4 to 16 mm day^{-1}. According to the authors, this large variation in water replacement is due to the great diversity of Brazilian climatic conditions, also agreeing with Quitaiski *et al*. (2018). In addition, the lack of technical knowledge and the use of technology contribute to this great variation (VIEIRA *et al*., 2011; BERNARDINO *et al*., 2019). With this pointed out, the use of a general recommendation may lead to a deficit or excess application of water in eucalyptus seedlings.

The irrigation depth applied should vary according to the conditions of the weather, crop, soil (or substrate) and irrigation performance. According to Tatagiba *et al*. (2015), in most commercial nurseries, irrigation management is carried out subjectively, with decision based on visual observations of the leaves' turgidity state.

Thus, in most cases irrigation is carried out with high frequency and with higher water volume required by plants, which leads to waste of water (FREITAG *et al*., 2012). In addition, water excess can cause loss of seedlings due to hypoxia (MEDINA *et al*., 2019) or to diseases, causing curling and leaf chlorosis and negative geotropism of the roots (SILVA *et al*., 2015). Another important factor to consider is that excess water can cause the leaching of the nutrients present in the substrate, negatively influencing the development of the seedlings, besides providing a microclimate favorable to the development of diseases (FREITAG *et al*., 2012; QUEIROZ *et al*., 2017).

The lack of water can lead to water stress and lower absorption of nutrients by plants. Moreover, the scarcity of water resources dramatically affects plant metabolism, inducing stomatal closure to avoid the loss of water by transpiration, which causes reduction in the photosynthetic activity and a series of other processes in the plants (SILVA *et al*., 2015; MARTINS *et al*., 2018).

It is worth pointing out that these errors in irrigation management in forest plantations, in both cases, are potentialized in lower-tech nurseries, which causes irrigation frequency in these environments to be planned with special attention. The small volumes of substrate, where the seedlings develop, have low water storage (TATAGIBA *et al*., 2015). Consequently, low irrigation frequencies can lead to water deficit and significant losses in the production of forest seedlings, even leading to mortality. In contrast, the use of higher irrigation frequencies means a higher operation cost. Therefore, research is needed to identify the best irrigation frequencies and schedules to guarantee better-quality forest seedlings in lower-tech nurseries. With this, the aim was to determine the best irrigation frequency for production of eucalyptus seedlings in lower-tech nurseries.

MATERIAL AND METHODS

The experiment was conducted between April 8 and July 23, 2013 (106 days) in an experimental area of Federal University of Mato Grosso do Sul, in the municipality of Chapadão do Sul, MS, Brazil. The experimental area is located at 18°46'24"S, 52°37'25"W, Datum WGS-84, at an altitude of 820 m above sea level (Figure 1).

