

EVALUATION OF THE GROWTH AND SURVIVAL OF MANGROVE SEEDLINGS UNDER DIFFERENT LIGHT INTENSITIES: SIMULATING THE EFFECT OF MANGROVE DEFORESTATION

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ABSTRACT – Environmental factors, especially light, temperature, and edaphic conditions are of great importance for the establishment of plant communities. In areas degraded by deforestation, these factors can vary greatly, which may affect the recolonization of the typical populations in the altered area. This study evaluated the development of seedlings of pioneer mangrove species under different levels of shading in soil substrate degraded by deforestation, aiming to assess the effect of deforestation on the recolonization of mangrove forests, which may be of help in the production of seedlings and recovery of deforested areas. The study was conducted in the municipality of Acaraú in the state of Ceará, Brazil. The species *Avicennia schaueriana* Stapf and Leechm. ex Moldenke (1939) and *Laguncularia racemosa* C. F. Gaertn (1807) were used in the study, and the substrate was collected from an area impacted by deforestation. The propagules and seedlings were exposed to full sun and 30, 50 and 70% shading. The results revealed that the treatment at full sun had the lowest germination rate of 86.66% for *L. racemosa*. Seedlings of both species showed a significant difference and better quality between shading treatments and full sun. The height of the seedlings showed a correlation above -0.90 with ambient temperature. *L. racemosa* tested in full sun had a viable seedling reduction of 50% and *A. schaueriana* was superior. It is concluded that the natural regeneration of a mangrove area can be compromised under the conditions of total deforestation with high sun exposure and degraded soils. Human intervention in providing 50% shading is essential for the development of seedlings and regeneration of the area impacted by deforestation.

Keywords: Mangrove recovery; Seedling production; Plant development.

AVALIAÇÃO DO CRESCIMENTO E SOBREVIVÊNCIA DE PLÂNTULAS DE MANGUE SOB DIFERENTES INTENSIDADES LUMINOSAS: SIMULANDO O EFEITO DO DESMATAMENTO DOS MANGUEZAIS

RESUMO – Os fatores ambientais, principalmente a luminosidade, temperatura e as condições edáficas são de grande importância para o estabelecimento da comunidade vegetal. Em áreas degradadas por desmatamento, esses fatores podem passar por alterações de grande magnitude, podendo afetar a recolonização das populações típicas da área alterada. Neste contexto, o objetivo deste estudo foi avaliar o desenvolvimento de plântulas de espécies pioneiras de mangue sob diferentes níveis de sombreamento, em substrato de solo degradado pelo desmatamento, visando o efeito do desmatamento na recolonização das plântulas de mangue e gerar subsídios para a recuperação de áreas desmatadas e produção de mudas. O estudo foi realizado no Instituto Federal do Ceará, localizado no Município de Acaraú no Estado do Ceará, Brasil. Para o experimento foram escolhidas as espécies *Avicennia schaueriana* Stapf and Leechm. ex Moldenke (1939) e *Laguncularia racemosa* C. F. Gaertn (1807). O substrato para produção das mudas foi coletado em área impactada por desmatamento, apresentando baixa fertilidade e de textura franco argilosa. As plântulas foram testadas a



pleno sol e sob níveis de 30%, 50% e 70% de sombreamento. Os dados obtidos foram altura, diâmetro do coleto, anotações das condições fenológicas das plântulas, matéria fresca, matéria seca da raiz, parte aérea e a temperatura ambiente dos viveiros. Os resultados revelaram que em condições de desmatamento total da área de mangue, gerando alta luminosidade e solos degradados, a regeneração natural é comprometida, sendo essencial a intervenção humana, com sombreamento de 50% para uma boa estabilidade de plântulas.

Palavras-Chave: Recuperação de manguezais; produção de mudas; desenvolvimento de plantas.

1. INTRODUCTION

Mangroves are ecosystems established in coastal areas with average temperatures above 16 °C, brackish water, unconsolidated soil, and characterized by interactions between soil, freshwater and seawater (Saenger, 2002; Tomlinson, 2016; Duke, 2017). The mangrove forest is a component of great importance to the mangrove ecosystem, providing essential resources for the survival of numerous species, including humans, besides promoting the control of hydrodynamics and erosion, protecting against storms, and stabilizing climatic conditions along the coastline (Alongi, 2008; Lee et al., 2014).

Mangrove forests in the state of Ceará are composed of four plant species, namely *Avicennia germinans* L. (Stearn 1958), *A. schaueriana*, *Laguncularia racemosa*, and *Rhizophora mangle* L. (1753), while another species, *Conocarpus erectus* L. (1753), occupies higher ground and receives low tidal influence (Camargo Maia and Coutinho, 2012; Vale and Schaeffer-Novelli, 2018). Anthropogenic changes in the environment have a strong impact on this area, such as the deforestation of mangroves for firewood and charcoal, residential construction, making fishing artifacts, and various developments (Maia et al., 2018).

The canopy of mangrove forests can present a wide variety of sunflecks, depending on the plant species, arrangement of canopies, and conservation of the mangrove ecosystem (Asaeda et al., 2016). Sunflecks are small spaces in the canopy structure of a forest where the light passes through. Therefore, they are essential for the germination and growth of propagules, seedlings, and juvenile plants in the soil of mangroves (Maciel et al., 2002). Intense changes in this environment, such as deforestation, will result in a great increase in light as reported by Querino et al.

(2013), albedo elevation of 49%, fertility decline, and soil destruction and loss (Arruda, 2013).

