DOI: <http://dx.doi.org/10.1590/1807-1929/agriambi.v20n4p364-371>

Morphological and physiological responses of açaí seedlings subjected to different watering regimes

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Key words:

waterlogging

growth

water deficit

Euterpe oleracea

ABSTRACT

Seedlings of açaí obtained from plant material native to floodplains (from Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) were cultivated between March and October 2013 in a greenhouse, to test the hypothesis that water requirement for seedling production varies according to the origin of plant material. The seedlings were subjected to watering regimes corresponding to 40, 70, 100 and 130% of field capacity. Regardless of plant material, the production of vigorous seedlings was feasible only under irrigation of 100 and 130% of field capacity. The seedlings produced under 130% of field capacity showed higher plant height, stem diameter, number of leaves, total leaf area, leaf and root biomass, total plant biomass and root/shoot ratio than those produced under 100% of field capacity. The former also showed higher net CO₂ assimilation rate, lower stomatal conductance and transpiration and higher instantaneous water use efficiency. In conclusion, the water requirement to produce vigorous seedlings of açaí does not vary within plant material and more vigorous seedlings are produced under irrigation of 130% of field capacity.

Palavras-chave:

alagamento

crescimento

déficit hídrico

Euterpe oleracea

Respostas morfológicas e fisiológicas de mudas de açaizeiros submetidas à diferentes regimes hídricos

RESUMO

Mudas de açaizeiro produzidas a partir de materiais vegetais oriundos de várzea (procedência Laranjeira e Muaná) e adaptadas às áreas de terra firme (cv. BRS-Pará e cotipo Hideo) foram cultivadas entre março e outubro de 2013, em viveiro, para testar a hipótese de que a demanda de água para a produção de mudas vigorosas varia em função da origem do material vegetal. As mudas foram submetidas a regimes hídricos correspondentes a 40, 70, 100 e 130% da capacidade de campo. Independente do material vegetal, a produção de mudas vigorosas foi viável apenas nos regimes hídricos de 100% e 130% da capacidade de campo; desses, as mudas produzidas sob 130% da capacidade de campo apresentaram maior altura, diâmetro do caule, número de folhas, área foliar total, biomassa de raízes e folhas, biomassa total e razão raiz parte aérea; além disto, apresentaram maior taxa de assimilação líquida de CO₂, menor condutância estomática e transpiração e maior eficiência instantânea do uso da água; concluindo, a demanda hídrica para produção de mudas de açaizeiro não varia com a origem do material vegetal e a produção de mudas mais vigorosas se dá pelo uso de irrigação correspondente a 130% da capacidade de campo.

INTRODUCTION

Açaí (*Euterpe oleraceae* Mart.) is a very important fruit in the food chain of northeastern populations, especially in the state of Pará, constituting the staple food of riverside and low-income populations (Santana & Costa, 2008). Due to the relevant nutritive value of the pulp, which has high concentrations of vitamins, fibers, fats and anthocyanins, besides antioxidant properties (Menezes et al., 2008), the consumption of açai has substantially increased. As a consequence, an increase in fruit production has been observed over the last decade (SAGRI, 2015a, b), also stimulated by the growing demand of countries such as the United States, Japan and South Korea (CONAB, 2015).

Despite its evident economic potential, the production of açai fruits comes mainly from the extractive exploitation of native trees, which naturally occur in Amazonian lowlands (Homma et al., 2006). However, part of the açai fruit production comes from commercial plantations usually installed in upland areas, without the use of irrigation, thus depending exclusively on rainfall, or with the use of empirically managed irrigation (Homma et al., 2006). Such scenario tends to change over time, due to the development of new management techniques and employment of plant materials more adapted to upland areas, such as the cultivar BRS-Pará (Conforto & Contin, 2009; Oliveira & Farias Neto, 2004) and the ecotype Hideo.

In the current scenario, one of the greatest problems associated with the expansion of açai plantations is the lack of seedlings, in quantity and quality, in order to meet the demand of the producers. This problem is partially due to the lack of adequate management in nursery operations, especially regarding seedlings irrigation, which has been totally empirical, without any criterion to guide the amount of water to be daily applied.