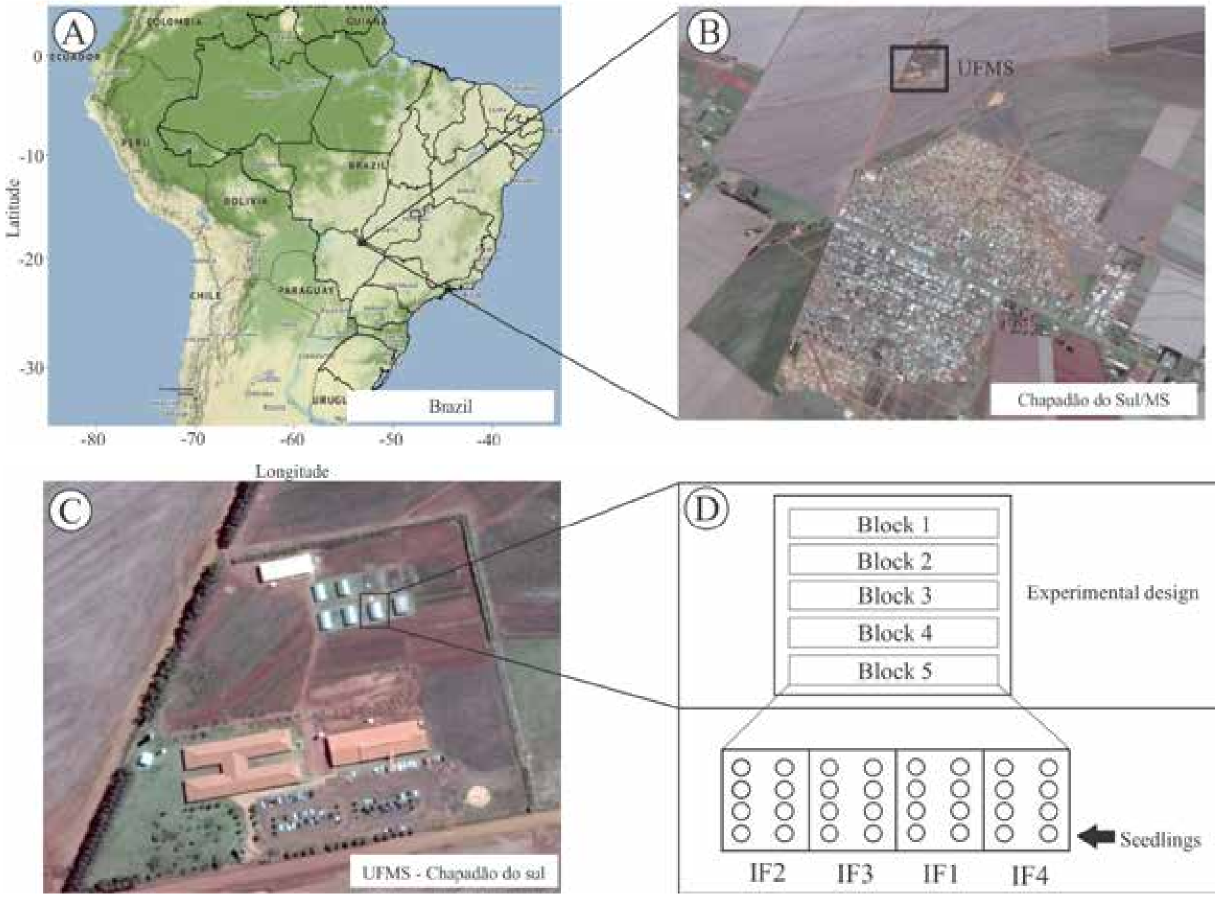


Figure 1. Geographic location of the State of Mato Grosso do Sul in relation to Brazil (A), Municipality of Chapadão do Sul-MS (B), Campus of the Federal University of Mato Grosso do Sul (C) and the sketch of the experimental area with the imposed treatments (D)

The climate is classified as tropical humid (Aw), with well-defined seasons, rainy summer and dry winter, with air temperature ranging from 13 °C to 28 °C and average annual relative humidity of 64.8% (CASTRO *et al*., 2012). The variation in meteorological elements occurred during the experimental period is presented in Figure 2.

The species used in the experiment was *Eucalyptus grandis*. Eucalyptus sowing was performed in tubes that received soil and vermiculite substrate at 1:1 ratio. The containers were manually filled uniformly and placed in suspended trays and maintained in a nursery covered by 50% shading polypropylene net, following Dutra *et al*. (2015) recommendations. The container type used had conical shape, with 50 cm^3 capacity to insert the substrate, with available water retention capacity of 50% of the total volume.

In general, the experiment was set up in a randomized block design (RBD), with five replicates - blocks (Figure 1D), and each sample unit was constituted by eight seedlings. Four irrigation frequencies (treatments) were tested: IF1 (one daily irrigation - 11:00 a.m.), IF2 (two daily irrigations - 11:00 a.m. and 7:00 p.m.), IF3 (three daily irrigations - 07:00 a.m., 11:00 a.m. and 7:00 p.m.) and IF4 (four daily irrigations - 07:00 a.m., 11:00 a.m., 3:00 p.m. and 7:00 p.m.).

