

Nursery water management on initial development
and quality of *Piptadenia gonoacantha* seedlingsA influência do manejo hídrico no desenvolvimento inicial
e qualidade das mudas de *Piptadenia gonoacantha*Richardson Barbosa Gomes da Silva¹ e Magali Ribeiro da Silva²**Resumo**

O objetivo deste trabalho foi avaliar o efeito de três lâminas brutas diárias de água (8, 11 e 14 mm) aplicadas em duas frequências de irrigação (duas e quatro vezes ao dia) sobre o desenvolvimento inicial e a qualidade de mudas *Piptadenia gonoacantha* (Mart.) J. F. Macbr. O aumento na eficiência de irrigação não produz, necessariamente, maior desenvolvimento dos parâmetros morfológicos e qualidade do sistema radicular das mudas no viveiro. A lâmina de irrigação 11 mm é mais eficiente que a de 14 mm e utiliza 21% menos água. A lâmina de irrigação 11 mm aplicada na frequência de irrigação duas vezes ao dia produz mudas de *Piptadenia gonoacantha* com sistemas radiculares ótimos e desenvolvimento morfológico adequado no viveiro, o que permanece após o plantio. **Palavras-chave:** pau-jacaré, lâmina bruta de irrigação, frequência de irrigação, escoamento, viveiros florestais, desenvolvimento pós-plantio.

Abstract

The objective of this work was to evaluate the effect of three daily gross irrigation depths (8, 11 and 14 mm) applied in two irrigation frequencies (two and four times a day) on the initial development and quality of *Piptadenia gonoacantha* (Mart.) J. F. Macbr. seedlings. Increases in irrigation efficiency do not necessarily produce a greater development of morphological parameters and root system quality of seedlings in the nursery. The 11 mm irrigation depth is more efficient than the 14 mm and uses 21% less water. The 11 mm irrigation depth applied in two irrigation frequencies produce *Piptadenia gonoacantha* seedlings with optimum root systems and proper morphological development in the nursery, which continues after planting. **Keywords:** pau-jacaré, gross irrigation depth, irrigation frequency, runoff, forest nurseries, development after planting.

INTRODUCTION

The Brazilian Atlantic forest is a vast heterogeneous region (1,481,946 km², with approximately 17.4% of the Brazilian territory), including a large variety of forest physiognomies and compositions distributed through > 3300 km along the Brazilian Atlantic coast, from 3° S to 30° S and from sea level up to 2700 m (METZGER, 2009). Degradation has taken place through much of the forest with only 11.7% of the original vegetation remaining (RIBEIRO et al., 2009). Most of the remaining Atlantic Forest exists in small fragments that are isolated from one another and which will require some form of management to facilitate their recovery (ENGEL; PARROTA, 2001).

Tree seedling plantings are a potential option to accelerate the restoration of this ecosystem and prevent further environmental damage (MODNA et al., 2010). To optimize plantings, it is important to improve the morphological, physiological and genetic quality of seedlings (WILSON; JACOBS, 2006) in order to increase the survival and growth of seedlings after planting (MATTSSON, 1997).

To recover eroded areas with low fertility and restore degraded riparian areas and soils not subject to flooding, it is recommended to plant the pioneer species of Brazilian Atlantic forest such as *Piptadenia gonoacantha* (Mart.) J. F. Macbr. (Pau-jacaré) (CARVALHO, 2003).

In nurseries, the main factors that affect the development and quality of seedlings

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are the quality of its genetic materials, water management, nutrition, the type of container and the substrates used (SILVA et al., 2012). Of all the resources that plants need to grow, water is the most abundant and, at the same time, the most limiting to its productivity (TAIZ; ZEIGER, 2004). Frequently the water management (irrigation depth and irrigation frequency) in some Brazilian nurseries is solely determined by the visual examination of the seedlings.

Over- or deficit-watering of seedlings may have adverse consequences. Overwatering may lead to nutrient leaching which may affect environmental quality and increase production costs, while a water deficit can deleteriously affect potential growth and cause seedling death (BAUERLE et al., 2002; MONTAGUE; KJELGREN, 2006).

