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Biomass of sugar-apple seedlings under saline water irrigation in substrate with polymer

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Key words:
Annona squamosa
volume of containers
saline stress
irrigation interval

ABSTRACT

Application of saline water causes water and salt stress, changing the behavior of the plants. The aim of this work was to evaluate the accumulation and allocation of biomass in sugar-apple seedlings under frequencies of irrigation with saline water in a substrate with soil conditioner, as well as the effect of container volume. The treatments were obtained from the arrangement between polymer doses (0, 0.2, 0.6, 1.0 and 1.2 g dm^{-3}) and electrical conductivity of irrigation water (0.3; 1.1; 2.7; 4.3 and 5.0 dS m^{-1}), associated with irrigation frequencies (daily and alternated), plus two additional treatments to evaluate container volume (0.75 and 1.30 dm^3), distributed in blocks. The evaluations were performed at 120 days after sowing. Irrigation frequency affected the variables, and the highest values were obtained with daily irrigation, except for root/shoot dry matter ratio. Increase in the electrical conductivity of the irrigation water inhibited biomass accumulation. The effect of the container was significant for daily irrigation; higher volume led to higher root, shoot and total biomass. Polymer doses did not affect the biomass of the seedlings. Daily irrigation with non-saline water favored biomass production in sugar-apple seedlings. In the production of sugar-apple seedlings, water with electrical conductivity below 1.0 dS m^{-1} should be used on a daily frequency of application in 1.30 dm^3 containers.

Palavras-chave:
Annona squamosa
volume de recipiente
estresse salino
turno de rega

Biomassa de mudas de pinha sob irrigações com água salina em substrato com polímero

RESUMO

A aplicação de água salina ocasiona estresse hídrico e salino, alterando o comportamento das plantas. Objetivou-se com o trabalho avaliar o acúmulo e a alocação de biomassa em mudas de pinha sob frequências das irrigações com água salina em substrato com condicionante de solo, como também o efeito do volume de recipientes. Os tratamentos foram obtidos do arranjo entre doses de polímero (0; 0,2; 0,6; 1,0 e; 1,2 g dm^{-3}) e condutividade elétrica da água de irrigação (0,3; 1,1; 2,7; 4,3 e; 5,0 dS m^{-1}), associado a frequências de irrigação (diária e alternada), mais dois tratamentos adicionais para avaliar o volume do recipiente (0,75 e 1,30 dm^3), distribuídos em blocos. As avaliações foram realizadas aos 120 dias após a semeadura. A frequência de irrigação afetou as variáveis, obtendo-se os maiores valores com irrigação diária, com exceção na relação entre as biomassas seca da raiz e parte aérea. O aumento da condutividade elétrica da água de irrigação inibiu o acúmulo de biomassa, sem afetar a relação entre biomassa da raiz e da parte aérea, e na razão de massa foliar. O efeito do recipiente foi significativo para rega diária, onde o maior volume proporcionou maiores biomassas. As doses de polímero não afetaram a biomassa das mudas. Irrigação diária com água não salina favoreceu o aporte de biomassa nas mudas de pinha. Na produção de mudas de pinha, deve-se utilizar água com condutividade elétrica abaixo de 1 dS m^{-1} com frequência diária de aplicação em recipientes com capacidade de 1,30 dm^3.

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Introduction

Seedling production is a determinant factor for successful installation of orchards. The use of vigorous seedlings can promote more uniform stands, lower mortality due to biotic and abiotic stresses, and higher yield in the plantation (Santos et al., 2017); however, the excess of soluble salts, commonly found in water sources of Northeast Brazil (Cavalcante et al., 2012), may even make seedling production unviable.