The daily amount of water applied to IF1 corresponded to 200% of the reference evapotranspiration (ETo) that occurred on the previous day, i.e., a crop coefficient (Kc) equal to two according to Rodrigues *et al*. (2011) and Silveira *et al*. (2012). It is worth mentioning that water loss due to drainage may have occurred in treatments with lower irrigation frequencies. However, this value was not quantified due to the impossibility of separating this water from that drained in the leaves and sides of the tubes. This value so much higher than ETo is to compensate for the bouquet and oasis effects existing in tubes. The applied water amounts in other treatments were fractionated according to the number of daily irrigations. The irrigations were done manually

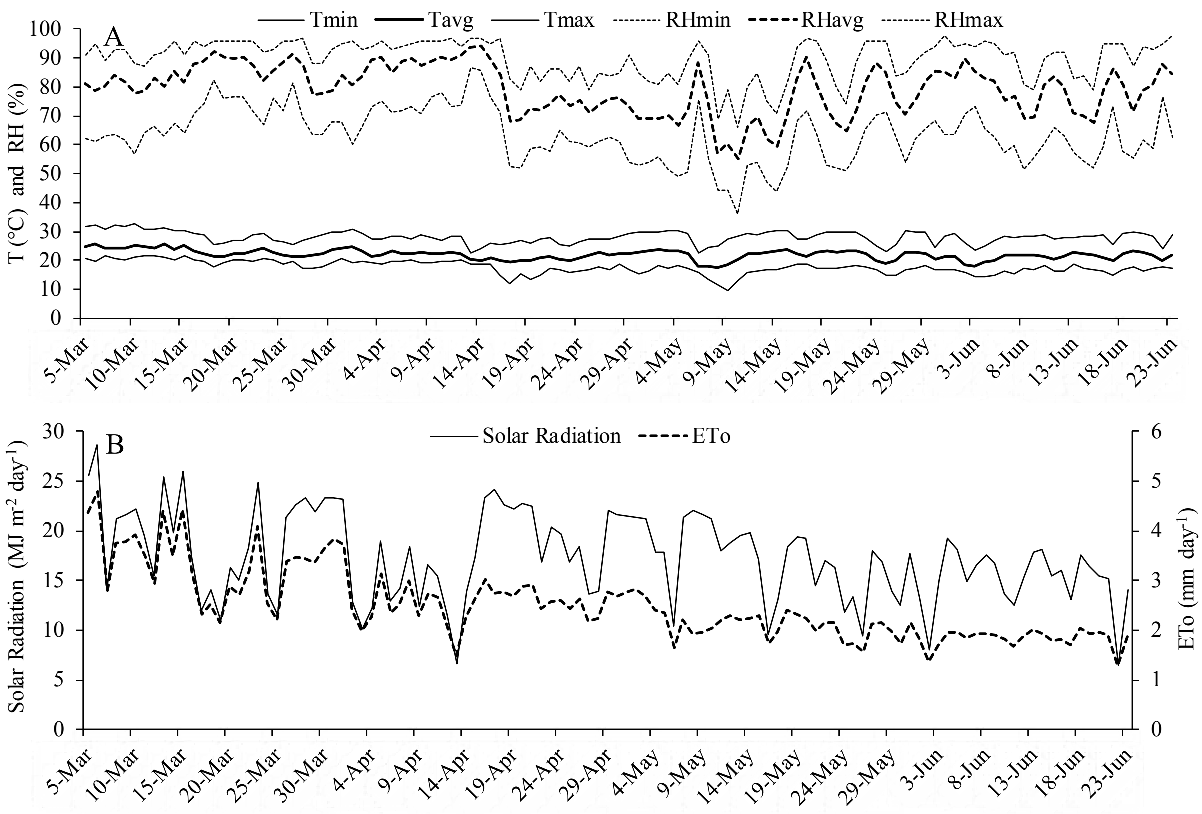


Figure 2. Daily variation of (A) minimum (Tmin), average (Tavg) and maximum (Tmax) air temperature; minimum (RHmin), mean (RHavg) and maximum (RHmax) relative humidity; (B) solar radiation and reference evapotranspiration (ETo) during the experimental period

with watering cans, which were filled with volumes measured with test tubes.