To produce quality seedlings, water management should be used in order to minimize the negative environmental, economic and social consequences of inadequate water supply.

The objective of this work is to evaluate the effect of gross irrigation depths and irrigation frequencies on the initial development and quality of *Piptadenia gonoacantha* (Mart.) J. F. Macbr. seedlings.

MATERIAL AND METHODS

The experiment was conducted from October 2011 to October 2012 in a suspended and sectorized nursery located in Botucatu, São Paulo State, Brazil (22°1'S, 48°25'O). The climate of the region is Cwa according to the Köppen climate classification.

The *Piptadenia gonoacantha* seeds were collected in October 2011 in a forest fragment located in Botucatu, Brazil. The seeds were packed in polyethylene bags and transported to the nursery. In the nursery, the seeds were stored for 7 days at a temperature of 10°C ± 2°C and a relative humidity between 8 and 12%, where they remained until sowing. Plastic tubes (92

cm³) were used in seedling production. The plastic tubes were placed in 108 cells of each polypropylene tray and filled with a substrate consisting of *Sphagnum* peat, vermiculite and carbonized rice chaff (2:1:1; volume basis).

Substrate physical analyses were conducted according to methods described by Guerrini and Trigueiro (2004), and chemical analyses were conducted according to methods described by Brasil (2007) (Table 1).

The soluble fertilizers Yoorin® Master 1S and Fosmag® 500B and the controlled release fertilizer Osmocote® with NPK (19:6:10) were added to the substrate. These fertilizers provide macronutrients in dosages of 42.3, 69, 31.3, 25.2, 48.2 and 18 mg/plastic tube of N, P, K, S, Ca and Mg, respectively, and dosages of micronutrients 0.3, 0.1, 0.6, 18.4 and 1 mg/plastic tube of B, Cu, Mn, Si and Zn, respectively.

Sowing was performed manually by placing a seed in each plastic tube. The trays were transferred to an automated greenhouse with temperature control (less than or equal to 30°C) and relative humidity (greater than 80%, maintained through spraying) with a 7 L h⁻¹ flow nozzle, triggered automatically by an electric panel for 10 seconds, every 15 minutes, from 9:00 am to 4:00 pm. After sowing, the seedlings remained in this environment for 14 days after which they were transferred to a shade house (with 50% light reduction) where they were irrigated with micro-sprinklers with a 200 L h⁻¹ flow nozzle, triggered automatically by an electric panel for 20 seconds, every 30 minutes, from 9:00 am to 4:00 pm, and where they remained for 42 days.

The experiment was conducted using a completely randomized design with a factorial scheme that consisted of three daily gross irrigation depths (8, 11 and 14 mm), split into two and four irrigation frequencies by micro-sprinklers (Table 2).

Each treatment consisted of 4 replications (trays). In each tray, the percentage occupancy of the seedlings was 25%. In each replication, the 12 central seedlings were the useful seedlings,

Tabela 1. Physical and chemical properties of substrate used in this experiment.

Table 1. Propriedades físicas e químicas do substrato utilizado neste experimento.

Physical properties	Porosity (%)			Water retention (mL per plastic tube)
	Macro	Micro	Total	
	24.2	59.3	83.4	54.6
Chemical properties	Electrical conductivity (mS cm ⁻¹)			pH
	0.5			6.5

Tabela 2. Treatments used in the experiment⁽¹⁾.**Table 2.** Composição dos tratamentos utilizados neste experimento.

Treatments	Compositions
ID8F2	4 mm 10:00 am and 4 mm 2:00 pm
ID8F4	2 mm 9:00 am, 2 mm 11:00 am, 2 mm 1:00 pm and 2 mm 3:00 pm
ID11F2	5.5 mm 10:00 am and 5.5 mm 2:00 pm
ID11F4	2.75 mm 9:00 am 2.75 mm 11:00 am, 2.75 mm 1:00 pm and 2.75 mm 3:00 pm
ID14F2	7 mm 10:00 am and 7 mm 2:00 pm
ID14F4	3.5 mm 9:00 am, 3.5 mm 11:00 am, 3.5 mm 1:00 pm and 3.5 mm 3:00 pm

⁽¹⁾ID - irrigation depths (mm) and F - irrigation frequencies (times a day).

and the 18 other surrounding seedlings constituted the boundary, totaling 48 used seedlings per treatment.

