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Emergence and initial growth of açaí palm under different light levels after seed dormancy breaking treatments

Emergência e crescimento inicial de açaizeiro sob diferentes níveis de luminosidade após tratamentos de superação de dormência na semente

Emergencia y crecimiento inicial de açaí bajo diferentes niveles de luz después de tratamientos para superar la latencia de la semilla

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Abstract
Light availability and dormancy are two factors that interfere with germination and initial plant growth. This study aimed to evaluate the influence of different pre-germination treatments on the emergence and initial growth of *Euterpe oleracea* Mart. seedlings subjected to different levels of luminosity. A completely randomized design was adopted in a 4 × 3 factorial scheme with four methods of overcoming dormancy (intact seed, hot water at 60 °C, soaking for 24 h in water, and mechanical scarification with sandpaper No. 100) and three levels of luminosity (25 %, 65 %, and 100 %) with 16 repetitions per treatment. The emergence percentage, speed index, and mean time were analyzed. The initial growth was evaluated using the following variables: plant height, stem diameter, shoot dry mass, root dry mass, total dry mass, leaf area, and root mass ratio. There was an interaction between light factors and dormancy breakage for plant height, stem diameter, and leaf area. The variables root dry mass, shoot dry mass, and root mass ratio showed better results with full sun. It was concluded that shade treatments provided greater initial growth for the açaí palm with intact seeds.
Keywords: *Euterpe oleraceae*; Shading; Arecaceae.

Resumo
A disponibilidade de luz e dormência são dois fatores que interferem na germinação e crescimento inicial de plantas. O objetivo desse estudo é avaliar a influência de diferentes tratamentos pré-germinativos na emergência e crescimento inicial de plântulas de *Euterpe oleracea* submetidas a diferentes níveis de luminosidade. Foi adotado o delineamento inteiramente casualizado, no esquema fatorial 4 x 3, sendo quatro métodos de superação de dormência (semente intacta, água quente a 60°C, embebição por 24 h em água e escarificação mecânica com lixa nº 100) e três níveis de luminosidade (25%, 65% e 100%) e para cada tratamento utilizou-se 16 repetições. Avaliou-se a porcentagem (PE), índice de velocidade (IVE) e tempo médio de emergência (TME) e o crescimento inicial através das seguintes variáveis: altura das plantas (AP), diâmetro do colo (DC), massa seca da parte aérea (MSA), da raiz (MSR), total (MST), área foliar (AF), razão de massa da raiz (RMR) e razão raiz/parte aérea (RRPA). Houve interação entre os fatores luz e superação de dormência para AP, DC e AF. As variáveis MSR, MSA e RRPA apresentaram melhores resultados a pleno sol. Conclui-se que os tratamentos com sombra proporcionaram maior crescimento inicial para o açaizeiro em sementes intactas.
Palavras-chave: *Euterpe oleraceae*; Sombreamento; Arecaceae.

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Resumen
La disponibilidad de luz y la latencia son dos factores que interfieren con la germinación y el crecimiento inicial de las plantas. El objetivo de este estudio es evaluar la influencia de diferentes tratamientos pregerminativos en la emergencia y crecimiento inicial de plántulas de *Euterpe oleracea* sometidas a diferentes niveles de luz. Se adoptó un diseño completamente al azar, en esquema factorial 4 x 3, con cuatro métodos de superación de la latencia (semilla intacta, agua caliente a 60°C, remojo por 24 h en agua y escarificación mecánica con lija nº 100) y tres niveles de luminosidad (25%, 65% y 100%) y para cada tratamiento se utilizaron 16 repeticiones. Se evaluó el porcentaje (PE), índice de velocidad (IVE) y tiempo medio de emergencia (TME) y el crecimiento inicial a través de las siguientes variables: altura de planta (AP), diámetro de tallo (DC), masa seca de la parte aérea (MSA), raíz (MSR), total (MST), área foliar (AF), relación de masa de raíz (RMR) y relación raíz/vástago (RRPA). Hubo una interacción entre la luz y los factores de interrupción de la latencia para AP, DC y AF. Las variables MSR, MSA y RRPA mostraron mejores resultados a pleno sol. Se concluyó que los tratamientos con sombra proporcionaron un mayor crecimiento inicial de açaí en semillas intactas.
Palabras clave: *Euterpe oleraceae*; Sombreado; Arecaceae.

1. Introduction

Light availability and dormancy interfere with the germination and initial growth of plants, and are essential criteria to be considered in the production of seedlings of tropical species, including those of the Arecaceae family.