We used the Penman-Monteith model (ALLEN *et al*., 1998) to calculate the ETo (Equation 1). The data to calculate the ETo were extracted from an automatic and complete weather station. The weather station belongs to the National Meteorological Institute of Brazil (INMET) and has the code OMM 86772. In relation to the experimental area, the weather station was installed at vertical and horizontal distances of 1 m and 2.3 km, respectively.

$$ETo = \frac{0.408\, s\,(R_N - G) + \gamma \frac{900}{t + 273} U_2 \frac{(e_s - e_a)}{10}}{s + \gamma\,(1 + 0.34\, U_2)} \qquad (1)$$

where,

ETo = reference evapotranspiration (mm day^{-1});
s = slope of the saturation vapor pressure curve (kPa $ºC^{-1}$);
R_N = net radiation (MJ m^{-2} day^{-1});
G = soil heat flux (MJ m^{-2} day^{-1});
γ = psychrometric constant (kPa $ºC^{-1}$);
t = average air temperature (ºC);
U_2 = wind speed at two meters height (m s^{-1});
e_s = saturation water vapor pressure (hPa); and
e_a = actual water vapor pressure (hPa).

To evaluate the development of the seedlings through the application of the four daily irrigation frequencies, the following characteristics were analyzed: plant height and number of leaves of each *E. grandis* seedling. Plant height was measured from the collar region, in centimeters, using a millimeter ruler. These parameters were evaluated along the seedling cycle after 15, 30, 45, 61, 76, 91 and 106 days after sowing. For these variables, a split-plot RBD design was considered for statistical purposes, having in the plots the four irrigation frequencies and in the subplots the time dependent evaluations.

After the 106 days, the number of surviving seedlings was counted and converted to percentage. Afterwards, the seedlings were cut in the collar region separated into aerial part and root part. The root part was washed (with potable water) in metal trays with 1 mm mesh, for substrate removal. Both parts were placed in paper bags previously identified according to each treatment and oven-dried with air circulation (65 ± 3 °C) until reaching constant weight (shoot, root and total dry masses). After this procedure, the Dickson quality index (DQI), to determine seedling quality, was calculated according to Equation 2 (DICKSON *et al.*, 1960):

$$DQI = \frac{TDM}{\frac{PH}{PD} + \frac{SDM}{RDM}} \quad (2)$$

where,

DQI = Dickson Quality Index (unitless);
TDM = total dry mass (g $unit^{-1}$);
PH = plant height (cm);
PD = plant diameter (mm);
SDM = shoot dry mass (g $unit^{-1}$); and
RDM = root dry mass (g $unit^{-1}$).

Water use efficiency (WUE, in kg m^{-3}) was obtained by the relation between the total dry mass of eucalyptus seedlings and the amount of water applied in each plot.

The data were submitted to analysis of variance. The comparison of means was performed using the Tukey test at 5% probability, for qualitative independent variables. Regression analysis with fitting of linear and quadratic models were tested for quantitative independent variables. The selection of the model was based on the significance of the regression coefficients (using the t test at 5% probability), on the determination coefficient (R^2) and on the biological phenomenon (changes in plant morphology). The statistical analyses were conducted with the experimental package "Designs" of R software (R DEVELOPMENT CORE TEAM, 2017).

RESULTS

There was interaction between irrigation frequency and days after sowing of eucalyptus seedlings for number of true leaves and plant height. The analysis of the significant interactions was performed, and Table 1 shows the means comparison test for the effect of irrigation frequencies on number of true leaves and plant height.

It is verified that, regardless of the age of the eucalyptus seedlings, IF2 and IF3 did not differ from one another and always had the highest means. Until 45 and 61 days after sowing, the irrigation frequencies did not affect the number of leaves and height of eucalyptus plants, respectively. It was only after these dates that the effects of the treatments imposed by the irrigation frequencies were noted.