The use of irrigation systems for seedlings production is a management technique widely used for many crops. However, for irrigation to be efficient and the seedling to be able to express its total potential development, it is essential to take into consideration crop water demand, which considerably varies among dicotyledons (Fachini et al., 2004; Vellini et al., 2008; Carvalho et al., 2011) and monocotyledons (Barcelos et al., 2001; Ramos et al., 2002; Alves Júnior et al., 2005). The water demand necessary for the production of açai seedlings that meet the patterns of morphological quality and vigor regulated by the norm (Brasil, 1997) has not been determined yet.

Considering that the açai palm has its center of dispersion in the Amazonian lowlands and that soil water availability is not limiting due to the daily floods caused by the tides (Parolin et al., 2004), it is assumed that this crop is very demanding in water during its entire cycle, including the seedling stage. On the other hand, the phenotypical selection of materials more adapted to upland areas (such as the cv. 'BRS Pará') suggests that these plants can grow and produce in areas of lower water availability.

Given the above, doubts on the water demand of açai seedlings according to the origin of the plant material (lowland or upland) have raised the hypothesis that materials adapted to upland conditions would be less demanding in water during the formation of seedlings, compared with materials native to

lowlands. In order to test this hypothesis, morpho-physiological responses of lowland açai seedlings and materials adapted to upland areas were evaluated under different watering regimes, with the aim of (i) verifying whether the origin of the material influences water demand for the formation of vigorous seedlings and (ii) indicating, if possible, the best irrigation depth for the formation of vigorous açai seedlings.

MATERIAL AND METHODS

The study was conducted from March to October 2013, in a greenhouse covered with 100- μ m polyethylene film treated against UV radiation, at the Institute of Agricultural Sciences of the Federal University of Amazônia, in Belém-PA, Brazil (1° 27' 19" S; 48° 26' 19" W). The local climate is Af, according to Köppen's classification. The seedlings of the four plant materials were produced using seeds. For lowland materials, the seeds were obtained from local markets in the islands of Muaná (1° 19' 46" S; 49° 17' 0" W) and Laranjeira (1° 31' 2" S; 48° 31' 7" W) in Northern Pará, which are approximately 98 km distant from each other on a straight line. These materials do not constitute varieties, cultivars or ecotypes and were used in the experiment to guarantee the lowland origin; hereinafter, they will be referred to as "Muaná origin" (or simply Muaná) and "Laranjeira origin" (or simply Laranjeira). The materials adapted to upland areas came from seeds of the cv. BRS-Pará (registration n° 11.300 RNC/MAPA, provided by the Embrapa Eastern Amazon, Belém, PA) and the ecotype Hideo (obtained from a local producer, in Santa Izabel, PA).

The seedlings were produced on polyethylene trays (50 x 33 x 10 cm) using coconut fiber (Golden Mix 87, Sococo Agroindústria da Amazônia, Ananindeua-PA, Brazil) as a substrate. After 47 days of sowing, seedlings with only one closed leaf (known as "toothpick seedlings") were transferred to polyethylene bags (15 x 25 cm) containing a mix of soil and weathered poultry litter (2.5:1; v/v). The soil used as a substrate was a medium-textured Yellow Latosol, which was air-dried and sieved. Seedlings were daily irrigated using pressure-compensating drippers (PCJ, Netafim, São Paulo, Brazil), with flow rate of 1.92 L h⁻¹ per emitter. The dripper was adjusted in order to maintain the soil close to field capacity (FC) and the volume of water was determined through the gravimetric method (Klar et al., 1966).

Foliar fertilizations with macro and micronutrients were performed by applying a solution of the commercial product FHHF (Heringer, São Paulo, Brazil) at the proportion of 4 g L⁻¹. The applications were performed every 30 days from the transplantation to the definitive bags, using 3.9 mL of the solution per plant.