The Açai palm (*Euterpe oleracea* Mart.) is commonly found in the Brazilian regions of Pará, Amazonas, Amapá, and Maranhão. It is adapted to flooded soils and floodplains (Lorenzi et al., 1996), is among the ten most economically important palm trees in South America (Vedel-Sorensen et al., 2013), and ranks 6th among the most produced fruit trees in Brazil de acordo com o Anuário Brasileiro de Horti & Frut 2022 (Kist et al., 2022). Açaí pulp and palm hearts have been generating interest in the export market because of their high nutritional value, as they provide a source of proteins, vitamins, fibers, and lipids, and have a high caloric value (Lima, 2018).

Light capture by leaves produces organic molecules that are used to form new tissues in plants (Gurevitch et al., 2009). Therefore, changes in light availability induce morphological and physiological changes in such areas as plant height and leaf thickness, as well as the alteration of the proportion of photosynthetic tissue to non-photosynthetic tissue, leading to different biomass distributions (Poorter et al., 2010; Hodgson et al., 2011; Bachmann et al., 2018; Wyka et al., 2022; Pardos & Calama, 2022).

Species such as Euterpe edulis develop best with a maximum of 30% sunlight (Nakazono et al., 2001) and E. oleracea shows good development between 50% (Conforto & Contin, 2009) and 60% (Dapont et al., 2016) luminosity.

Seed dormancy is characterized by the inhibition of germination, even under adequate conditions (Carvalho & Nakagawa, 2012). In Arecaceae, this is one of the causes of variation in the quantity and speed of plant emergence (Reis et al., 2011; Pinto et al., 2012; Jorge et al., 2014; Silva et al., 2015). Soaking carnauba seeds (*Copernicia prunifera*) promoted a 10% higher emergence and a decreased time to emergence of 11 days compared to seeds without treatment (Reis et al., 2011). Açaí seeds (*E. oleracea*) achieved 54.4% emergence when pretreated with mechanical scarification and 8 % when untreated (Silva et al., 2015). In guariroba (*Syagrus oleracea*), pre-germination treatments, such as immersion in hot water and mechanical and chemical scarification, did not increase the germination percentage and showed varying mean emergence times in relation to untreated seeds (Reis et al., 2011).

The initial growth of seedlings influences productivity, as healthy young plants with intact leaves and well-formed roots develop an increased amount of dry mass and form a more productive adult plant. Factors such as temperature (Pivetta & Luz, 2013; Silva et al., 2020;), water (Martins et al., 2009), oxygen (Gonçalves et al., 2010), light, and seed dormancy (Pinto et al., 2012; Assis et al., 2022) can affect the initial growth of a plant.

Gama et al. (2010) recorded 97% germination in açaí seeds and Pivetta and Luz (2013) reported up to 100% germination in seeds without pre-germination treatments. Seeds that do not have a germination block, that is dormancy

(Cardoso, 2004) create seedlings that emerge earlier and in a higher percentage than those with dormancy. However, these results can be changeable, as factors other than dormancy can affect germination.

Given the above, it is believed that seeds without pre-germination treatments to overcome dormancy and subjected to greater luminosity show low and uneven germination. Therefore, this study aimed to evaluate the influence of different pre-germination treatments on the emergence and initial growth of *E. oleracea* seedlings subjected to different levels of luminosity.

2. Methodology

Ripe açaí fruits were collected in November 2018, from 10 mother plants in the Roncador community in the municipality of Codó-MA, Brazil. The fruits were taken to the multidisciplinary laboratory of the Federal Institute of Maranhão, Campus Codó for physical cleaning to eliminate unripe fruits, those damaged by insects, and vegetable debris. The fruits were then immersed in water at 40 °C, cooled, and pulped by rubbing the fruits against a 60 mesh sieve until total detachment of the epicarp and mesocarp, after which the seeds were dried in the shade.

The seeds underwent dormancy-breaking treatments consisting of intact seeds, hot water at 60 °C followed by cooling to room temperature, soaking for 24 h in water at room temperature, and mechanical scarification with sandpaper No. 100 in the region opposite the embryo. The seeds were then sown in polyethylene bags (25 × 30 cm) with a capacity of 2 L, in a substrate of soil, cattle manure, and sawdust in a volumetric proportion of 3:1:1 with a planting depth of 5 cm.