The regression analysis showed the behavior of the number of true leaves and plant height as a function of the effect of the time after sowing (Figure 3) of the eucalyptus seedlings for each frequency of irrigation. It is important to highlight

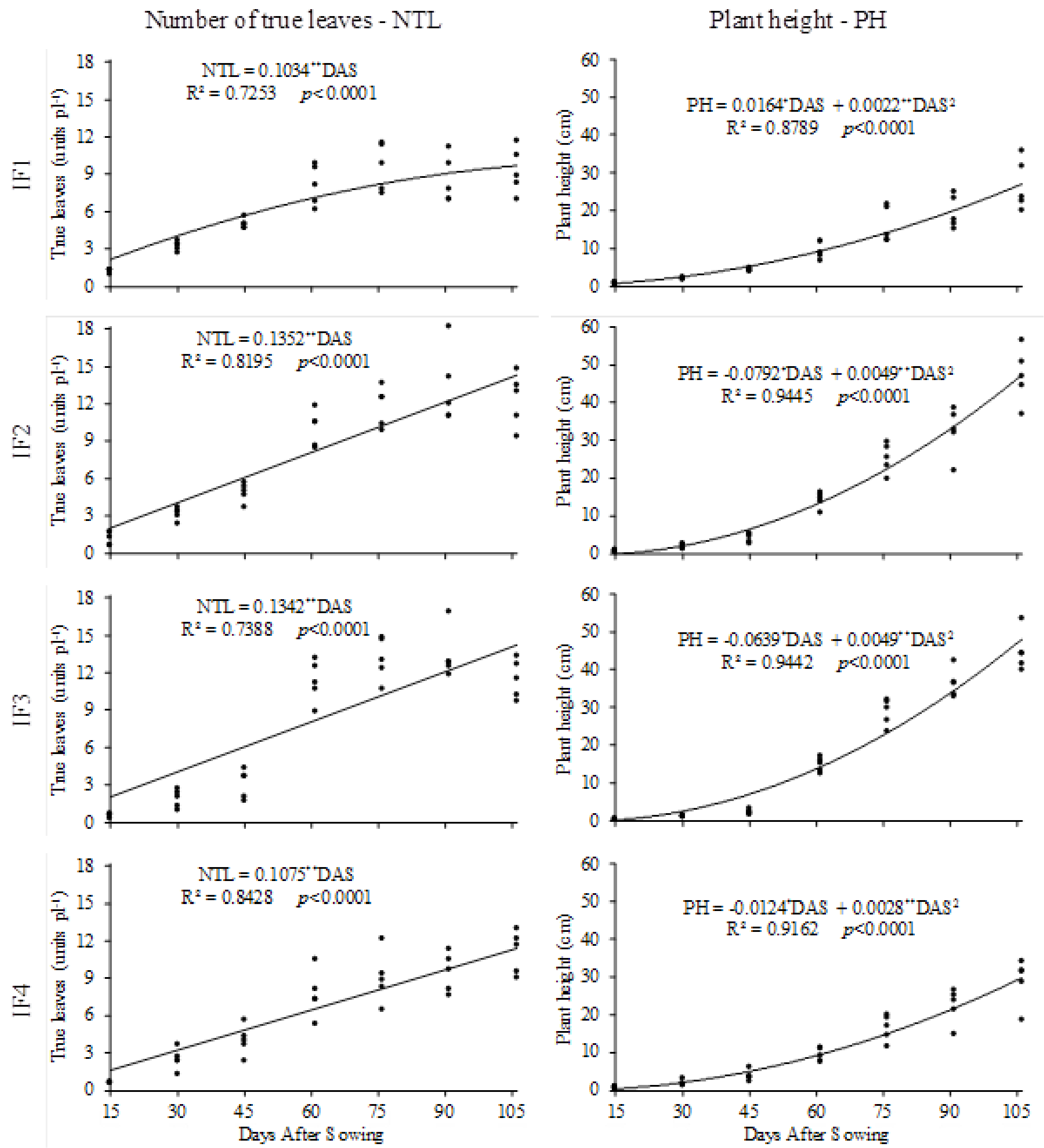
Table 1. Mean values of the number of true leaves and plant height as a function of irrigation frequencies and days after sowing for eucalyptus seedlings