Before starting the treatments, seedlings were selected in order to homogenize the replications, ensuring that height and stem diameter averages did not statistically differ ($p < 0.05$). The mean values and standard deviations of height and stem diameter were $6.3 \text{ cm} \pm 0.7$ and $1.24 \text{ mm} \pm 0.15$, respectively.

To begin the treatments, the replications were distributed in a completely randomized design in three outdoor beds, covered with a plastic light diffuser, in the sunlit area of the nursery. Each outdoor bed received the two treatment replications, which were automatically applied by the electric panel-powered irrigation system.

The side dressing fertilization was performed twice a week for 85 days after the start of the treatment application. In each fertilization, the 4 mm irrigation depth of nutrient solution was applied via ferti-irrigation in all treatments. The solution comprised the following fertilizers: purified mono-ammonium phosphate, magnesium sulfate, potassium nitrate, calcium nitrate and urea in concentrations of 488, 155.4, 328.1, 312, 72.2 and 98.8 mg L⁻¹ of N, P, K, Ca, Mg and S, respectively, and micronutrients solution of boric acid, sodium molybdate and manganese sulfate, zinc, copper and iron in concentrations of 3, 3.9, 1.2, 0.6, 0.3 and 48 mg L⁻¹ of B, Mn, Zn, Cu, Mo and Fe, respectively.

The hardening fertilization was performed twice a week from 85 until 120 days after the beginning of treatments. In each fertilization the 4 mm irrigation depth of nutrient solution was applied via ferti-irrigation in all treatments. The fertilizer solution was composed of potassium chloride at a concentration of 750 mg L⁻¹ and micronutrient solutions for boric acid, sodium molybdate, manganese sulfate, zinc, copper and iron concentrations of 4.2, 5.5, 1, 7, 0.8, 0.4 and 67 mg L⁻¹ K, B, Mn, Zn, Cu, Mo and Fe, respectively.

To evaluate the quality of the seedlings in the nursery, the following morphological parameters were measured 120 days after the start of treatments: height (cm), measured using a millimeter ruler, from the base of the stem to the apical bud and stem diameter (mm) measured using a precision caliper (these two parameters were evaluated in the 12 useful seedlings per replication) as well as shoot, root and total dry mass (g) of the segment of the seedlings that was closest to the substrate. To determine the root dry mass, the roots were washed on a sieve using tap water. The roots and shoots were subsequently dried to a constant mass in an oven at 70 °C and then weighed with a high-precision electronic scale. The roots and shoots measurement was conducted on 6 useful seedlings per repetition. From the combination of morphological parameters, the total dry mass (g) and the Dickson quality index was determined using the following equation:

$$DQI = \left(\frac{\text{Height (cm)}}{\text{Stem diameter (mm)}} \right) + \left(\frac{\text{Shoot dry mass (g)}}{\text{Root dry mass (g)}} \right)$$

The quality of the root system was also evaluated in the same seedlings. This parameter had four categories: "optimum" indicating a well-structured root system with no flexibility and the presence of new roots (Figure 1A); "good" indicating root systems that had good structure but some flexibility which would require greater care in planting to avoid harming the field performance (Figure 1B); and "poor" indicating root systems that had no aggregated substrate or new roots and which were considered unfit for planting in the field (Figure 1C). Both "optimum" and "good" root systems were considered "able" for planting.

The irrigation efficiency (IE) of each treatment was assessed at 120 days after the start of the treatment application, in two useful seedlings



Figura 1. Quality categories assigned to the root systems of *Piptadenia gonoacantha* seedlings: optimum (A), good (B) and poor (C). The seedlings with the concepts (A) and (B) were considered able for planting.