After sowing, the bags were placed under a wooden base 1 m above the ground, in a protected environment of 2 × 2 × 2 m with all sides covered with shade net. According to the manufacturer, this allowed a 25 and 65% passage of incident sunlight, without the use the screen that constituted the zero level of shading. There was no local control and the temperature and relative humidity were recorded. Irrigation was performed when necessary to maintain adequate moisture for seedling growth.

Prior to sowing, the seed moisture content was determined using the greenhouse method at 105 ± 3 °C, as described by the Seed Analysis Rules (Brasil, 2009). Four replicates of 25 seeds were used for the test.

The following variables were evaluated: emergence percentage (EP), which was determined as the number of seedlings that emerged in the first 100 days after sowing, with the results expressed as a percentage; emergence speed index (ESI) that was based on the daily count of emerged seedlings, and calculated according to Maguire (1962); and mean time of emergence (MTE), whereby data from the daily counts of emerged seedlings were used in the calculation described by Labouriau (1983).

The plants were harvested 90 d after sowing to evaluate the following variables: plant height (PH), stem diameter (SD), shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM), leaf area (LA) and root mass ratio (RMR).

The height of the plant was measured with a ruler from the level of the substrate to the tip of the last leaf; stem diameter was determined using a digital caliper; dry mass was obtained by maintaining the fresh plant material in an oven at a temperature of 70 ± 5 °C for 24 h; total dry mass was calculated as the sum of RDM and SDM; leaf area was determined using the ImageJ software; and root mass ratio was provided by dividing the root dry mass by the total dry mass.

A completely randomized design was adopted, in a 4 × 3 factorial scheme, with four treatments for overcoming dormancy and three levels of shading. Sixteen repetitions were performed for each treatment. All data, except that for EP, ESI, and MTE, were subjected to analysis of variance, followed by a comparison between the means, with the application of the Tukey test, at 5% probability using the computer program SAS versão 8.02 (SAS Institute, 2001).

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3. Results and Discussion

The moisture content of the *E. oleracea* seeds was 23.5%. The emergence results are shown in (Table 1), and it was observed that shading promoted up to 100% emergence of intact seeds. The treatments with 25 and 65% luminosity revealed the highest ESI values for all dormancy-breaking methods and for the intact seeds.

Table 1 – Percentage (EP), speed index (ESI), and mean emergence time (MTE) of *E. oleracea* seeds subjected to different light levels and dormancy-breaking methods.

Light levels	Intact seed	Hot water at 60 °C	Soaking for 24 h	Mechanical scarification
	Emergence percentage (%) - EP			
25 %	100	93.7	93.7	81.2
65 %	87.5	93.7	93.7	87.5
100 %	6.2	37.5	6.2	18.7
	Emergence speed index - ESI			
25 %	7.1	7.2	7.0	4.6
65 %	4.8	6.4	6.0	4.8
100 %	0.1	3.4	0.2	2.3
	Mean emergence time (days) - MTE			
25 %	3.3	3.4	4.0	4.6
65 %	4.0	4.3	4.8	4.7
100 %	7.0	4.6	5.0	1.6

Source: Authors.

The moisture content of *E. oleracea* seeds was below the values found by Gama et al. (2010) and Pivetta and Luz (2013), who reported humidity levels of 38% and 39.9%, respectively. According to Oliveira et al. (2002), Nascimento and Silva (2005), and Nascimento et al. (2010), germination of this species is unfeasible at values lower than 15% because of its recalcitrant nature.

The emergence results are shown in Table 1, reveals that shading promoted up to 100% emergence at the two shade levels with the intact seeds, indicating that the species does not present an impediment to germination when the light is low or moderate. This contrasts the results of Silva et al. (2015) who showed improved EP results with scarified seeds, but corroborates those of Pivetta and Luz (2013), who obtained 95% germination in this species without pre-germination treatment. However, in the treatment with 100% light and with application of dormancy breaking, the PE ranged from 6.2% to 37%, indicating that in the presence of light, the seed of *E. oleraceae* can develop physiological dormancy.

The treatment with 100% luminosity increased the MTE for intact seeds, reaching emergence at 7 d, which is 4 days more than that of the 25% luminosity level. The same behavior was observed by Reis et al. (2011) with *Copernicia prunifera*, in which the presence of light increased the MTE to 11 days, and shading promoted 80% germination and increased the ESI. The scarified seeds emerged at 2 d, but only at 18.7%, while the intact and shaded seeds reached 100% emergence.

The analysis of variance in (Table 2) shows that there was an interaction between the light and dormancy-breaking factors for stem diameter, plant height, and leaf area, and that the light level caused significant differences in all variables, while the dormancy-breaking factor was significant for SD, PH, and LA.