Parameters	Days after sowing	Irrigation frequency			
		IF1	IF2	IF3	IF4
Number of true leaves	15	1.27 a	1.21 a	0.60 a	0.67 a
	30	3.22 a	3.13 a	1.88 a	2.47 a
	45	4.98 a	4.87 a	3.11 a	4.03 a
	61	8.10 b	10.08 ab	11.27 a	7.74 b
	76	9.65 bc	11.76 ab	13.10 a	9.03 c
	91	8.61 b	13.27 a	13.37 a	9.46 b
	106	9.29 b	12.33 a	11.48 ab	11.07 ab
Plant height (cm)	15	0.74 a	0.70 a	0.33 a	0.67 a
	30	2.06 a	1.92 a	1.00 a	1.84 a
	45	4.34 a	4.12 a	2.20 a	3.84 a
	61	9.53 a	14.09 a	14.77 a	9.35 a
	76	16.03 b	25.25 a	28.68 a	16.53 b
	91	19.39 b	32.32 a	36.22 a	22.35 b
	106	26.70 b	47.05 a	44.67 a	28.90 b

Means followed by different letters in the row differ statistically by the Tukey test (p <0.05) that the models should be applied from 15 to 106 days after sowing (valid range).

We found a good fit of the regression models, where the obtained significance was lower than 1% for most of the regression coefficients by "t" test. Also, all calculated coefficients of determination (R^2) were above 80%, which reflects the precision of the model to explain the variability of the response data around its mean. Seedling age caused a negative quadratic effect on the number of true leaves and a positive quadratic effect on plant height.

The means comparison tests for the shoot, root and total dry masses, DQI, survival and efficiency of water use by eucalyptus seedlings is presented in Table 2. It was verified in the analyses of variance that all the evaluated characteristics were affected by the irrigation frequencies.



*** and * significant at 1 and 5% probability levels, respectively.*

Figure 3. Estimation of the number of true leaves and plant height of eucalyptus according to the days after sowing (DAS)

Table 2. Mean values of shoot, root and total dry masses, DQI, survival and efficiency of water use by eucalyptus seedlings as a function of irrigation frequencies

Parameters	Irrigation frequency			
	IF1	IF2	IF3	IF4
Shoot dry mass (g unit^{-1})	2.141 b	4.420 a	3.533 a	1.579 b
Root dry mass (g unit^{-1})	0.339 c	0.894 a	0.597 b	0.281 c
Total dry mass (g unit^{-1})	2.480 b	5.314 a	4.135 a	1.862 b
DQI (unitless)	0.071 b	0.165 a	0.119 ab	0.087 b
Survival (%)	76.69 b	91.85 a	90.07 a	80.56 b
Water use efficiency (kg m^{-3})	3.517 b	7.536 a	5.857 a	2.638 b

Means followed by different letters in the row differ statistically by the Tukey test (p <0.05)

The frequency of two irrigation events per day led to the highest root dry masses of eucalyptus seedlings, followed by the frequency of three irrigations per day. The irrigation frequencies of one and four irrigation events per day did not differ and were those that caused the lowest root dry masses of eucalyptus seedlings. The irrigation frequencies of one and four times per day did not differ from each other. For DQI, the frequency of two irrigations per day was superior to the frequencies of one and four times a day. For the other characteristics, it was verified that the frequencies of two and three irrigations per day did not differ from one another and were superior to the other irrigation frequencies evaluated.