High salt concentrations compromises water absorption by plants and negatively influences the absorption of nutrients (Munns & Tester, 2008; Taiz et al., 2017). The deleterious effects of salinity on physiological processes direct affect biomass accumulation and allocation pattern. Sá et al. (2015) observed a reduction in the dry matter of sugar-apple (*Annona squamosa* L.) seedlings with the increment in irrigation water salinity; thus, it is essential to adopt measures that allow lower-quality water to be used. An alternative is the use of water-absorbing polymer, which reduces the need for irrigation (Agaba et al., 2011), but studies establishing these relations are still incipient.

Management of irrigation frequency can be determinant in water availability to seedlings (Navroski et al., 2015). Container volume is also a determinant factor in seedling production, as observed in papaya (Mesquita et al., 2012), passion fruit (Santos et al., 2012), sugar-apple (Dantas et al., 2013), among others. The dimensioning of the containers for seedling production is of great importance because larger substrate volume promotes greater availability of space and nutrients for root growth, but it increases costs.

Given the above, this work was conducted to evaluate biomass accumulation and allocation in sugar-apple seedlings under frequencies of irrigation with saline water, produced in containers with different volumes, filled with substrate containing water-absorbing polymer.

Material and Methods

The study was conducted in a greenhouse covered with transparent plastic on top and screen on the sides, at the Department of Soils and Rural Engineering (6° 58' 11" S, 35° 42' 59" W; 518 m), in the Center of Agrarian Sciences of the Federal University of Paraíba, municipality of Areia, Paraíba, Brazil.

Treatments were arranged in the $[(2^2 + 2 \times 2 + 1) \times 2] + 2$ scheme, where $(2^2 + 2 \times 2 + 1)$ was obtained from the combinations between five doses of the polymer Hydroplan®-EB/HyA [0; 0.2; 0.6; 1.0 (recommended by the manufacturer); and 1.2 g dm^{-3}] and five levels of irrigation water electrical conductivity (0.3; 1.1; 2.7; 4.3 and; 5.0 dS m^{-1}) using the Box's Central Composite design (Montgomery, 2013), associated with two irrigation frequencies (daily and alternated), and two additional treatments to evaluate the effect of container volume (0.75 and 1.30 dm^3), as shown in Table 1. The experimental design was randomized blocks with four replicates and the experimental unit comprised four containers.

The substrate consisted of a mixture of soil, sand and bovine manure at 3:1:1 proportion, respectively. The soil was collected in the 0-20 cm layer in a profile of a Red Yellow Latosol (Santos et al., 2013), at the experimental station Chã do Jardim,

Table 1. Scheme between the levels of the factors (HyA – polymer; ECw – electrical conductivity of the irrigation water; IF – irrigation frequency; and CtV – container volume) used in the experiment

Treat.[1]	Levels[2]		Doses/Concentrations		IF	CtV (dm^3)
	HyA	ECw	HyA (g dm^{-3})	ECw (dS m^{-1})		
1	-1	-1	0.2	1.1	Daily	1.30
2	-1	1	0.2	4.3	Daily	1.30
3	1	-1	1.0	1.1	Daily	1.30
4	1	1	1.0	4.3	Daily	1.30
5	-1.41 (-α)[3]	0	0.0	2.7	Daily	1.30
6	1.41 (α)	0	1.2	2.7	Daily	1.30
7	0	-1.41 (-α)	0.6	0.3	Daily	1.30
8	0	1.41 (α)	0.6	5.0	Daily	1.30
9	0	0	0.6	2.7	Daily	1.30
10	-1	-1	0.2	1.1	Alternated	1.30
11	-1	1	0.2	4.3	Alternated	1.30
12	1	-1	1.0	1.1	Alternated	1.30
13	1	1	1.0	4.3	Alternated	1.30
14	-1.41 (-α)	0	0.0	2.7	Alternated	1.30
15	1.41 (α)	0	1.2	2.7	Alternated	1.30
16	0	-1.41 (-α)	0.6	0.3	Alternated	1.30
17	0	1.41 (α)	0.6	5.0	Alternated	1.30
18	0	0	0.6	2.7	Alternated	1.30
19	0	0	0.6	2.7	Daily	0.75
20	0	0	0.6	2.7	Alternated	0.75