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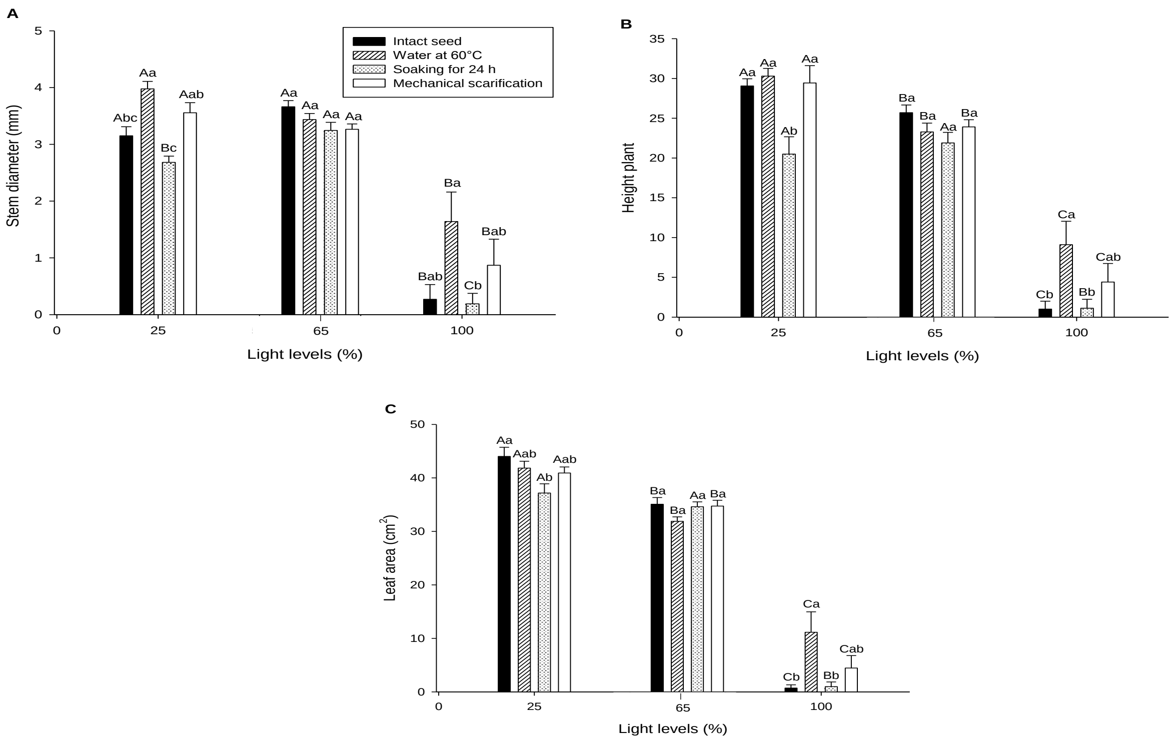
Table 2 – Summary of analysis of variance in *E. oleracea* seedlings grown from seeds subjected to different light levels and dormancy breaking treatments at 100 days after planting.

Sources of variation	**Mean squares**				
	A	**B**	**Interaction AxB**	**Residue AxB**	**CV (%) AxB**
SD	119,3890*	6,5267*	1,8778 *	0,7823	35,4
PH	8262,0075*	286,4656*	102,3424 *	30,8345	30,3
SDM	1,3893*	0,0582^{ns}	0,0313^{ns}	0,0296	70
RDM	0,9471*	0,0217^{ns}	0,0143^{ns}	0,0088	39
LA	19689,3622*	99,7082*	175,7473*	37,2808	23
TDM	4,6286*	0,1134^{ns}	0,0558^{ns}	0,0495	45
RMR	0,0246*	0,0188^{ns}	0,0088^{ns}	0,0051	14,1
DF	2	3	6	144	

*, significant at 5 %; ns, not significant; SD, stem diameter; PH, plant height; SDM, shoot dry mass; RDM, root dry mass; LA, leaf area; TDM, total dry mass; RMR, root mass ratio; DF, degrees of freedom; CV, coefficient of variation; A, luminosity; B, overcoming dormancy. Source: Authors.

The average stem diameter, plant height, and leaf area are shown in (Figure 1A, Figure 1B and Figure 1C). With 65% luminosity, the dormancy-breaking methods did not influence these variables, as all values were similar to those from plants with intact seeds.