DISCUSSION

During the experimental period, all treatments received 552.6 liters of water per square meter of the tray, which generated a daily average water depth of 5.5 mm. It should be noted that this value cannot be recommended for irrigation of eucalyptus seedlings for other regions or periods different from those used in the present study, since these values were used taking into account the local evapotranspiration demand. Silva *et al.* (2015), applying irrigation in eucalyptus seedlings in Viçosa - MG - Brazil, during the summer, showed that the best daily irrigation depth was 11 mm, while Queiroz *et al.* (2017) found a 4.5 mm depth for Montes Claros - MG - Brazil. This large variation of irrigation depth is due to the great diversity of the Brazilian climatic conditions. Microclimatic conditions, such as the structure of the protected environment, may also interfere in evapotranspiration. Thus, agreeing with Wang *et al*. (2018), using a general recommendation may lead to deficit or excess of water application in forest seedlings.

Regardless of seedling age, treatments with frequencies of two and three daily irrigations led to higher values of the number of true leaves and height of eucalyptus plants (Table 1). The true leaves are related to the development of the seedling and, according to Martins and Streck (2007), are the main responsible for the production of energy for the plant, through photosynthesis. It is also verified in Table 1 that, until 45 and 61 days after sowing, irrigation frequencies did not affect the number of leaves and height of eucalyptus plants, respectively. Possibly, this result is due to the plasticity of eucalyptus seedlings to adapt in an environment (MARTINS *et al*., 2018), and also due to the evaporation and transpiration components. At the beginning of the seedling phase, eucalyptus had a low leaf area index and, consequently, low evapotranspiration rates, since this phenomenon was only governed by the evaporation component. After 45 days, according to the regression equations of Figure 3, the seedlings already had, on average, six true leaves. Thus, the transpiration component was already significant in the evapotranspiration process, and the amounts of water applied were already limited for some treatments, resulting in this differentiation observed from 45 and 61 days.

Plant height showed a quadratic behavior with the increase in the age of the eucalyptus seedlings (Figure 3). These results corroborate those obtained by Queiroz *et al*. (2017) evaluating *Eucalyptus globulus* in Montes Claros-MG between the ages of 30 and 120 days after sowing. It was also verified, in Figure 3, that increases in the age of the eucalyptus seedlings caused a quadratic effect on the number of true leaves. According to the regression equation, the 100 days after sowing maximized the number of true leaves of eucalyptus seedlings for irrigation frequencies of once a day, resulting in value of 9.4 leaves per plant (Figure 3). For the other irrigation frequencies, we can observe from the fitted models that the maximum value did not occur until 106 days after sowing. However, it is verified through Figure 3 that the numbers of true leaves of the seedlings were already stabilizing, which demonstrates that the seedlings were already at the moment of transplanting. This stabilization is possibly due to the root system being confined to a small volume of substrate (50 cm^3 in the present research), limiting the development of eucalyptus seedlings.

It can be seen in Table 2 that IF2 always promoted higher values of dry matter (shoot, root and total) and seedling quality index, as well as higher percentages of survival and greater efficiency of water use. Treatments with frequencies of one and four irrigation applications per day had the worst performances (Table 2). Treatment with only one irrigation per day had worse results possibly because the soil-substrate set, with 50% water retention capacity, did not retain all the water applied and needed by the plant. However, it is important to highlight that the drainage at the bottom of the tubes was not measured.

According to Felippe *et al*. (2016), the substrate has the maximum capacity to retain water around 58%. However, Tatagiba *et al*. (2015) verified that 70% of this maximum water retention capacity is the level that promotes better performance of eucalyptus seedlings in vermiculite substrate. At the moment of irrigation, a fraction of the applied water was responsible for saturating the soil-substrate set, not following the recommendation of Tatagiba *et al*. (2015), and the other fraction was drained, leaching nutrients. In addition, the small fraction of water that was retained in the soil-substrate set was not yet sufficient for water maintenance throughout the day. It should be noted that, in the present study, there was only a difference in irrigation fractionation, but all treatments received the same water depth.

The possible explanation for the low performance in the treatment with four daily irrigations is mainly due to the loss of water retained in the leaves. In this treatment, despite the high frequency, there was application of low irrigation depth. According to Costa (1994), the vegetation cover is responsible for retaining up to one millimeter per rainfall event or irrigation. Thus, it is estimated that in this treatment a loss of up to four millimeters of irrigation depth (four liters of water for each square meter of tray) was retained in the leaves and did not reach the tubes where the root-substrate set was. It should be noted that this water is considered as loss because it has been evaporated from the surface of the leaf and has not been used by the plant in any metabolic process.