The experiment started when seedlings showed one cotyledon leaf, mean height of approximately 10 cm from the collar base to the tip of the petiole and mean collar diameter of 4.5 mm. The seedlings were subjected to different watering regimes (WR) corresponding to daily water replenishments of 40, 70, 100 (control) and 130% of field capacity (FC). The WRs were established through the differential regulation of the operating time of the drippers. The water volume applied in each WR was calculated always after weighing the experimental

units (bag + seedling + substrate), based on the methodology of Klar et al. (1966). Irrigations were daily performed, between 7:30 and 8:00 a.m.

During the experiment, daytime means of air temperature (T_{air}), relative air humidity (RH) and incident radiation (IR), determined by an automated weather station (HOBO U12-012, Onset Computer Corporation, Bourne, USA), were respectively 34 °C, 61% and 390 $\mu\text{mol m}^{-2} \text{s}^{-1}$. The mean vapor pressure deficit, determined according to Murray (1967), was 2.3 kPa.

Plants were evaluated before treatment application (Day 0) and at 45, 90, 135 and 180 days after WR application. The period of the experiment (180 days) was determined based on the normative regulation for the production of açaí seedlings (Brasil, 1997). On each evaluation date, the following variables were determined: plant height (PH), collar diameter (CD), number of leaves (NL), total leaf area (TLA), leaf dry matter (LDM), root dry matter (RDM), total dry matter (TDM), water potential (Ψ_w) and gas exchanges.

PH was measured using a ruler from the collar base to the petiole tip of the highest leaf. CD was determined with a digital caliper and NL through direct count of the emerged leaves.

Net CO_2 assimilation (A), stomatal conductance to water vapor (g_s) and transpiration (E) were determined with an infrared gas analyzer (LCpro, ADC Bioscientific Ltd., Hoddesdon, RU) from 9 and 10 h, under ambient CO_2 concentration and photosynthetically active radiation of 900 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Instantaneous water use efficiency (A/E) was calculated as the ratio between A and E. Immediately after the evaluation of gas exchanges, the same leaf was collected for the determination of Ψ_w using a Scholander-type pressure chamber (m 670, Pms Instrument Co., Albany, USA) (Pinheiro et al., 2008).

After the determination of the above mentioned variables, the seedlings were removed from the bags and separated into roots and shoots. Leaves were separated from the petioles and leaf blades were digitized using a scanner for the determination of leaf area, with the program ImageJ (v.1.47, National Institute of Mental Health, Bethesda, USA). TLA was calculated as the sum of all the folioles. The root system was carefully washed in running water, using a fine-screen sieve, in order to remove the substrate. Then, folioles, petioles and root system were placed in paper bags and dried in a forced-air oven at 70 °C until constant mass, for the determination of their respective dry matters. LDM was calculated as the sum of leaf blade dry matter (LBDM) and petiole dry matter (PDM). TDM was calculated as the sum of RDM and LDM; AFE, as the ratio between TLA and LBDM, and R/S, as the ratio between RDM and LDM.

The experiment was conducted in a completely randomized design and the treatments consisted of combinations between WR (40, 70, 100 and 130% FC), plant materials (Muaná, Laranjeira, BRS-Pará and Hideo) and evaluation periods (0, 45, 90, 135 and 180 days after WR differentiation), with five replicates per treatment. One plant per bag was considered as an experimental replicate. Statistical analysis for morphological and physiological data was performed only at the end of the experiment (day 180) in order to compare the final quality of the produced seedlings as a function of the WRs. The data

were subjected to ANOVA and the comparisons of means were performed through the Newman-Keuls test ($p < 0.05$) using the program SAEG v. 9.1 (SAEG, 2007).