[1] Number of treatments for each arrangement between polymer doses and irrigation water electrical conductivity = $2^k + 2k + 1$ (k = 2, nº of factors) $\therefore 2^2 + 2 \times 2 + 1 = 9$; [2] Levels established according to the Box's central matrix; [3] $\alpha = \sqrt{k}$

municipality of Areia, Paraíba, Brazil. Fertility attributes were: 5.9 of pH; 0.46 dS m^{-1} of electrical conductivity (soil-water suspension); 0.50; 9.47; 1.74; 1.28; 0.23 and 0.88 cmol$_c$ dm^{-3} of Al^{3+}, $H^+ + Al^{3+}$, Ca^{2+}, Mg^{2+}, Na^+, K^+, respectively, 45 mg dm^{-3} of phosphorus; and 24.3 g dm^{-3} of organic matter. The saturation paste extract had pH value of 5.9 and electrical conductivity of 1.97 dS m^{-1}. Regarding physical characteristics, there were 68.67% of sand, 18.17% of silt and 13.16% of clay, 1.35 and 2.64 g cm^{-3} for bulk and particle densities, respectively, with porosity of 48.86%. These analyses were carried out according to methodologies compiled in Teixeira et al. (2017).

In the preparation of the substrate, phosphorus content was increased to 300 and 100 mg kg^{-1} of nitrogen were applied, using the respective sources single superphosphate and urea. The water-absorbing polymer was hydrated with distilled water before being mixed with the substrate. Irrigation was performed with saline waters, prepared by the addition of sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in the form of chloride, following the proportion (mass basis) of 5:2:1 (Silva Júnior et al., 1999), respectively, in public-supply water with 0.3 dS m^{-1} electrical conductivity. Irrigation at alternated frequency applied the equivalent to 70% of the volume applied on the daily frequency, reducing the application of salts through irrigation water. The daily water depth was applied to maintain the substrate close to field capacity, until drainage began.

Sugar-apple fruits were purchased at the local market to produce the seedlings. The seeds were manually extracted from the fruits and then washed in running water and air dried in the shade. Prior to sowing, to accelerate and uniformize seedling emergence, the seeds were immersed in water for 24 h. Three seeds were planted in each container at approximately 1.5 cm depth and, after emergence, thinning was performed to leave one plant per container.

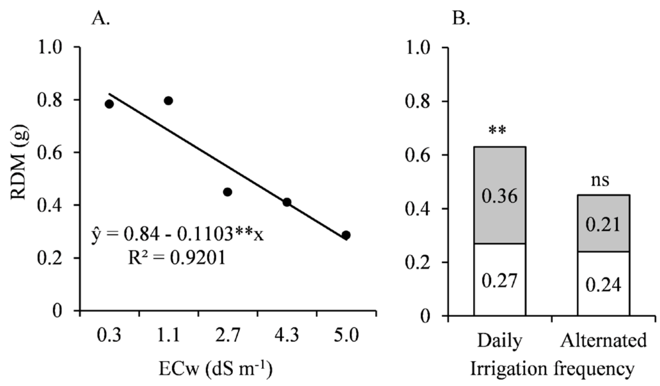
At 120 days after sowing, the seedlings were collected and separated into roots, stem and leaves. These parts were dried in an oven at 65 °C and the following parameters were evaluated: root dry matter, shoot dry matter (leaves + stem), total dry matter (roots + shoots), root/shoot dry matter ratio (RDM/SDM), and leaf mass ratio (leaf dry matter/total dry matter).

The data were subjected to analysis of variance. Quantitative effects of polymer doses and irrigation water electrical conductivity were subjected to regression analysis by F test ($p \leq 0.05$). Statistical evaluation was conducted in the program SAS® University Edition.

Results and Discussion

The effects of the factors irrigation water electrical conductivity, water-absorbing polymer, irrigation frequency and container volume on biomass accumulation and allocation in sugar-apple seedlings are presented in Table 2.