These changes affect mangrove seedlings, influencing their establishment, early development and resilience (Clarke, 2004; Krauss et al., 2008; Balke et al., 2015). The adaptation of plant species to new environmental conditions, particularly light, is especially important in juvenile plants because it conditions morphogenetic and physiological alterations in their structure and function, determining the success of regeneration (Pérez et al., 2017).

In the case of mangrove forest species, studies addressing issues such as seedling development under different shading levels and recolonization of clearings are scarce. Hence, this study evaluated the development of seedlings of pioneer mangrove species under different levels of shading in soil substrate degraded by deforestation, aiming to assess the effect of deforestation on the recolonization of mangrove seedlings and generate subsidies for the recovery of deforested areas and production of seedlings.

2 MATERIAL AND METHODS

2.1 Study area

The study was carried out at the Federal Institute of Ceará - Acaraú *Campus* (-2.889037 °S and -40.113054 °W) located in the Municipality of Acaraú in the State of Ceará, Northeastern Brazil. According to the aridity index (AI) from several rainfall stations in the state of Ceará (Funceme, 2017), the municipality shows a sub-humid type of regional climate ($65 \leq AI < 100$). Data from the National Institute of Meteorology (INMET) (Lima Junior et al., 2016) showed a mean annual temperature of 27.6 °C, relative humidity (RH) of 80.73%, and wind speed of 4.2 m/s in the period of 1976 to 2011.

2.2 Choice of species and procedures with propagules, substrate and irrigation

The species *A. schaueriana* and *L. racemosa* were chosen because they are pioneer mangrove species (Costa et al., 2014). Propagules were collected near the Curral Velho village in the municipality of Acaraú - CE (-2.889037°S and -40.077642°W), according to Silva and Maia (2018). The propagules were collected by manual harvesting, found on the soil, and they were viable and non-germinated. Propagules were visually sorted for apparent health and size in the laboratory to select propagules with similar characteristics. Propagules were subsequently washed in running water, immersed in 1% sodium hypochlorite (NaClO) for 5 min for disinfection, and washed again in running water according to Silva and Maia (2018).

The substrate for seedling production was collected between zero and 20 cm deep in the first layer of soil and 15 m from the riverbank in an area impacted by deforestation (-2.876921°S and -40.126909°W), because most environmental factors undergo modifications in deforested areas (Arruda, 2013). This collection method was chosen to avoid the soils of the riverbank where nutrient concentration is maintained in the system, mainly due to the mixing of fresh water with salt water (Baran and Hambrey 1998; Alves, 2001).

The substrate was sun-dried, fragmented into small-sized clumps and homogenized, ensuring greater uniformity. Afterwards, the propagules were sown and irrigated using the public water supply. The seedlings were irrigated with 40 ml/plant on average in each treatment, twice a day, at 8 am and 5 pm.

2.3 Time of experiment, design, evaluation, and data collection

The study was carried out from May to July of 2017 (60 days), ending when the development of the seedlings was considered completed. The beginning of the juvenile phase, on average 60 days after sowing, is recognized by the loss of the cotyledons (embryonic leaves) in *L. racemosa* and *A. racemosa* and by the formation of adult-like leaves representing the end of the supply of compounds from the embryonic (Oliveira, 2017).

We used a 2 x 4 x 3 factorial completely randomized design (two species, four levels of shading, and three replications). Each treatment contained ten seedlings of each species, totaling 240 seedlings (10 seedlings x 2 species x 4 treatments x 3 replicates). The seedlings were exposed to full sunshine (0% shading) and levels of 30, 50 and 70% shading using polyethylene screens. The seedlings were monitored daily, and data on plant structure and germination percentage were collected every eight days after the stems were completely erect and showed the first pair of leaves in *A. schaueriana* and *L. racemosa*.

The structural data collected were height, root-collar diameter (RCD), and phenological conditions of seedlings (coloration and number of leaves and branches). A graduated ruler was used to measure height, and an analog caliper with an accuracy of 0.005 mm was used to measure the RCD.

The Dickson quality index (DQI) (Dickson et al., 1960) was used to obtain structural height (H) and RCD data using nine randomly collected seedlings of each species (three seedlings per replicate per treatment). Subsequently, the aerial part of the root system was separated and dehydrated at 60 °C for 20 h in a drying oven to obtain root, shoot, and total dry matter. A precision balance (SHIMADZU AY220), with a precision of 0.0001 g, was used to weigh fresh matter and root and shoot dry matter. The following formula was used to calculate the quality index: $DQI = \frac{\text{total dry matter}}{((H+RCD+\text{aerial dry matter})/(\text{root dry matter}))}$.

For the analysis of total dry matter and water content of the seedling (total fresh matter minus total dry matter) the data obtained for DQI were used. The temperature of the experimental units was measured using a mercury thermometer placed for seven minutes in each experimental unit during the hottest period of the day, between 2 and 4 pm; these data were collected twice a month.

2.4 Statistical analysis

Descriptive analysis was performed on the following parameters: number of viable plants, percentage of germination, and physiological and phenological characteristics. Two-way ANOVA was used (species and treatment) to evaluate the height, RCD, dry matter and water content data. One-way

ANOVA was performed to analyze the variation in RCD during the experimental time. Tukey's test was used to compare results when differences between treatments were observed at a 95% confidence interval. Linear correlation analysis was conducted to verify the correlation between shading percent and germination rate, height, and temperature in the experimental units. Pearson's correlation was used in three sample pairs with 12,000 simulations at a 95% confidence interval, resulting in the r correlation.