RESULTS AND DISCUSSION

The watering regimes of 40 and 70% FC caused lower plant growth in all materials (Figures 1 and 2). This response occurred due to the lower values of Ψ_w , A, g_s and E shown by the plant materials at the days 45 (40% FC) and 90 (70% FC) (Figure 3). Under water deficit, the reduction in Ψ_w leads to greater stomatal closure in order to reduce the loss of water through transpiration, but the lower g_s increases the resistance to CO_2 flow into the leaves, decreasing A (Chaves et al., 2009). Reduction in Ψ_w , combined with reductions in A, g_s and E, was also reported in coconut (Gomes et al., 2010), peach palm (Ramos et al., 2002; Alves Júnior et al., 2005) and oil palm (Suresh et al., 2010; Silva et al., 2016), subjected to water deficit with negative effects on vegetative growth. WRs of 40 and 70% favor the death of 100% of the plants from all the materials at 45 and 90 days of experiment, respectively (Figures 1 and 2); thus, these WR values make the production of açaí seedlings unviable. Such high mortality of seedlings under water restriction may have been due to a combined effect of the severity of the stress, resulting from the limited daily replenishment of water at the WR of 40 and 70% FC and especially from the period in which plants were subjected to these WRs (45 and 90 days). The sensitivity of açaí seedlings to water deficit was also evidenced in seedlings planted in areas of secondary vegetation in the municipality of Bragança-PA, when a high mortality of seedlings (90%) occurred in the dry months (Sousa & Jardim, 2007b).

From 90 days of experiment on, the seedlings of all plant materials subjected to the watering regimes of 100 and 130% FC showed more expressive increments in PH, CD, NL and TLA (Figure 1). Indeed, increments in LDM, RDM and TDM were also observed from 90 days on, especially in seedlings under 130% FC (Figure 2). On the day 180, PH and CD did not differ ($p > 0.05$) between plant materials subjected to WR of 100% FC, but at the WR of 130% FC, the highest PH mean was observed for BRS-Pará and the lowest one for Hideo, while the highest CD mean was observed for Hideo and the lowest one for BRS-Pará (Table 1). According to WR effects on each plant material, the results indicate that only the WR of 130% FC induced the formation of seedlings with greater PH and CD, and means that meet the determinations of the norm (Brasil, 1997).

NL mean did not differ significantly between plant materials compared under WR of 100% FC or 130% FC (Table 1); however, the effect of different WRs for a same plant material indicates that plants subjected to 130% FC show higher NL compared with plants under 100% FC (Table 1). It should be pointed out that only plants subjected to 130% FC showed, in 180 days, definitive leaves, as recommended in the norm proposed by CSM-PA (Brasil, 1997).

All plant materials subjected to WR of 40 and 70% for 45 days showed lower absolute values of TLA in comparison to those subjected to 100 or 130% FC. This effect was more evident

The data refer to the mean $\pm$ standard deviation (SD) of five replicates

Figure 1. Plant height (PH), collar diameter (CD), number of leaves (NL) and total leaf area (TLA) in seedlings of açaí native to lowland areas (Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) cultivated under different watering regimes

Table 1. Morphology of shoots (plant height - PH; collar diameter - CD; number of leaves - NL and total leaf area - TLA) of seedlings of açaí native to lowland areas (Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) cultivated under different watering regimes[#]

Plant material	Watering regime (% FC)	Variables			
		PH (cm)	CD (mm)	NL (Unit)	TLA (cm²)
Laranjeira	100	26.8 $\pm$ 1.9 Ba	14.4 $\pm$ 1.6 Ba	6.6 $\pm$ 0.54 Ba	341.4 $\pm$ 21.3 Ba
	130	40.5 $\pm$ 4.2 Aab	22.3 $\pm$ 0.6 Aab	7.4 $\pm$ 0.54 Aa	425.7 $\pm$ 35.8 Aa
Muaná	100	23.2 $\pm$ 3.2 Ba	11.7 $\pm$ 3.3 Ba	5.6 $\pm$ 0.90 Ba	246.6 $\pm$ 28.7 Bc
	130	40.8 $\pm$ 5.3 Aab	21.4 $\pm$ 0.7 Aab	7.0 $\pm$ 0.70 Aa	362.4 $\pm$ 27.4 Ab
BRS-Pará	100	24.4 $\pm$ 3.1 Ba	12.8 $\pm$ 1.8 Ba	5.5 $\pm$ 0.54 Ba	173.4 $\pm$ 28.3 Bd
	130	43.8 $\pm$ 4.0 Aa	20.2 $\pm$ 0.9 Ab	7.0 $\pm$ 0.70 Aa	338.1 $\pm$ 14.5 Ab
Hideo	100	23.3 $\pm$ 2.6 Ba	11.9 $\pm$ 1.2 Ba	6.2 $\pm$ 0.83 Ba	282.8 $\pm$ 31.8 Bb
	130	35.9 $\pm$ 6.1 Ab	23.4 $\pm$ 2.4 Aa	7.8 $\pm$ 1.00 Aa	444.2 $\pm$ 45.6 Aa