Root dry matter of sugar-apple seedlings was influenced only by irrigation water electrical conductivity and container volume (Table 2). Unit increase in irrigation water electrical conductivity reduced biomass accumulation in the roots by 0.11 g or 14%, changing from 0.81 to 0.29 g at the respective salinity levels of 0.3 and 5.0 dS m^{-1} (Figure 1A).



^{ns}; ** Not significant and significant at 0.01 probability level by F test, respectively; ▢ Actual effect: large container (1.30 dm^3) – small container (0.75 dm^3)

Figure 1. Root dry matter (RDM) of sugar-apple seedlings as a function of irrigation water electrical conductivity (A) and container volume under daily and alternated irrigation frequencies (B)

Reduction in root dry matter of sugar-apple seedlings with the increment in irrigation water salinity was also observed by Sá et al. (2015). The accumulation of salts in the root zone hampers root growth initially because of the osmotic effect of the salts, affecting cell water relations (Willadino & Camara, 2010), besides negatively influencing the absorption of nutrients (Munns & Tester, 2008), leading to reduction in biomass accumulation (Bezerra et al., 2014).

Table 2. Summary of the analyses of variance, regression and contrasts for root dry matter (RDM), shoot dry matter (SDM), total dry matter (TDM), root/shoot dry matter ratio (RDM/SDM) and leaf mass ratio (LMR) of sugar-apple (*Anna squamosa* L.) seedlings at 120 days after sowing as a function of irrigation water electrical conductivity (ECw), water-absorbing polymer (P), irrigation frequency (F) and container volume

Source of variation	DF	Mean square				
		RDM♦	SDM	TDM	RDM/SDM♦	LMR
Block	3	0.0082^{ns}	0.0497^{ns}	0.2358^{ns}	0.0082^{ns}	0,0100*
Treatment	(19)	0.0145**	0.9991**	1.9545**	0.0032^{ns}	0,0039^{ns}
Frequency (F)	1	0.0060^{ns}	4.1043**	5.2782**	0.0291*	0,0092^{ns}
Factorial[1] x F	8	0.0039^{ns}	0.1590*	0.3825*	0.0021^{ns}	0,0036^{ns}
Residual	57	0.0032	0.0739	0.1669	0.0044	0,0028
CV (%)		31.64	22.39	23.41	41.75	13.11
Mean		0.53 g	1.21 g	1.75 g	0.46	0.40
				Regression[2]		
P-L	1	0.0000^{ns}	-	-	-	0.0090^{ns}
P-Q	1	0.0005^{ns}	-	-	-	0.0004^{ns}
ECw -L	1	0.1813**	-	-	-	0.0000^{ns}
ECw -Q	1	0.0000^{ns}	-	-	-	0.0001^{ns}
P-L x ECw -L	1	0.0005^{ns}	-	-	-	0.0032^{ns}
				Regression[3] / Daily Irrigation		
P-L	1	-	0.0206^{ns}	0.0040^{ns}	0.0008^{ns}	-
P-Q	1	-	0.0013^{ns}	0.0472^{ns}	0.0022^{ns}	-
ECw-L	1	-	9.1189**	19.9524**	0.0028^{ns}	-
ECw-Q	1	-	0.0116^{ns}	0.0010^{ns}	0.0010^{ns}	-
P-L x ECw -L	1	-	0.0415^{ns}	0.0630^{ns}	0.0001^{ns}	-
				Regression[3] / Alternated Irrigation		
P-L	1	-	0.0000^{ns}	0.0304^{ns}	0.0003^{ns}	-
P-Q	1	-	0.0264^{ns}	0.0083^{ns}	0.0004^{ns}	-
ECw-L	1	-	3.1164**	5.6146**	0.0069^{ns}	-
ECw-Q	1	-	0.0645^{ns}	0.0677^{ns}	0.0007^{ns}	-
P-L x ECw-L	1	-	0.0001^{ns}	0.1050^{ns}	0.0018^{ns}	-
				Contrasts[4]		
Y1	1	0.0213*	0.6747**	1.7547**	0.0020^{ns}	
Y2	1	0.0070^{ns}	0.1784^{ns}	0.4705^{ns}	0.0024^{ns}	