3 RESULTS

The results showed that germination rates were good for both species tested (Table 1). *A. schaueriana* had rates above 90% and the treatments with 50 and 0% shading reached 100% germination; however, 0% shading did not maintain 100% of seedlings during the experiment time. We also found that the higher the level of shading the better the germination rate in the first week; thus, better germination rates were achieved with greater shading, with a positive Pearson correlation of $r = 0.9852$. On the other hand, the propagules of *L. racemosa* in the treatment with 50% shading had a 100% germination rate and the treatment in full sun (0% shading) produced the lowest germination rate.

All treatments with shading showed a significant difference in height compared to 0% shading for *L. racemosa* ($F_{3,99} = 23.984$, $p = 0.00001$) (Figure 1). The seedlings with 50 and 70% shading differed significantly from those with 30% shading, but there was no difference between the two higher shading levels. *A. schaueriana* seedlings in the 50 and 70% shading treatments differed significantly in height from those produced at 0% shading, but did not differ

from those with 30% shading ($F_{3,109} = 6.3428$, $p = 0.00053$).

The *L. racemosa* species was significantly different in the 30 and 50% shade treatments, with the largest RCD ($F_{3,99} = 9.0339$, $p = 0.00002$) (Figure 2). *A. schaueriana* showed no significant difference between shading treatments, the mean RCD was 3.4296 mm for full sun, 3.6893 mm for 30% shading, 3.6800 mm for 50% shading and 3.4000 mm for 70% shading, proving to be a species with good adaptability variation in light.

The 50% shading treatment provided greater accumulation of dry matter in *L. racemosa* seedlings, differing significantly from those with full sun exposure ($F_{3,32} = 4.6811$, $p = 0.00804$). The means obtained were 0.5732 g with full sun, 0.7977 g with 30% shading, 0.9110 g with 50% shading, and 0.6626 g with 70% shading. *L. racemosa* seedlings produced under 50% shading also showed the highest water content with 4.7411 g, followed by seedlings with 30% shading (3.5389 g), 70% shading (3.0100 g), and full sun exposure (2.3411 g). The seedlings treated with 50% shading differed significantly from those produced in full sun and 70% shading ($F_{3,32} = 8.7120$, $p = 0.00023$) (Figure 2).

A. schaueriana seedlings showed no significant difference in total dry matter gain; however, seedlings grown under 50% shading showed the highest mean of 0.9897 g for dry matter gain, followed by 30% shading with 0.9554 g, 70% shading with 0.8372 g, and full sun exposure with 0.7674 g. *A. schaueriana* seedlings also showed no significant difference in water content between treatments. The seedlings showed the following amounts of water content: full

Table 1 – Germination rates of *Avicennia schaueriana* seedlings during the experimental weeks (1 to 7) and under different shading treatments (0, 30, 50, and 70%).

Tabela 1 – Taxa de plântulas das espécies *Avicennia schaueriana* e *Laguncularia racemosa* por semanas experimentais (1 a 7) nos tratamentos de sombreamento (0%, 30%, 50% e 70%).

Avicennia schaueriana					Laguncularia racemosa				
Weeks	Treatments				Weeks	Treatments			
	0%	30%	50%	70%		0%	30%	50%	70%
1	50,00	60,00	73,33	86,66	1	23,33	56,66	44,33	56,66
2	80,00	96,66	100	93,33	2	66,66	56,66	100	96,66
3	93,33	96,66	100	90,00	3	70,00	96,66	100	96,66
4	93,33	96,66	100	93,33	4	70,00	93,33	100	96,66
5	100	93,33	100	90,00	5	86,66	83,33	100	96,66
6	90,00	93,33	100	93,33	6	66,66	93,33	96,66	90,00
7	90,00	93,33	100	93,33	7	66,66	93,33	93,33	90,00

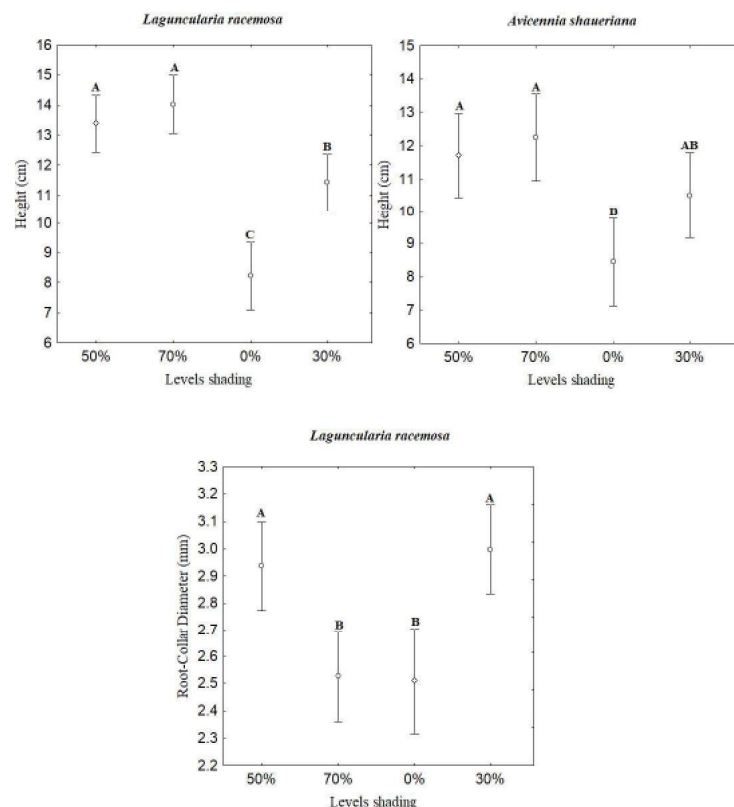


Figure 1 – Height and Collar diameter, average + standard error between different shading levels (0%, 30%, 50%, and 70%) in seedlings of *Laguncularia racemosa* and *Avicennia schaueriana*. Different letters indicate significant differences according to the Tukey's Test.