It is also seen in Table 2 that for many times the treatment with three irrigations per day provided the same results as the treatment with two irrigations per day. However, it is recommended that the management of the eucalyptus seedlings in lower-tech nurseries be performed with two daily irrigations (schedules from 11:00 a.m. and 7:00 p.m.), because less work will be done compared to the management with three irrigation events. Freitag *et al*. (2012), applying the same treatments in the production of *Pinus elliottii* seedlings in Santa Maria-RS, concluded that frequencies of three daily irrigations would be better suited to produce physiologically better seedlings and with lower water costs during their production. However, it is known that the species studied by Freitag *et al*. (2012) requires more water than *Eucalyptus grandis*, in addition to having a lower capacity to retain water on the leaf surface due to the acicular leaves. It is worth mentioning that it is necessary to perform other tests with the same frequencies of irrigation during the day and using the same methodology to estimate the need for water already used in this research, but with different times of application, in order to reach the maximum level of development of eucalyptus seedlings in nursery.

The recommendation for twice-a-day irrigation frequency can also be reinforced by the best performance observed for the root dry mass parameter (Table 2). The more abundant the root system is, the greater the chance of survival of the seedling in the field, regardless of its height, so root dry mass is an important indicator of seedling quality, which is directly related to the survival and initial growth of the seedling (MENDONÇA *et al*., 2016; TENG *et al*., 2018). In this context, the greater root dry mass produced in the treatment with frequency of two irrigations per day is evidence of the potential of this water management for the production of eucalyptus seedlings. Greater root production can also provide greater substrate stability and consequently better quality of the seedlings.

The quality index of seedlings (DQI) proposed by Dickson *et al*. (1960) is an important weighted morphological measure. This is a good indicator of the quality of the seedlings, considering their robustness and the balance of biomass distribution (CERQUEIRA *et al*., 2017; SILVA *et al*., 2017). The higher the DQI value, the better the quality of the seedling. Therefore, eucalyptus seedlings that received irrigation frequency twice a day (Table 2) can be considered of better quality, further reinforcing the recommendation of this water management for the production of eucalyptus seedlings in lower-tech nurseries.

There was great adaptive plasticity of eucalyptus seedlings at different irrigation frequencies in relation to survival, since there was no treatment that stood out numerically (Table 2), as observed for the other characteristics evaluated. Berenguer *et al*. (2017), evaluating different species of eucalyptus under different levels of water stress, verified that this genus has different adaptive mechanisms to cope with the continuous water deficit and also capacity of total recovery after a situation of stress in the short term. The authors highlighted the physiological advantages of eucalyptus and justified that these are the main reasons for the genus being the world leader in cultivated area.

As with the other parameters, the frequency of two daily irrigations (Table 2) promoted a higher value of water use efficiency (WUE) by eucalyptus seedlings. The mean value of WUE, considering all treatments, was 4.89 g L^{-1}. This result indicates that, to produce one kilogram of dry biomass of eucalyptus in the seedling phase, 205 liters of irrigation water are required. Considering only the treatment with the frequency of two irrigations per day, the required volume would be 133 liters of water, allowing for lower water and electricity costs in the production of eucalyptus seedlings. It should be noted that *Eucalyptus grandis* has the highest water use efficiency among the species of the *Eucalyptus* genus. This was confirmed by Fei *et al*. (2015), who observed greater efficiency of water use by *Eucalyptus grandis* compared to *Eucalyptus urophylla*.

CONCLUSIONS

- For lower-tech nurseries installed in Chapadão do Sul and in regions with similar climatic conditions, the water management with two daily irrigations, one at 11:00 a.m. and the other at 7:00 p.m., is recommended for the production of *Eucalyptus grandis* seedlings.

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