[1]Refers to the combinations between levels of irrigation water electrical conductivity and water-absorbing polymer doses, using the Box's central composite; [2]Absence of effect of irrigation frequency; [3]Considering the effect of irrigation frequency; [4]Effect of container volume (1.30 x 0.75 dm^3) for daily (Y1) and alternated (Y2) irrigation frequencies; ♦: Transformed to the function log (y +1) ; ^{ns}, * and **: Not significant and significant at 0.05 and 0.01 probability levels by F test, respectively

The effect of container volume was significant only under daily irrigation frequency, causing gain of 0.36 g (133%) in the root dry matter of seedlings grown in the larger container, i.e., it changed from 0.27 to 0.63 g when container volume increased from 0.75 to 1.30 dm^3 (Figure 1B). Mesquita et al. (2012), in papaya seedlings, and Santos et al. (2012), in passion fruit seedlings, also observed that containers with larger substrate volume led to higher accumulation of dry matter in the roots. This fact may have occurred because larger containers, besides favoring root growth in the seedlings, provide more nutrients and store a greater volume of water.

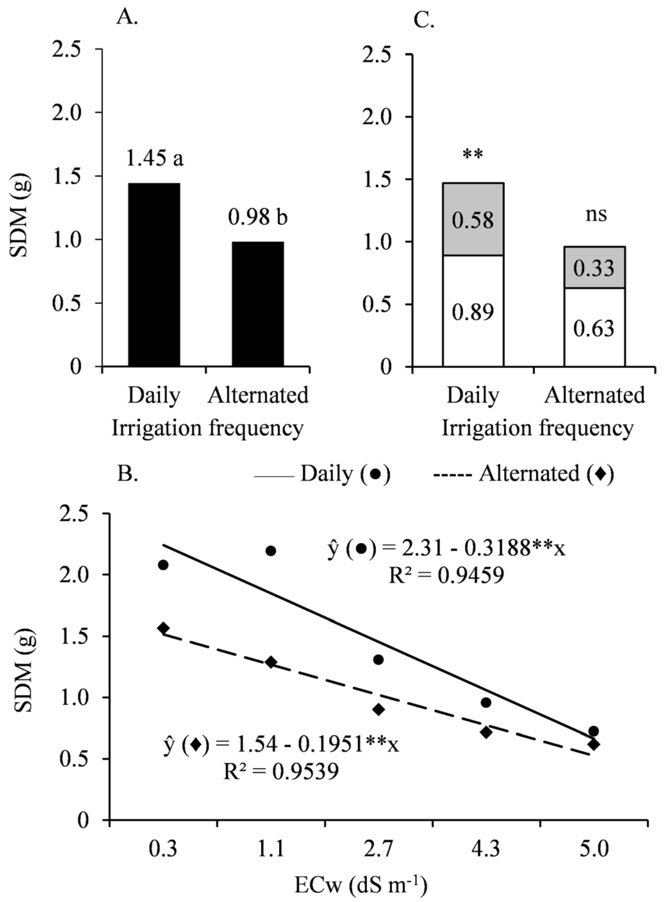
Dry matter accumulation in the shoots was affected by irrigation frequency, water salinity and container volume (Table 2). Under daily frequency, highest dry matter was obtained, decreasing by 32% (0.47 g) when the alternated irrigation frequency was adopted (Figure 2A). Increasing levels of irrigation water electrical conductivity, under both irrigation frequencies, reduced shoot dry matter in the seedlings (Figure 2B). Regarding container volume, only under daily irrigation, there was a gain of 0.58 g (65%) in shoot dry matter using a container with larger volumetric capacity, 1.47 g per seedling on average (Figure 2C).