Figura 1 – Altura e diâmetro do collar, média + erro padrão entre diferentes níveis de sombreamento (0%, 30%, 50% e 70%) em mudas de *Laguncularia racemosa* e *Avicennia schaueriana*. Letras diferentes indicam diferenças significativas de acordo com o teste de Tukey.

sun exposure, 2.9767 g; 30% shading, 3.8967 g; 50% shading, 3.8589 g; and 70% shading, 3.3800 g.

In relation to the nursery temperature and seedling height, linear correlation analysis showed that the lower the ambient temperature, the greater growth was for both study species with -0.981 for *L. racemosa* and -0.984 for *A. schaueriana*. The best DQI was obtained in seedlings in the 50% shading treatment for both species. The lowest indices were obtained in full sun and 70% shading treatments (Table 2).

Through the monitoring of the structure of the seedlings it was possible to observe branching development. *L. racemosa* had a higher percentage of branches at the 30% shading level. *A. schaueriana* showed a higher percentage of branches at the 50% shading level (Figure 3A). Finally, the quality of seedlings grown at different levels of shading

showed some percentage of chlorinated or non-germinated seedlings, probably due to the fact that the substrate comes from degraded area soil. However, degraded soils and in full sun impacted the seedlings negatively. Therefore, both species studied had a higher percentage of chlorinated, non-germinated and dead seedlings with 0% shading treatment, where *A. schaueriana* was more affected (Figure 3B).

4 DISCUSSION

Germination rates were good in *A. schaueriana* for all treatments, showing rates above 90%, which may be related to nutritional reserves and the water content level in the propagules, making germination less sensitive to treatments. *L. racemosa* had high germination potential, except with full sun treatment (0% shading), which showed the lowest germination rate of 86.66%. This demonstrated that in deforested

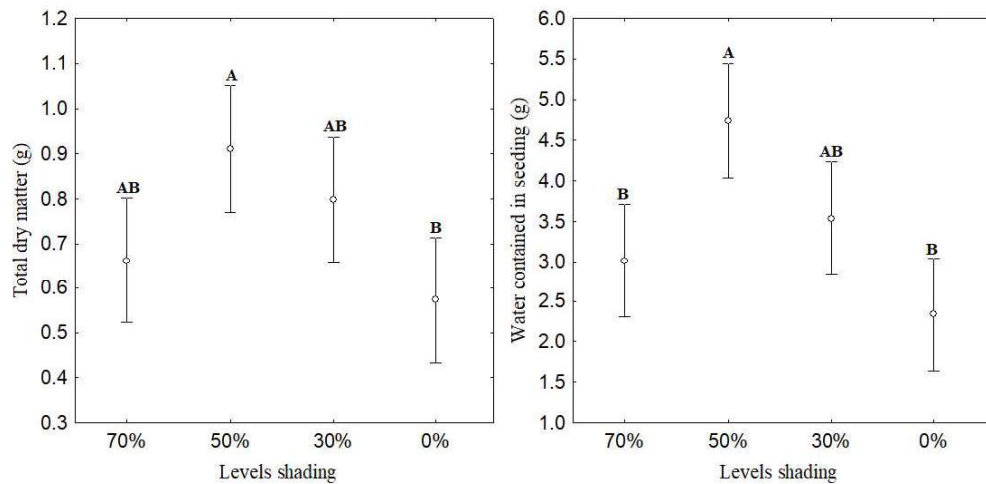


Figure 2 – Total dry matter and Water contained in the seedlings, average + standard error in *Laguncularia racemosa* seedlings according to different shading levels (0%, 30%, 50%, and 70%). Different letters indicate significant differences according to the Tukey's Test.

Figura 2 – Total de matéria seca e água contida nas mudas, média + erro padrão nas mudas de *Laguncularia racemosa* de acordo com diferentes níveis de sombreamento (0%, 30%, 50% e 70%). Letras diferentes indicam diferenças significativas de acordo com o teste de Tukey.

Table 2 – Quality index of seedlings produced under different levels of shading.

Tabela 2 – Índice de qualidade das plântulas produzidas sob diferentes níveis de sombreamento.

Species	SL	DMAP	RDM	TDM	H	RCD	IQD
Avicennia schaueriana	0%	5,1626	1,7442	6,9068	10,8667	3,1915	0,6268
	30%	6,3226	2,2759	8,5985	11,0000	3,3636	0,9460
	50%	6,2547	2,6527	8,9074	11,8542	3,3269	1,1023
	70%	5,6726	1,8624	7,5350	11,4333	3,2388	0,6898
<i>Laguncularia racemosa</i>	0%	3,9093	1,2495	5,1588	11,0714	3,1628	0,3553
	30%	5,5344	1,6448	7,1792	11,1591	3,2439	0,5923
	50%	6,1399	2,0594	8,1993	11,4898	3,2000	0,8107
	70%	5,0446	0,9188	5,9634	11,6491	3,2500	0,2747

SL = Shading level, TDM = Total Dry Matter (g), H = Seedling height (cm), RCD = Root Collar Diameter (mm), DMAP = Dry matter in the Aerial Part (g), and RDM = Root Dry Matter (g).