[#] The data refer to the evaluations at the end of the experiment (day 180) and represent the mean $\pm$ standard deviation (SD) of five replicates

Uppercase letters compare the same plant material at the two different watering regimes. Lowercase letters compare different plant materials evaluated under the same watering regime. Different uppercase and lowercase letters indicate statistical difference between the means (Newman-Keuls, $P < 0.05$)

from 90 days on (Figure 1). Since there was no leaf abscission, the lower TLA in plants under water deficit can be explained by the lower NL emerged during the experimental period and/or by the smaller expansion of folioles already emerged before the beginning of the treatments. Comparatively, a lower emergence

of leaves in açaí seedlings was observed due to the decrease in rainfall during the driest period of the year (Sousa & Jardim, 2007a) and reductions of up to 31% in TLA of açaí seedlings were observed in plants subjected to two cycles of water deficit induced by the suspension of irrigation (Mar et al., 2013).

The data refer to the mean $\pm$ standard deviation (SD) of five replicates

Figure 2. Leaf dry matter (LDM), root dry matter (RDM) and total dry matter (TDM) in seedlings of açaí native to lowland areas (Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) cultivated under different watering regimes

In plants subjected to 100% FC, the TLA was higher in seedlings from Laranjeira and lower in the seedlings of BRS-Pará; under 130% FC, the TLA was higher in seedlings from Laranjeira and the ecotype Hideo (Table 1). The effect of WR on each plant material indicates that plants subjected to 130% FC showed higher TLA than those subjected to 100% FC (Table 1). The increases of TLA in plants subjected to 100 and 130% FC can be explained by the higher NL and especially by the increase in the expansion of the leaf blade area of each foliole. Within certain limits and when water is not a limiting factor, higher TLA must favor greater photosynthetic capacity of the plant, as a whole, for increasing the efficiency of interception of light energy, necessary to the photochemical stage of photosynthesis. Additionally, higher TLA must favor the transport of water and nutrients to the shoots through the mass flow resulting from transpiration (Larcher, 2005).

LBDM means did not differ ($p > 0.05$) between the seedlings of the different plant materials under 100% FC (Table 2). Under 130% FC, LBDM means were significantly higher ($p < 0.05$) in the seedlings of Laranjeira, BRS-Pará and the ecotype Hideo, in comparison to the seedlings from Muaná (Table 2). For all plant materials, LBDM was higher under 130% FC than under 100% FC (Table 2). The differences in LBDM reflect the increases in NL and TLA observed in plants subjected to 130% FC in relation to those subjected to 100% FC, as previously demonstrated with açaí seedlings under full irrigation (Mar et al., 2013).

RDM in plants cultivated under 100% FC in seedlings from Laranjeira was higher ($p < 0.05$) than in the other plant materials, but did not differ between plant materials compared at 130% FC (Table 2). Notably, plants of all materials under WR of 130% FC showed RDM expressively higher (from 290 to 570%) than the respective plants cultivated under 100% FC, indicating that the former showed a more robust root system than the latter (Table 2). In addition, it was observed that R/S ratio did not differ between plant materials cultivated under 100% FC, but under 130% FC, it was significantly higher ($p < 0.05$) in plants from Muaná and the ecotype Hideo (Table 2). It should be pointed out that WR of 130% FC induced a significant increase in R/S ratio of plants from Muaná, the ecotype Hideo and the cv. BRS-Pará (Table 2).