Figure 1. Categorias de qualidade atribuídas aos sistemas radiculares de mudas de *Piptadenia gonoacantha*: ótimo (A), bom (B) e ruim (C). As mudas com os conceitos (A) e (B) foram consideradas aptas para o plantio.

per replication, totaling eight seedlings per treatment, from the equation of Fain et al. (1998):

$$IE = \frac{\text{Water applied (mL)} - \text{Water drained (mL)}}{\text{Water applied (mL)}} \times 100$$

The mass of the whole plastic tubes + seedlings was measured before and after each irrigation on a precision electronic scale to quantify the amount of water applied to the substrate. The volume of water drained from the plastic tube after each irrigation was collected by plastic bags secured with elastic and measured on an electronic precision scale.

After the end of nursery phase, the seedlings were kept in their treatments for more 20 days, when six seedlings from each treatment were planted in pots of 7 L, containing 8 kg of soil each. The soil was collected from the surface layer (0-20 cm), corresponding, according to Carvalho et al. (1983), to dystrophic Red Latosol, medium texture. The fertilizer NPK (4:14:8) in dosages of 2 kg of fertilizer per cubic meter and limestone, in the same dose, were added to the soil and mixed for 5 minutes in a mixer. Before and immediately after planting, each pot was irrigated, respectively, with 2 and 1 L of water. The plants were kept in a completely randomized design in the greenhouse covered with transparent plastic for 120 days and also irrigated with 0.5 L every nine days.

The plants were evaluated immediately after planting and thereafter at intervals of 30 days for the following parameters: height (cm), measured using a millimeter ruler, from the base

of the stem to the apical bud, and stem diameter (mm) measured using a precision caliper. At 120 days after planting, shoot and root dry mass of plants (g) of the segment of the seedlings that was closest to the soil. To determine the root dry mass, the roots were washed on a sieve using tap water. The roots and shoots were subsequently dried to a constant mass in an oven at 70°C and then weighed with a high-precision electronic scale.

An analysis of variance was performed to compare the effect of irrigation depths and irrigation frequency of the parameters analyzed in the nursery. When the value of the F test indicated a significant effect, we used Tukey's test ($p < 0.05$) to compare differences between means of treatments.

In the analysis of initial development, when the value of the F test indicated a significant effect, we used regression analysis over time (height and stem diameter) and Tukey's test ($p < 0.05$) (shoot and root dry mass).

RESULTS AND DISCUSSION

Nursery results

The irrigation frequency did not influence irrigation efficiency. The 8 and 11 mm irrigation depths, where irrigation times were smaller than 14 mm irrigation depth, increased the irrigation efficiency. This may be related to the duration of irrigation, which at the 14 mm irrigation depth exceeds the capacity of irrigation water retention of the substrate (Table 3).

According to Mathers et al. (2005), irrigation efficiency depends on seedling architecture,

stage of development, physical properties of the substrate, height of the container and duration of irrigation.

All irrigation depths applied in two irrigation frequencies formed seedlings with equal or greater shoot height, shoot, root and total dry mass and DQI than those applied in four irrigation frequencies. The situation was the same in parameter stem diameter, except in the 8 mm irrigation depth (Table 4).

The seedlings irrigated with four irrigation frequencies showed this behavior because they

were likely saturated just a few inches below the surface layer of the substrate, causing water deficits during seedling production in the nursery. According to Groves et al. (1998) and Warren and Bilderback (2005), if low water volumes are used without taking into account the maintenance of adequate water in the container, stomata closure may occur, reducing photosynthesis and consequently reducing plant growth. These results are consistent with Warren and Bilderback (2005), who stated that the cycles may vary from two to twelve per

Tabela 3. Effect of irrigation depths on irrigation efficiency, when applied to *Piptadenia gonoacantha* seedlings 120 days after the beginning of treatments ⁽¹⁾.

Table 3. Efeito das lâminas de irrigação sobre a eficiência de irrigação quando aplicadas em mudas de *Piptadenia gonoacantha* 120 dias após o início dos tratamentos.

Irrigation depths (mm)	Irrigation efficiency (%)	CV (%)
8	85.2a	16.5
11	85.2a	16.5
14	72.8b	19.3

⁽¹⁾Means followed by the same letter are not significantly different according to Tukey's test ($p < 0.05$).