NS = Nível de sombreamento, MST = Matéria Seca Total (g), H = Altura da plântula (cm), DC = Diâmetro do Coleto (mm), MSPA = Matéria Seca da Parte Aérea (g) e MSR = Matéria Seca da Raiz (g).

areas, the germination potential of *L. racemosa* can be reduced. Even so, these results corroborate those of other studies where germination tests with *L. racemosa* propagules resulted in a high germination rate (Silva et al., 2017; Silva and Maia, 2018).

The growth rates of *A. schaueriana* and *L. racemosa* were very similar in the treatments evaluated, with greater growth in the 70% shading treatment and lower growth in full sun exposure. Pereira et al. (2009) produced seedlings in full sun and irrigation with fresh water, which are conditions similar to those used in the present study in the 0% shading treatment. These data reinforce the effect of

direct sunlight on mangrove seedlings, reducing their size.

The seedlings of *L. racemosa* and *A. schaueriana* of the 50 and 70% shading treatments had the best heights, but they did not differ significantly. These results corroborate those reported by Clara and Giordano (2014) in the state of São Paulo when monitoring the development of *L. racemosa* seedlings in full sun exposure and 35, 50, and 80% shading, with the best result obtained with 50% shading. Similar results have been obtained in forest species in other ecosystems and agroecosystems (Paiva et al., 2003; Oliveira and Perez, 2012; Rezende et al., 2017).

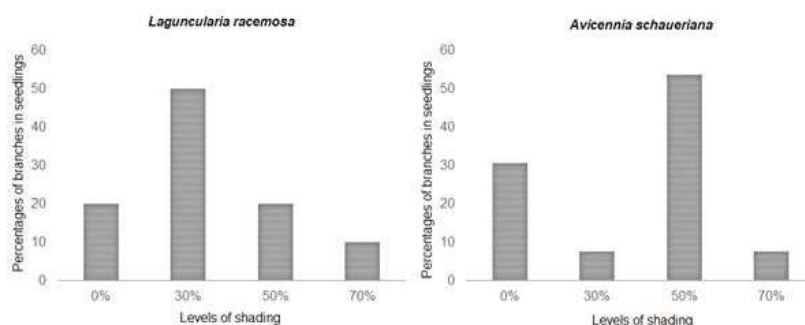


Figure 3 - A

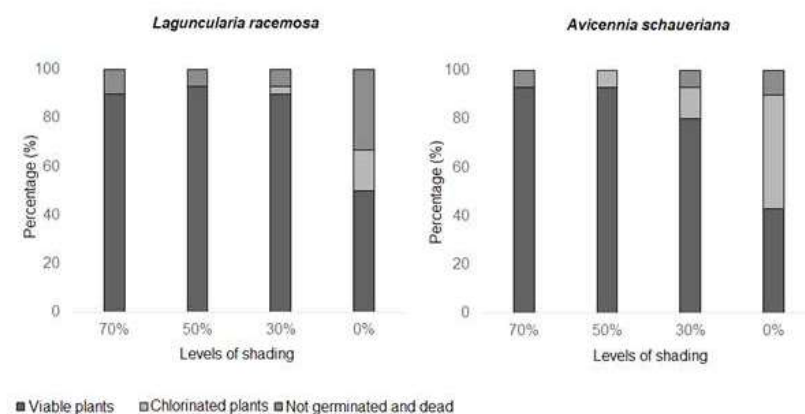


Figure 3 – A) Percentages of branches in *Laguncularia racemosa* and *Avicennia schaueriana* seedlings under different shading levels; B) Percentage representation of physiological characteristics, germination, and mortality in *Laguncularia racemosa* and *Avicennia schaueriana* seedlings at different levels of shading (0%, 30%, 50%, and 70%).

Figura 3 – A) Porcentagens de ramificações nas espécies *Laguncularia racemosa* e *Avicennia schaueriana* por nível de sombreamento. B) Representação em porcentagem das características fisiológicas, germinação e mortalidade das plântulas de *Laguncularia racemosa* e *Avicennia schaueriana* nos diferentes níveis de sombreamento (0%, 30%, 50% e 70%).

The 30 and 50% shading treatments provided greater environmental comfort for *L. racemosa*, with a consequent increase in photosynthesis and photoassimilates in plant tissue, which significantly affected the RCD. In general, differences in light conditions may lead to variations in chlorophyll content (Brant et al., 2011) and thus reflect on biomass. The RCD of seedlings exposed to 0% shading was probably restricted by the strong sunlight and substrate drying up, which compromise photosynthesis (Pereira et al., 2015).

Dry matter analysis showed that the best growth was obtained with 50% shading. According to Paiva et al. (2003), the total amount of dry matter accumulated by a plant, as a parameter of growth evaluation, is a direct reflection of the net

photosynthetic production added to the amount of absorbed mineral nutrients, reinforcing the results of Clara and Giordano (2014).

It is believed that 50% shading has a positive effect on seedling transpiration, and this may explain the higher amount of water in *L. racemosa* and *A. schaueriana* seedlings produced under this level of shading. Dutra et al. (2012) evaluated physiological parameters in copaíba (*Copaifera langsdorffii* Desf.) under the same four levels of shading used in this study and found that the 50% shading treatment provided the lowest values of daily transpiration and at time points measured throughout the day in the plants. This result may explain the greater amount of water in *L. racemosa* and *A. schaueriana* seedlings produced under 50% shading.