Based on the results obtained for LBDM, PDM and RDM, the highest TDM in plants cultivated under 100% FC was observed in the seedlings from Laranjeira and the lowest one in seedlings of the ecotype Hideo. Under 130% FC, TDM was higher for seedlings from Laranjeira, cv. BRS-Pará and ecotype Hideo (Table 2). The WR of 130% FC caused higher total biomass in the plants, compared with the WR of 100% FC (Table 2).

The Ψ_w of all plant materials cultivated under 100 or 130% FC was similar along the period (Figure 3 and Table 3). The A of plants cultivated under 100% FC was higher ($p < 0.05$) for the seedlings from Laranjeira and lower for the seedlings of BRS-Pará, but differences between plant materials stopped occurring

The data refer to the mean $\pm$ standard deviation (SD) of five replicates

Figure 3. Water potential (Ψ_w), net CO_2 assimilation rate (A), stomatal conductance to water vapor (g_s), transpiration (E) and instantaneous water use efficiency (A/E) in seedlings of açaí native to lowland areas (Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) cultivated under different watering regimes

when plants were compared under 130% FC (Table 3). g_s , E , and A/E did not differ between plant materials compared under the same WR (100 or 130% FC, Table 3); however, all the plant materials subjected to 130% FC showed significant reductions in g_s and E , along with increases in A/E , compared with the respective plants subjected to 100% FC (Table 3).

The differences in A , g_s and E between WRs of 100 and 130% FC cannot be explained by the Ψ_w values recorded for these plants from 9 to 10 h, since they did not differ significantly along the experiment (Figure 3). However, it should be pointed out that Ψ_w decreases along the day due to the increases in air temperature, radiation and water vapor deficit between

the leaf and the atmosphere and reduction in relative air humidity (Cordeiro et al., 2009; Carvalho et al., 2013). Since the replenishment of 130% FC leads to greater volume of water applied, it can be inferred that this additional water volume causes greater expansion of the wet bulb in the substrate (Maia & Levien, 2010), allowing the occupation of micropores and part of the macropores by water, without causing hypoxia and/or anoxia to plants, which are common in conditions of partial or prolonged flood in the soil. Thus, the water excess of 30% in relation to the WR of 100% FC means more water available to the roots, supplied by the longer time of operation of the drippers in this treatment, which must allow plants under the

Table 2. Biomass allocation (leaf blade dry matter - LBDM; root dry matter - RDM and total dry matter - TDM) and root/shoot ratio (R/S) of seedlings of açai native to lowland areas (Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) cultivated under different watering regimes[#]

Plant material	Watering regime (% FC)	Variables			
		LBDM	RDM	TDM	R/S
		(g DM)			
Laranjeira	100	3.52 ± 0.83 Ba	3.05 ± 0.85 Ba	10.12 ± 2.51 Ba	0.43 ± 0.02 Aa
	130	9.24 ± 1.09 Aa	8.80 ± 1.40 Aa	26.59 ± 2.70 Aa	0.49 ± 0.03 Ab
Muaná	100	2.33 ± 0.40 Ba	1.84 ± 0.62 Bb	6.49 ± 1.63 Bab	0.39 ± 0.04 Ba
	130	5.36 ± 0.80 Ab	8.50 ± 1.45 Aa	20.97 ± 2.10 Ab	0.68 ± 0.03 Aa
BRS-Pará	100	2.48 ± 0.80 Ba	1.68 ± 0.23 Bb	6.55 ± 1.29 Bab	0.37 ± 0.01 Ba
	130	8.42 ± 0.90 Aa	9.81 ± 1.29 Aa	26.78 ± 1.78 Aa	0.57 ± 0.04 Ab
Hideo	100	1.90 ± 0.30 Ba	1.72 ± 0.27 Bb	5.54 ± 0.67 Bb	0.46 ± 0.03 Ba
	130	8.61 ± 2.60 Aa	9.81 ± 1.27 Aa	24.86 ± 4.60 Aa	0.66 ± 0.05 Aa

[#] The data refer to the evaluations at the end of the experiment (day 180) and represent the mean ± standard deviation (SD) of five replicates