Figure 1 – Stem diameter (A), plant height (B) and leaf area (C) of plants emerging from *E. oleracea* seeds subjected to different light levels and dormancy-breaking methods. Means followed by the same upper letter for the light levels and lowercase letters for the methods of dormancy-breaking methods, do not differ by Tukey's test at 5% probability.



Source: Authors.

The use of dormancy-breaking methods increased stem diameter values at 25 % luminosity (Figure 1A). The methods with hot water at 60 °C and mechanical scarification obtained the largest diameters of 3.97 mm and 3.55 mm, respectively. However, the 24 h soaking method returned similar results to those of the intact seeds.

Analysis of the initial growth of *E. oleracea* at 25 % light using the soaking method for 24 h showed that the plant height was less than that of intact seeds, seeds subjected to water at 60 °C, and those enduring mechanical scarification with sandpaper. In the study by Silva et al. (2015), there was no difference in this variable between the methods with hot water and mechanical scarification.

At 25% luminosity using the 24 h soaking method, the plant height was less than those of intact seeds, as well as those subjected to water at 60 °C or mechanical scarification with sandpaper (Figure 1B). With a decrease in luminosity, plants grown from intact seeds obtained greater heights at 25% and 65% luminosity, with 29.05 cm and 25.7 cm, respectively.

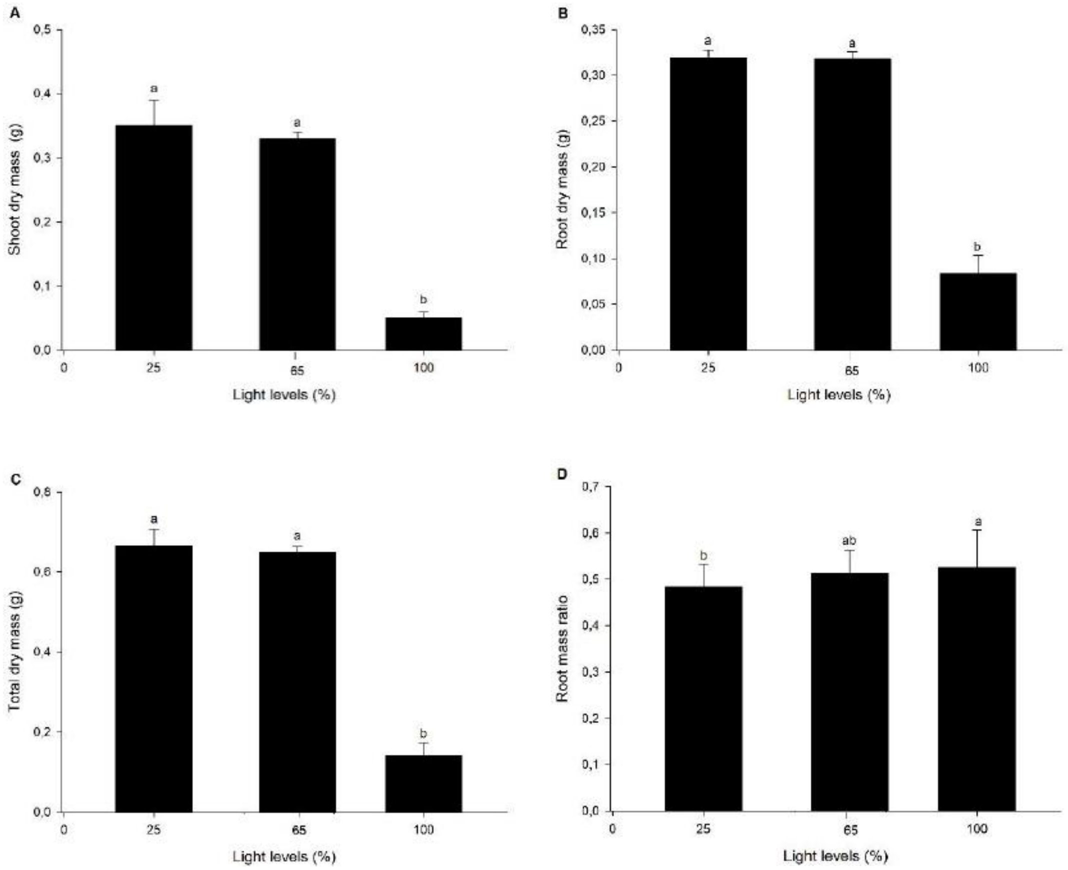
Dapont et al. (2016) found that the growth of açaí was reduced with light restrictions above 50%, which agrees with the observations of this study, and Conforto and Contin (2009) reported no effect between 50% and 84% luminosity on the height of young açaí plants.