Tabela 4. Effects of the interaction between irrigation depths and the irrigation frequencies on height, stem diameter, shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM) and Dickson quality index (DQI) in *Piptadenia gonoacantha* seedlings 120 days after the beginning of treatments ⁽¹⁾.

Table 4. Efeitos da interação entre as lâminas de irrigação e as frequências de irrigação sobre a altura da parte aérea, diâmetro do colo, massa seca aérea (SDM), massa seca radicular (RDM), massa seca total (TDM) e índice de qualidade de Dickson (DQI) em mudas de *Piptadenia gonoacantha* 120 dias após o início dos tratamentos.

Irrigation depths (mm)	Height (cm)			Stem diameter (mm)		
	Frequencies		CV (%)	Frequencies		CV (%)
	2x	4x		2x	4x	
8	13.4Ba	14.4Ba	23.8	2.96Bb	3.28Ba	13.6
11	17.7Aa	14.4Bb	20.2	3.81Aa	3.37Bb	13.2
14	18.7Aa	17.2Ab	19.5	4.01Aa	3.75Ab	13.9
CV (%)	21.1	20.8		12.4	14.9	

Irrigation depths (mm)	SDM (g)			RDM (g)		
	Frequencies		CV (%)	Frequencies		CV (%)
	2x	4x		2x	4x	
8	0.89Ba	0.98Ba	29.7	0.61Ba	0.68Ba	31
11	1.36Aa	0.98Bb	25.4	0.97Aa	0.70Bb	25.6
14	1.42Aa	1.53Aa	24.3	1.11Aa	0.99Aa	27.5
CV (%)	26.9	25.7		27.5	28.9	

Irrigation depths (mm)	TDM (g)			DQI		
	Frequencies		CV (%)	Frequencies		CV (%)
	2x	4x		2x	4x	
8	1.50Ba	1.66Ba	28.5	0.25Ba	0.29Ba	34.3
11	2.33Aa	1.68Bb	22.2	0.39Aa	0.29Bb	26.4
14	2.53Aa	2.52Aa	23.8	0.43Aa	0.42Aa	31.9
CV (%)	24.7	24.9		30	33.2	

⁽¹⁾Means followed by the same capital letter in the column and the same lowercase letter across the row are not significantly different according to Tukey's test ($p < 0.05$).

day, but that about two at an appropriate time application, is appropriate.

The 8 mm irrigation depth, even with the increased irrigation efficiency, produced smaller seedlings in all morphological parameters when the two irrigation frequencies was applied, showing that water management which produces little runoff from the plastic tubes may not always be the best, given that if the water requirement of the changes is not supplied, growth reduction occurs.

The 11 and 14 mm irrigation depths, applied in two irrigation frequencies, provided the same development in all of the seedlings morphological parameters. According to Fox and Montague (2009), the largest plant growth is not always associated with the highest rates of irrigation. Furthermore, the 11 mm irrigation depth generated less runoff than the 14 mm irrigation depth. According to Montague and Kjelgren (2006), excess watering can lead to the nutrient leaching, causing damage to the environment, low plant growth and increased maintenance costs.

The 14 mm irrigation depth produced a smaller amount of seedlings with poor root systems and an increased amount of able-bodied seedlings; however, the seedlings quality did not differ significantly from the seedlings that had the 11 mm irrigation depth applied (Figure 2).

According to Zhu et al. (2005), nurseries apply water to seedlings by connecting the

valves of the irrigation system, without knowing the amount of water that is lost through runoff. Furthermore, according to Thomas and Perry (1980), nutrients are leached when the volume exceeds the capacity of irrigation water retention of the substrate.

The 8 mm irrigation depth, applied in two irrigation frequencies produced a greater amount of seedlings with good root systems; however, seedling quality did not differ from seedlings treated with the 14 mm irrigation depth. In four irrigation frequencies, there was no significant difference between the irrigation depths in determining root system quality (Table 5).