The results also showed a significant linear correlation between the height of seedlings and ambient temperatures provided by the shading levels, so the higher the temperature (full sun) the smaller the seedling. Dalastra et al. (2012) and Costa et al. (2011) also observed greater heights in cultivars of arugula and Mimosa lettuce with increasing shading levels (0, 30, 40, and 50%). Shading may reduce vapor pressure deficit, air and soil temperature, and wind speed, which were significantly lower in the shaded system in coffee crops compared to full sun (Lunz, 2006).

The best DQI was obtained in seedlings with the 50% shading treatment in both species. The 50% shading treatment provides seedlings with the greatest robustness and biomass balance. Although seedlings in the 70% shading treatment showed higher mean height values than those in the 30% shading for *A. schaueriana* and 50% for *L. racemosa*, they displayed lower quality indices after 0% shading treatment. This was caused by cellular stretching, which contributes to greater heights under shade environments (King, 1994; Carvalho et al., 2006).

The development of leaves was not affected by any of the treatments in either species. *A. schaueriana* had three pairs of leaves and *L. racemosa* four pairs of leaves at the end of the experiment. Clara and Giordano (2014) followed the development of *L. racemosa* seedlings for 130 days and did not observe a significant difference in leaf gain between different shading levels. Morandi et al. (2009) performed a study with *Calophyllum brasiliensis* Camb. under full sun exposure and 30, 50, 70, and 90 shading and did not observe a difference in the number of leaves during the study.

Regarding lateral development, both species developed branches in all treatments. *L. racemosa* showed more branched individuals in the 30% shading treatment, representing 50% of the branched seedlings. *A. schaueriana* showed more branched individuals in the 50 and 30% shading treatments, representing respectively 53.85% and 30.77% of the branched seedlings. Thus, increased branching is not attributed to greater light intensity and solar radiation in mangrove seedlings because mangrove forest altered by deforestation showed more branched individuals of *L. racemosa* (Santos et al., 2012).

We found that the higher the shading, the better the seedling performance in soils degraded by deforestation. *L. racemosa* responded well to the 50% shading treatment with a high rate of viable seedlings and low rate of non-germinated and dead seedlings. *A. schaueriana* seedlings exhibited a better performance in the 50 and 70% shading treatments and appeared to be more sensitive to areas degraded by deforestation, showing a low rate of viable seedlings and high rate of chlorinated, non-germinated, and dead seedlings. In summary, soils degraded by deforestation and exposed to full sunshine show decreased seedling survival rate and high rates of chlorinated individuals that lead to mortality and non-germinated and dead seedlings.

5. CONCLUSION

We conclude that deforestation of mangroves interferes with the recolonization of the mangrove by reducing the germination rate of *L. racemosa* species and mortality of seedlings of both species studied. *L. racemosa* seedlings exhibited higher physiological resistance in soil conditions of deforested areas under full sun. Deforested areas with high light intensity require intervention with shading, planting and replanting due to the high mortality of seedlings. 50% shade treatment provided higher quality and stability of seedlings in deforested environments.

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6. REFERENCES

Alves JRP. Manguezais: educar para proteger. Cooperação Técnica Brasil - Alemanha, Projeto Planágua Semads-GTZ. Rio de Janeiro: FEMAR: SEMADS. 2001; [cited 2017 December 16].

Available: http://www.mma.gov.br/estruturas/sqa_pnla/_arquivos/manguezais.pdf

Alongi DM. Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. *Estuarine Coastal and Shelf Science*. 2008;76(1):1-13. doi: <https://doi.org/10.1016/j.ecss.2007.08.024>.

Arruda CPS. Monitoramento de mudas de espécies arbóreas de mangue na rodovia PA do km 17, Bragança-Pará. [Trabalho de Conclusão de Curso]. Campus de Bragança (PA): Universidade Federal do Pará; 2013.

Asaeda T, Barnuevo A, Sanjaya K, Fortes MD, Kanesaka Y, Wolanski E. Mangrove plantation over a limestone reef – good for the ecology? *Estuarine, Coastal and Shelf Science*. 2016;173:57-64. doi: <https://doi.org/10.1016/j.ecss.2016.02.017>.

Balke T, Swales A, Lovelock CE, Herman PMJ, Bouma TJ. Limits to seaward expansion of mangroves: translating physical disturbance mechanisms into seedling survival gradients. *Journal of Experimental Marine Biology and Ecology*. 2015;467:16-25. doi: <https://doi.org/10.1016/j.jembe.2015.02.015>.

Baran E, Hambrey J. Mangrove conservation and coastal management in southeast Asia: what impact on fishery resources? *Marine Pollution Bulletin*. 1999;37(8-12):431-440. doi: [https://doi.org/10.1016/S0025-326X\(99\)00076-4](https://doi.org/10.1016/S0025-326X(99)00076-4).

Bernardino AF, Gomes LEO, Hadlich HL, Andrades R, Correa LB. Mangrove clearing impacts on macrofaunal assemblages and benthic food webs in a tropical estuary. *Mar Pollut Bull*. 2018;126:228–235. doi: <https://doi.org/10.1016/j.marpolbul.2017.11.008>.

Brant RS, Pinto JEBP, Rosal LF, Alves C, Oliveira C, Albuquerque CJB. Adaptações fisiológicas e anatômicas de *Melissa officinalis* L. (Lamiaceae) cultivadas sob malhas termorrefletoras em diferentes intensidades luminosas. *Revista Brasileira de Plantas Mediciniais*. 2011;13(4):467-474. doi: <http://dx.doi.org/10.1590/S1516-05722011000400012>.