Plant height and leaf area were inversely proportional to the light level, with increased light resulted in decreased PH and LA values. The leaf area at the 25 % luminosity level with the use of the 24 h soaking method obtained the lowest value (37.17 cm2), which was similar to that of the treatments with water at 60 ºC (41.84 cm^2) and mechanical scarification (40.92 cm2; Figure 1C). The latter two values were similar to that of intact seeds (44.02 cm^2), which showed the highest value for this variable.

Plant height may not be a strong indicator of quality in shading studies, as low light intensity can induce etiolation or favor a low leaf temperature, which stimulates stomatal opening and carbon fixation (Dias & Marenco, 2007) therefore, plant dry mass results combined with height can provide more accurate conclusions.

There was no significant difference between shade treatments for root, shoot, and total dry mass, and the root mass ratio (Figure 2A, Figure 2B and Figure 2C). However, there was a difference between these results and those in full sunlight, revealing that light reduction increases dry mass in *E. oleracea*. Silva et al. (2020) observed the same behavior for *Macroptilium lathyroides* seedlings submitted to different temperatures in the presence and absence of light.

Figure 2 – Shoot (A), root (B), and total dry mass (C), and root mass ratio (D) of plants emerged from E. oleracea seeds subjected to different light levels and dormancy-breaking methods.



Source: Authors.

The root mass ratio results at the 25% luminosity level were lower than those at the 100% level. By relating the height values to the shoot and total dry mass values presented in Figure 2, which were equal for the 25% and 65% light levels, the gain in plant height between the two shading levels did not reflect dry mass gain, indicating that etiolation occurred.

As there was a decrease in leaf area with increasing light level, the species appears to adapt well to shading, since shaded leaves are thinner, thicker, and larger (Bachmann et al., 2018). The results of this study are in agreement with those of Conforto and Contin (2009), who observed a greater leaf area for *E. oleracea* with reduced light.

Considering that at 25 % luminosity, the plants from intact seeds had greater leaf areas, it is noteworthy that dormancy-breaking methods did not favor an increase in leaf area when the species was grown in the shade. For guariroba (*S. oleracea*), a species of the Arecaceae family, the use of dormancy-breaking methods interfered with leaf length, with immersion in water for 12 and 48 h, providing the highest values at 30 d after emergence (Pinto et al., 2012).

Overcoming dormancy interfered with plant height, stem diameter, and leaf area at 100 % luminosity; however, these variables showed lower values at this level than at 25 % and 65 % illumination, indicating that young açai plants are harmed by excess sunlight. According to Oliveira et al. (2002), this species must be kept under 50% shading during the seedling formation phase, while Dapont et al. (2016) analyzed the initial growth of *E. oleracea* and found that full sun was harmful to the species.

Dapont et al. (2016) found that plants grown in 20%, 30%, 50%, 65%, 82%, and 100% shading had significant differences in dry masses between the shade treatments and between shade and full sun, with the latter being the least effective treatment for the variables under study. This was verified by Nakazono et al. (2001) for E. edulis in plants under 20%, 30%, 50%, 70%, and 100% light. These results agree with those of the present study, in which only two shading levels were tested. Both Dapont et al. (2016) and Nakazono et al. (2001), showed improved performance of plants in a shady environment in relation to that of full sun.

The root mass ratio results at the 25% luminosity level were lower compared to the 100% level, indicating that shading provided a greater investment in the aerial part than in the root system, which reflected the greater assimilation of sunlight in shaded plants than that of plants under full sun, and the initial growth of *E. oleracea* was favored with the shading condition. For the variable RMR in initial growth of Arecaceae, there are no results in the literature, Assis et al (2022) analyzed the initial growth of an Asteraceae to *Artemisia alba*, at 100%, 60% and 20% of luminosity and the authors did not found differences in RMR results.

4. Conclusion

Light attenuation in intact seeds provided better emergence of açaí tree seedlings in the greenhouse and improved the physiological parameters for the initial growth up to 100 days. Treatment for overcoming dormancy after soaking for 24 h is not recommended, while the treatments with water at 60 °C and scarification with sandpaper did not interfere with emergence and initial growth. The high luminosity can promote a physiological dormancy in the studied species.

The results showed in this study support the analysis of physiological dormancy in the presence and absence of light in future studies. The use of gibberellic acid in açaí seeds with and without the presence of light has not yet been found in the literature. This information may help to clarify the following question. Does açaí seed show physiological dormancy when exposed to high incidence of sunlight?

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