In comparing the two irrigation frequencies in the formation of seedlings with good root systems, only the 11 mm irrigation depth applied in two irrigation frequencies differed from the others. This may be because the 11 mm irrigation depth applied in four irrigation frequencies throughout the period of the production of seedlings, saturated the surface layer just inches below the substrate, hindering the complete development and quality of roots. According to Taiz and Zeiger (2004), the proliferation of roots depends on the availability of water and nutrients in the microenvironment surrounding the root, called the rhizosphere. If the rhizosphere is nutrient-poor or too dry, root growth is slow.

The 11 and 14 mm irrigation depths, applied in two irrigation frequencies, provided the

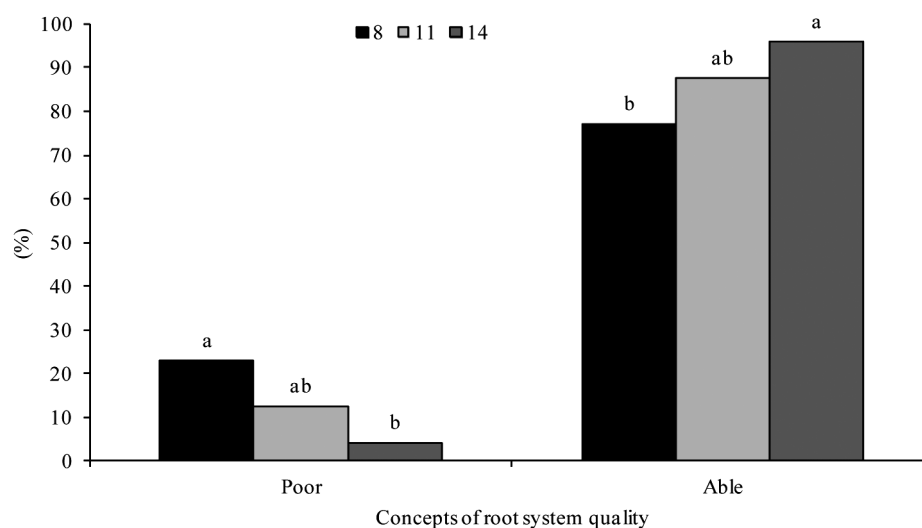


Figura 2. Effect of irrigation depths (mm) on the categories “poor” and “able” of root system quality of *Piptadenia gonoacantha* seedlings 120 days after the beginning of treatments. Means followed by the same letter in the same category are not significantly different according to Tukey’s test ($p < 0.05$).

Figure 2. Efeito das lâminas de irrigação (mm) sobre as categorias “ruim” e “apto” de qualidade do sistema radicular de mudas de *Piptadenia gonoacantha* 120 dias após o início dos tratamentos. Médias seguidas da mesma letra na mesma categoria não são significativamente diferentes de acordo com o teste de Tukey ($p < 0,05$).

same amount of seedlings with optimum root systems, proving that it is possible to reduce water application without causing damage to the root system quality.

Initial development results

The effect of treatments on height and stem diameter of the seedlings showed linear behavior, with the exception of 8 mm irrigation depth applied in two irrigation frequencies (height and stem diameter) and 11 mm irrigation depth applied in this same irrigation frequency (stem diameter) (Figure 3).

The 11 mm irrigation depth applied in two irrigation frequencies, which formed greater seedlings at the nursery phase, continued producing greater heights after planting, showing the influence of seedlings quality in the initial development. With the greater development of the seedlings in the subsequent months after planting, there has been a decrease in the need for cleaning of plantations, which implies a considerable reduction of implementation costs (CARNEIRO, 1995).

The 8 mm irrigation depth applied in two irrigation frequencies, though it had the recovery of growth in height and stem diameter after the 30th day, has not overcome the results promoted by 11 mm irrigation depth applied in this same irrigation frequency at 120 days after planting.

The seedlings produced with 14 mm irrigation depth applied in two irrigation frequencies showed greater stem diameters until day 90, however, after that period, they were overcome by the seedlings produced with 11 mm irrigation depth applied in this same irrigation frequency, showing the possibility of saving water in irrigation of this species in the nursery. The amount of water available for nursery irrigation is forecasted to decline over the next decade. Along

with declining availability, the cost of water for irrigation is predicted to increase substantially for most nurseries. Limited availability, higher direct costs, and irrigation runoff issues are projected to compel the container nursery industry to adopt procedures and technology that will increase irrigation water use efficiency (BEESON et al., 2004).