The consequence in the increase of irrigation frequency is directly related to greater variation in water availability to the seedlings, which may lead to temporary water stress, and such stress may result in a series of deleterious effects (Oliveira et al., 2013), including the reduction in biomass production.

Effect of salinity on shoot biomass accumulation has also been observed in seedlings of papaya (Sá et al., 2013), passion fruit (Bezerra et al., 2014; Nascimento et al., 2017) and sugar-apple (Sá et al., 2015). Saline stress causes modification in leaf morphology, generally reducing leaf area and, consequently, photosynthesis (Munns & Tester, 2008), culminating in lower biomass.

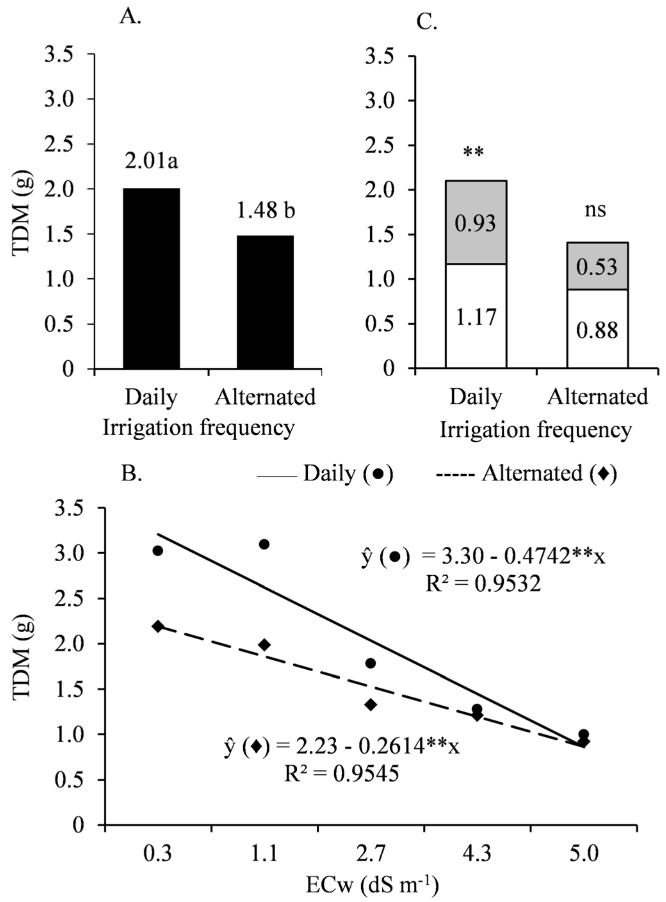
The effect of container volume on shoot biomass accumulation of seedlings is directly associated with the responses obtained in the root system, as observed in papaya seedlings, when containers with larger substrate volume led to seedlings with higher dry matter of roots and shoots (Mesquita et al., 2012).

Dry matter in sugar-apple seedlings followed the same behavior of shoot dry matter, being affected by irrigation frequency, water salinity and container volume. Under daily frequency, seedlings had more biomass (2.01 g) than under alternated frequency (1.48 g), a reduction of 26% due to the reduction in irrigation frequency (Figure 3A). The increase in irrigation water electrical conductivity, at both frequencies, reduced the total dry matter of the seedlings (Figure 3B).



Means followed by the same letter do not differ by F test ($p \leq 0.05$); ns and **Not significant and significant at 0.01 probability level by F test, respectively; ▢ Actual effect: Large container (1.30 dm^3) – Small container (0.75 dm^3)

Figure 2. Shoot dry matter (SDM) of sugar-apple seedlings as a function of irrigation frequency (A), irrigation water electrical conductivity (B) and container volume under daily and alternated irrigation frequency (C)



Means followed by the same letter do not differ by F test ($p \leq 0.05$); ns and **Not significant and significant at 0.01 probability level by F test, respectively; ▢ Actual effect: Large container (1.30 dm^3) – Small container (0.75 dm^3)

Figure 3. Total dry matter (TDM) of sugar-apple seedlings as a function of irrigation frequency (A), irrigation water electrical conductivity (B) and container volume under daily and alternated irrigation frequencies (C)

Reduction in container volume, under daily irrigation frequency, also reduced biomass production, which changed from 2.10 to 1.17 g in containers with capacity for 1.30 and 0.75 dm^3, respectively (Figure 3C).