Brasil. Lei nº 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nºs 4.771, de 15 de setembro

de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de agosto de 2001; e dá outras providências. Disponível em:

http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/L12651compilado.htm

Camargo Maia R, Coutinho R. Structural characteristics of mangrove forests in Brazilian estuaries: a comparative study. *Revista de Biología Marina y Oceanografía*. 2012;47(1):87-98. doi: <http://dx.doi.org/10.4067/S0718-19572012000100008>.

Carvalho NOS, Pelacani CR, Rodrigues MOS, Crepaldi IC. Crescimento inicial de plantas de licuri (*Syagrus coronata* (Mart.) Becc.) em diferentes níveis de luminosidade. *Revista Árvore*. 2006;30(3):351-357. doi: <http://dx.doi.org/10.1590/S0100-67622006000300005>.

Clara MM, Giordano F. Acompanhamento do desenvolvimento de mudas de *laguncularia racemosa* cultivadas em viveiros com diferentes níveis de sombreamento. *Anais do 14 Congresso Nacional de Iniciação Científica*; 2014; Universidade Santa Cecília. São Paulo: Semesp/Unicid; 2014.

Clarke PJ. Effects of experimental canopy gaps on mangrove recruitment: lack of habitat partitioning may explain stand dominance. *Journal of Ecology*. 2004;92(2):203–213. doi: <https://doi.org/10.1111/j.0022-0477.2004.00861.x>.

Costa CMF, Seabra Júnior S, Arruda GR, Souza SBS. Desempenho de cultivares de rúcula sob telas de sombreamento e campo aberto. *Semina: Ciências Agrárias*. 2011;32(1):93-102.

Costa DFS, Rocha RM, Cestaro LA. Análise fitoecológica e zonação de manguezal em estuário hipersalino. *Mercator*. 2014;13(1):119-126. doi: <http://dx.doi.org/10.4215/RM2014.1301.0009>.

Dalastra GM, Hachmann TL, Echer MM, Guimarães VF, Fiametti MS. Características produtivas de cultivares de alface Mimosa, conduzida sob diferentes níveis de sombreamento, no inverno. *Revista Cultivando o Saber*. 2012;8(3):294-301. doi: <http://dx.doi.org/10.1818/sap.v15i1.10360>.

Dickson A, Leaf AL, Hosner JF. Quality appraisal of white spruce and white pine seedling stock in

nurseries. *Forest Chronicle*. 1960;36(1):10-13. doi: <https://doi.org/10.5558/tfc36010-1>.

DUKE NC. Mangrove Floristics and Biogeography Revisited: further deductions from Biodiversity hot spots, ancestral discontinuities, and common evolutionary processes. In: Rivera-Monroy VH, Lee SY, Kristensen E, Twilley RR (eds.). *Mangrove Ecosystems: a global biogeographic perspective*. Springer, 2017;38:17-53. doi: 10.1007/978-3-319-62206-4

Dutra TR, Massad MD, Santana RC. Parâmetros fisiológicos de mudas de copaíba sob diferentes substratos e condições de sombreamento. *Ciência Rural*. 2012;42(7):1212-1218. doi: <http://dx.doi.org/10.1590/S0103-84782012005000048>.

Fundação Cearense de Meteorologia e Recursos Hídricos - FUNCEME. Índice de aridez para o Estado do Ceará. [cited 2017 June 17]. Available: <http://www.funceme.br/index.php/areas/17-mapas-tem%C3%A1ticos/542-%C3%ADndice-de-aridez-para-o-cear%C3%A1>

Krauss KW, Lovelock CE, Mckee KL, López-Hoffman L, Ewe SML, Sousa WP. Environmental drivers in mangrove establishment and early development: a review. *Aquatic Botany*. 2008;89(2):105-127.

King DA. Influence of light level on the growth and morphology of saplings in a panamanian forest. *American Journal of Botany*. 1994;81(8):948-957. doi: <http://dx.doi.org/10.2307/2445287>.

Lee SY, Primavera JH, Dahdouh-Guebas F, Mckee K, Bosire JO, Cannicci S, et al. Ecological role and services of tropical mangrove ecosystems: a reassessment. *Global Ecology and Biogeography*. 2014;23(7):726-743. doi: <https://doi.org/10.1111/geb.12155>.

Lima Junior JC, Arraes FDD, Oliveira JB, Nascimento FAL, Macêdo KG. Parametrização da equação de Hargreaves e Samani para estimativa da evapotranspiração de referência no Estado do Ceará, Brasil. *Revista Ciência Agronômica*. 2016;47(3):447-454. doi: <http://dx.doi.org/10.5935/1806-6690.20160054>.

Lunz AMP. Crescimento e produtividade do caféiro sombreado e a pleno sol. [tese]. Piracicaba (SP):

Universidade de São Paulo - Escola Superior de Agricultura "Luiz Queiroz"; 2006.

Maciel MNM, Watzlawick LF, Schoeninger ER, Yamaji FM. Efeito da radiação solar na dinâmica de uma floresta. *Revista Ciências Exatas e Naturais*. 2002;4(1):101-114.

Maia RC, Rosa Filho JS, Rocha-Barreira CA, Matthews-Cascon H, Santos ES, David HN, et al. Benthic Estuarine Assemblages of the Northeastern Brazil Marine Ecoregion. In: Lana P, Bernardino, A (eds). *Brazilian Marine Biodiversity*. Springer, Cham; 2018. p.75-94. ISBN 978-3-319-77778-8.