In root and shoot dry mass parameters, the 11 mm irrigation depth applied in two irrigation frequencies in the nursery resulted in greater growth after planting compared to the same irrigation depth applied in four irrigation frequencies (Table 6).

After planting, the shoot and root dry mass of seedlings produced in 14 mm irrigation depth did not differ with respect to irrigation frequency applied in the nursery. Furthermore, there was no difference between the irrigation depths applied in four irrigation frequencies. The 8 and 14 mm irrigation depths applied in two irrigation frequencies produced smaller shoot and root dry mass. Seedlings with reduced root system are stressed because they do not absorb enough water through the roots to balance the loss by transpiration (GONÇALVES; BENEDETTI, 2000). This triggers a series of effects throughout the plant, affecting mainly cell growth (FERREIRA et al., 1999; TAIZ; ZEIGER, 2004).

The 11 mm irrigation depth applied in two irrigation frequencies overcomes the other irrigation depths in shoot and root dry mass. The shoot dry mass is related to the quality and quantity of leaves. This parameter is very important because the leaves are main source of photo assimilates (sugars, amino acids and hormones) and nutrients to seedling acclimation after planting, which require good reserve of photo assimilates, which in turn serve

Tabela 5. Effects of the interaction between the irrigation depths and the irrigation frequencies on the categories "good" and "optimum" of root system quality of *Piptadenia gonoacantha* seedlings 120 days after the beginning of treatments⁽¹⁾.

Table 5. Efeitos da interação entre as lâminas de irrigação e as frequências de irrigação sobre as categorias "bom" e "ótimo" de qualidade do sistema radicular de mudas de *Piptadenia gonoacantha* 120 dias após o início dos tratamentos.

Irrigation depths (mm)	Good (%)		Optimum (%)	
	Frequencies		Frequencies	
	2x	4x	2x	4x
8	70.8Aa	54.2Aa	8.3Ba	20.8Ba
11	33.3Bb	62.5Aa	66.7Aa	12.5Bb
14	45.8ABa	29.2Aa	50.0Aa	66.7Aa

⁽¹⁾Means followed by the same capital letter in the column and the same lowercase letter across the row in the same category are not significantly different according to Tukey's test (p < 0.05).