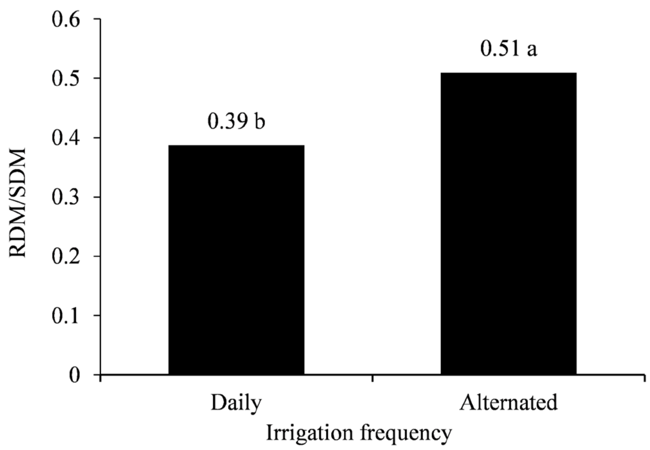
Decrease in irrigation frequency led to higher variability in water availability to the seedlings, maintaining them more susceptible to water stress. Navroski et al. (2015) report that lower values of shoot dry matter, as well as root dry matter, can be attributed to low water availability.

The lower biomass production caused by the increase in irrigation water electrical conductivity is due, initially, to the osmotic effect of the soluble salts. Increment of salinity in the root zone causes a reduction in the osmotic potential of the water in the soil, leading to greater energy expenditure in water absorption, besides loss of turgor in leaf cells, resulting in the reduction of cell elongation and division, producing smaller and thicker leaves (Munns & Tester, 2008; Saberi et al., 2011).

Root/shoot dry matter ratio (RDM/SDM) was only affected by irrigation frequency (Table 2). Sugar-apple seedlings irrigated daily had lower RDM/SDM ratio in comparison to seedlings under alternated irrigation, 0.39 and 0.51 respectively (Figure 4), indicating that under alternated irrigation frequency there was greater biomass allocation to the roots compared with seedlings irrigated daily.

The variation in dry biomass allocation between roots and shoots reflects the biometric adaptation of plants to the environmental conditions. As observed, accumulation of shoot dry matter (Figure 2B) and total dry matter (Figure 3B) decreased under alternated irrigation frequency, whereas RDM/SDM increased (Figure 4). This fact reflected the strategy of the seedlings to spend less resources in the shoots, because of the higher variation in water availability. In this context, Scalon et al. (2011) also found increase in RDM/SDM with the reduction in water availability for seedlings of *Guazuma ulmifolia* Lam. According to these authors, the decrease in water availability reduced photosynthesis, leading to lower net assimilation rate and relative growth of *G. ulmifolia* Lam.

Leaf mass ratio (LMR), which reflects the fraction of dry matter retained in the leaves and not exported to the other organs (Dantas et al., 2009), was not affected by the studied factors (Table 2).



Means followed by the same letter do not differ by F test (p ≥ 0.05)

Figure 4. Ratio between root dry matter and shoot dry matter (RDM/SDM) in sugar-apple seedlings as a function of irrigation frequency

Conclusions

1. Daily irrigation frequency was more efficient than alternated irrigation frequency with respect to biomass production.

2. The polymer did not have effect on biomass accumulation and allocation in sugar-apple seedlings.

3. Increasing irrigation water salinity caused reduction in shoot, root and total dry biomass.

4. Container with larger volume (1.30 dm^3) led to seedlings with higher dry matter.

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