Morandi PS, Marimon-Junior BH, Santos CO, Oliveira B, Reis SMA, Silva LS, et al. Germinação e Desenvolvimento Inicial de *Calophyllum brasiliensis* Camb. em Diferentes Níveis de Sombreamento. *Anais da 2ª Jornada Científica da Unemat*. 2009; Universidade do Estado de Mato Grosso. Barra do Bugues (MT); UNEMAT; 2009. p. 1-4.

Oliveira LEM. Temas em fisiologia vegetal: desenvolvimento de plântulas. Setor Fisiologia Vegetal do Departamento de Biologia da Universidade Federal de Lavras. [cited 2017 December 10]. Available: <http://www.ledson.ufla.br/metabolismo-da-germinacao/etapas-da-germinacao/desenvolvimento-de-plantulas/>.

Oliveira AKM, Perez SCJGA. Crescimento inicial de *Tabebuia aurea* sob três intensidades luminosas. *Revista Ciência Florestal*. 2012;22(2):263-273. doi: <http://dx.doi.org/10.5902/198050985733>.

Paiva LC, Guimarães RJ, Souza CAS. Influência de diferentes níveis de sombreamento sobre o crescimento de mudas de caféiro (*Coffea arabica* L.). *Ciênc. agrotec*. 2003;27(1):134-140. doi: <http://dx.doi.org/10.1590/S1413-70542003000100016>.

Pereira FHF, Sá FVS, Puiatti M, Finger FL, Cecon PR. Crescimento de planta, partição de assimilados e produção de frutos de melão amarelo sombreado por diferentes malhas. *Ciência Rural*. 2015;45(10):1774-1781. doi: <http://dx.doi.org/10.1590/0103-8478cr20141134>.

Pereira FV, Foletto F, Moreira TM, Gomes JML, Bernini E. Estrutura da vegetação em duas áreas com diferentes históricos de antropização no manguezal de Anchieta, ES. *Boletim do Laboratório de*

Hidrobiologia. 2009;22(1):1-8.

Pérez A, Machado W, Gutierrez D, Stokes D, Sanders L, Smoak JM, et al. Changes in organic carbon accumulation driven by mangrove expansion and deforestation in a New Zealand estuary. *Estuarine, Coastal and Shelf Science*. 2017;192:108-116. doi: <https://doi.org/10.1016/j.ecss.2017.05.009>.

Querino CAS, Moura MAL, Querino JKAS. Impacto do desmatamento de uma área de mangue no albedo superficial. *Revista Brasileira de Meteorologia*. 2013;28(4):401-408. doi: <http://dx.doi.org/10.1590/s0102-77862013000400006>.

Rezende AJ, Oliveira CP, Gonçalves FOM. Efeito de luminosidade no desenvolvimento inicial de mudas de *Lonchocarpus subglaucescens*. [cited 2017 September 22]. Available: http://fait.revista.inf.br/imagens_arquivos/arquivos_destaque/6wTEbVwbPXfBf0p_2014-4-16-16-16-16.pdf.

Rezende CE, Kahn JR, Passareli L, Vásquez WF. An economic valuation of mangrove restoration in Brazil. *Ecological Economics*. 2015;120:296-302. doi: <https://doi.org/10.1016/j.ecolecon.2015.10.019>

Saenger P. *Mangrove Ecology, Silviculture and Conservaton*. Dordrecht: Springer Science e Business Media; 2002. 351 p. doi: 10.1007/978-94-015-9962-7.

Santos TO, Andrade KVS, Santos HVS, Castaneda DAFG, Santana MBS, Holanda FSR, et al. Caracterização estrutural de bosques de mangue: estuário do São Francisco. *Scientia Plena*. 2012;8(4):1-7.

Silva NR, Maia RC. Avaliação do tamanho e peso de propágulos das espécies pioneiras de mangue na formação de plântulas para a recuperação de manguezais. *Gaia Scientia*. 2018;12(3):117-128. doi: <https://doi.org/10.22478/ufpb.1981-1268.2018v12n3.39306>.

Silva JPG, Rocha AP, Beltrão MRM, Oliveira ATS, Silva EPS, Passos MAA. Germinação de sementes de *Laguncularia racemosa* (L.). (mangue branco) coletadas com diferentes procedimentos. Universidade Federal de Pernambuco. [cited 2017 September 26]. Available: <http://www.eventosufrpe.com.br/jepex2009/cd/resumos/r1413-1.pdf>

Tomlinson PB. *The botany of mangroves*. 2. ed. University Press Cambridge; 2016. 418 p. doi: <https://doi.org/10.1017/CBO9781139946575>.

Vale CC, Schaeffer-Novelli Y. A Zona Costeira do Brasil e os manguezais. In: *Atlas dos Manguezais do Brasil*. Instituto Chico Mendes de Conservação da Biodiversidade. Brasília, 2018. 176 p. ISBN 978-85-61842-75-8. Available in: http://www.icmbio.gov.br/portal/images/stories/manguezais/atlas_dos_manguezais_do_brasil.pdf.

ERRATA

No artigo “EVALUATION OF THE GROWTH AND SURVIVAL OF MANGROVE SEEDLINGS UNDER DIFFERENT LIGHT INTENSITIES: SIMULATING THE EFFECT OF MANGROVE DEFORESTATION.”, publicado no número 3, volume 43, da Revista *Árvore*, onde se lê:

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