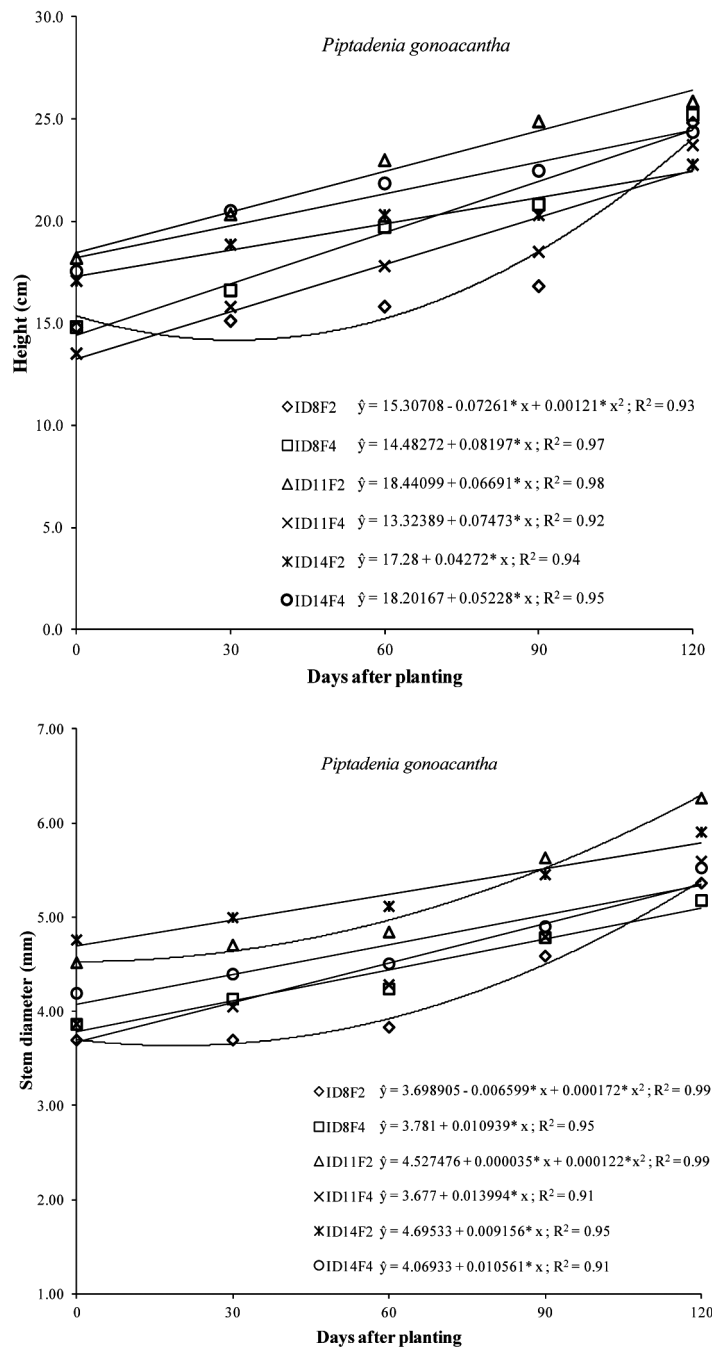


Figura 3. Effect of irrigation depths (ID) and irrigation frequencies (F) applied to *Piptadenia gonoacantha* seedlings in the nursery phase on the height and stem diameter 120 days after planting. *Significant according to the F test ($p < 0.05$).

Figure 3. Efeito das lâminas de irrigação e frequências de irrigação aplicadas às mudas de *Piptadenia gonoacantha* na fase de viveiro sobre a altura da parte aérea e o diâmetro do colo 120 dias após o plantio. *Significativo de acordo com o teste F ($p < 0,05$).

Tabela 6. Effects of the interaction between irrigation depths and the irrigation frequencies applied to *Piptadenia gonoacantha* seedlings in the nursery phase on the shoot dry mass (SDM) and root dry mass (RDM) at 120 days after the planting⁽¹⁾.

Table 6. Efeitos da interação entre as lâminas de irrigação e as frequências de irrigação aplicadas às mudas de *Piptadenia gonoacantha* na fase de viveiro sobre a massa seca aérea (SDM) e a massa seca radicular (RDM) aos 120 dias após o plantio.

Irrigation depths (mm)	SDM (g)			RDM (g)		
	Frequencies		CV (%)	Frequencies		CV (%)
	2x	4x		2x	4x	
8	2.50Ba	2.14Aa	25.7	1.30Ba	1.16Aa	26.1
11	4.21Aa	2.46Ab	13.5	3.38Aa	1.82Ab	19.9
14	2.40Ba	2.97Aa	11.6	1.88Ba	2.00Aa	23
CV (%)	14.2	17.7		24.3	25.7	

⁽¹⁾Means followed by the same capital letter in the column and the same lowercase letter across the row in the same parameter are not significantly different according to Tukey's test ($p < 0.05$).

as a supply of water and nutrients to the roots in the first month after planting (GONÇALVES; BENEDETTI, 2000). Moreover, the success of planting is largely dependent to the ability of plants to quickly generate new roots to maximize the absorption of water and compete with the local vegetation (BURDETT, 1990; HAASE; ROSE, 1993; GROSSNICKLE, 2005; MÁFIA et al., 2005; RILEY; STEINFELD, 2005; MAÑAS et al., 2009).

CONCLUSIONS

1. Increases in irrigation efficiency do not necessarily produce a greater development of morphological parameters and root system quality in the nursery.

2. The 11 mm irrigation depth is more efficient than the 14 mm and uses 21% less water.

3. The 11 mm irrigation depth applied in two irrigation frequencies produces *Piptadenia gonoacantha* seedlings with optimum root systems and proper morphological development in the nursery, which continues after planting.

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