Uppercase letters compare the same plant material evaluated under two different watering regimes; Lowercase letters compare different plant materials evaluated under the same watering regime; Different uppercase and lowercase letters indicate statistical difference between the means (Newman-Keuls, $P < 0.05$)

Table 3. Water potential (Ψ_w), net CO₂ assimilation rate (A), stomatal conductance to water vapor (g_s), transpiration (E) and instantaneous water use efficiency (A/E) of seedlings of açai native to lowland areas (Laranjeira and Muaná) and adapted to upland areas (cv. BRS-Pará and ecotype Hideo) cultivated under different watering regimes[#]

Plant material	Watering regime (% FC)	Variables				
		Ψ_w (MPa)	A ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	g _s	E	A/E
				(mmol m ⁻² s ⁻¹)		
Laranjeira	100	-0.59 ± 0.09 Aa	7.82 ± 0.87 Aa	68 ± 12 Aa	1.42 ± 0.08 Aa	5.41 ± 0.87 Ba
	130	-0.47 ± 0.04 Aa	7.96 ± 0.68 Aa	54 ± 9 Ba	1.13 ± 0.06 Ba	7.05 ± 0.68 Aa
Muaná	100	-0.51 ± 0.03 Aa	7.11 ± 0.67 Aab	60 ± 7 Aa	1.40 ± 0.18 Aa	5.14 ± 0.98 Ba
	130	-0.67 ± 0.03 Ab	7.85 ± 0.70 Aa	50 ± 1 Ba	1.17 ± 0.06 Ba	6.73 ± 0.93 Aa
BRS-Pará	100	-0.51 ± 0.08 Aa	6.48 ± 0.60 Bb	64 ± 12 Aa	1.34 ± 0.19 Aa	4.87 ± 0.37 Ba
	130	-0.54 ± 0.04 Aab	8.16 ± 0.90 Aa	54 ± 9 Ba	1.23 ± 0.17 Ba	6.62 ± 0.69 Aa
Hideo	100	-0.50 ± 0.01 Aa	6.85 ± 0.72 Bab	60 ± 19 Aa	1.32 ± 0.05 Aa	5.19 ± 0.32 Ba
	130	-0.50 ± 0.04 Aab	8.58 ± 0.87 Aa	48 ± 4 Ba	1.10 ± 0.09 Ba	7.82 ± 1.17 Aa

[#] The data refer to evaluations at the end of the experiment (day 180) and are the mean ± standard deviation (SD) of five replicates

Uppercase letters compare the same material evaluated under the two watering regimes; Lowercase letters compare different plant materials evaluated under the same watering regime; Different uppercase and lowercase letters indicate statistical difference between the means (Newman-Keuls, $P < 0.05$)

WR of 130% FC to remain hydrated for a longer period along the day, leading to greater C gains in the photosynthesis.

The morphological results allow inferring that all the evaluated plant materials show better vegetative development under WR corresponding to 130% FC. Among the analysed variables, there was marked effect of WR on the increment of RDM and maintenance (Laranjeira) or increments (Muaná, Hideo and BRS-Pará) in R/S ratio, which indicate that these seedlings used most of the C fixed by photosynthesis for the formation of the root system, instead of the shoots. From the physiological point of view, seedlings with more robust root system and higher R/S ratio must have better capacity to adapt to the field after transplantation, because this operation tends to cause damages to the root system of the seedlings and can even lead to plant death (Larcher, 2005). Furthermore, investing in the root system is a strategy of tolerance to water stress (Pinheiro et al., 2005) and can contribute to the adaptation of seedlings during the dry months.

CONCLUSIONS

1. Açai growth and development are not possible under water replenishments equal to or lower than 70% of field capacity.
2. Regardless of plant material origin (lowland or upland), the formation of açai seedlings that meet the required quality standard is obtained under irrigation corresponding to 130% of field capacity.

ACKNOWLEDGMENTS

The authors thank Dr. Maria do Socorro Padilha (Embrapa Eastern Amazon, Belém-PA) for the donation of açai seeds, cv. BRS-Pará.

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