EFFECTS OF ARTIFICIAL SHADING AND IRRIGATION WITH BRACKISH WATER ON THE INITIAL DEVELOPMENT OF *Anadenanthera colubrina* (Vell.) Brenan PLANTS

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ABSTRACT – The use of management strategies or changes in the cultivation environment can reduce the impacts of irrigation water salinity on plant development. Therefore, in this research, physiological responses, initial growth, and plant quality of *Anadenanthera colubrina* (Vell.) Brenan (Angico Branco) were evaluated under different levels of shading and electrical conductivity of the irrigation water, seeking to identify the most favorable conditions for the development of this species using brackish water. The experiment was carried out in randomized blocks with split plots and four replications. The plots were formed by four environments with different shading levels: 0 (full sun), 30, 50, and 70%, and the subplots, formed by five increasing levels of electrical conductivity of the irrigation water: 0.4, 1.6, 2.8, 4.0, and 5.2 dS.m^{-1}. The following variables were evaluated: substrate electrical conductivity, leaf gas exchange, plant height, biomass production, and Dickson quality index at 40 days in a nursery. The use of artificial shading favored plant development and photosynthesis rate, even when irrigated with moderate and high salinity water. The DQI showed that *A. colubrina* plants presented higher quality index when produced under intermediate shading (30% and 50%), with yield losses below 20% when irrigated with water with electrical conductivity up to 2.8 dS.m^{-1}.

Keywords: Angico Branco; Light intensity; Saline stress.

EFEITOS DO SOMBREAMENTO ARTIFICIAL E IRRIGAÇÃO COM ÁGUAS SALOBRAS SOBRE O DESENVOLVIMENTO INICIAL DE PLANTAS DE Anadenanthera colubrina (Vell.) Brenan

*RESUMO – O uso de estratégias de manejo ou alterações no ambiente de cultivo podem reduzir os impactos da salinidade da água de irrigação sobre o desenvolvimento vegetal. Assim, nessa pesquisa foram avaliadas respostas fisiológicas, crescimento inicial e qualidade de plantas de **Anadenanthera colubrina** (Vell.) Brenan (Angico Branco) sob diferentes níveis de sombreamento e condutividade elétrica da água de irrigação, buscando-se identificar as condições mais favoráveis para o desenvolvimento dessa espécie utilizando-se águas salobras. O experimento foi realizado em blocos casualizados com parcelas subdivididas e quatro repetições. As parcelas foram formadas por quatro ambientes com diferentes níveis de sombreamento: 0 (pleno sol), 30, 50 e 70%, e as subparcelas, formadas por cinco níveis crescentes de condutividade elétrica da água de irrigação: 0,4, 1,6, 2,8, 4,0 e 5,2 dS.m^{-1}. Foram avaliadas as variáveis: condutividade elétrica do substrato, trocas gasosas foliares, altura de plantas, produção de biomassa e índice de qualidade de Dickson aos 40 dias em viveiro. O uso do sombreamento artificial favoreceu o desenvolvimento das plantas e a taxa de fotossíntese, mesmo quando irrigadas com água de moderada e elevada salinidade. O IQD mostrou que as plantas de **A. colubrina***

apresentaram maior índice de qualidade quando produzidas sob sombreamento intermediário (30% e 50%), com perdas no rendimento inferiores a 20% quando irrigadas com água com condutividade elétrica de até 2,8 dS.m^{-1}.

Palavras-Chave: Angico Branco; Intensidade luminosa; Estresse salino.

1. INTRODUCTION

Caatinga is the only exclusively Brazilian biome and is completely inserted in the Northeast Region. In this region, the burning of wood from native vegetation for energy production has become one of the main sources of income and a devastating form of environmental degradation (Araújo Filho, 2013; Santos et al., 2014). However, this biome has a delicate balance and suffers with the intemperate climate, which favors degradation, since the abiotic factors (drought, radiation, high temperatures and salinity of the water) exert great influence on the vegetation (Silva et al., 2017; Lima et al., 2018a; Rivas et al., 2020).

Salt stress limits the development of plant species (Matias et al., 2018), physiology and quality of plants (Lima et al., 2018a; Neves et al., 2018), including native Caatinga species (Bessa et al., 2017). The salinity problem is present in thousands of brackish water wells in the Brazilian semiarid region, mainly in the crystalline areas (Silva et al., 2007). These water sources could be used in productive activities, including the production of seedlings of forest species. In most cases, this is due to the sensitivity of the species to salinity, especially in the initial phase of development. However, these impacts can be lessened with the use of management strategies or even changes in the growing environment (Cavalcante et al., 2021; Lacerda et al., 2021).

Artificial shading can be an alternative to mitigate the effects of some abiotic factors, including salt stress, since it limits the solar radiation incident on the leaf surface and modifies the environmental conditions in order to improve plant development (César et al., 2014; Ahemd et al., 2016; Echer et al., 2019; Asghar et al., 2021).

The 'angico branco' (*Anadenanthera colubrina*) *(Vell.) Brenan* is a tree species native to Brazil, being found in several biomes, among them the Caatinga. Among the native forest species with the greatest economic potential, the angico stands out, and

can be used for several purposes, such as urban forestation, recovery of degraded areas, animal feed, pharmaceutical industry, civil construction, energy generation, among others (Carvalho, 2003; Campos Filho and Sartorelli, 2015).

There is a growing demand for forestry technologies that allow an increase in productivity and quality of seedlings in non-traditional regions, especially for native species. Every year, new businesses emerge, guided mainly by the increase in production efficiency and environmental and economic sustainability. The objective of this study was to evaluate the initial development of (*A. colubrina*) plants, under different levels of shading and salinity of the irrigation water, through the analysis of biometric and physiological characteristics in the initial phase of development.

2. MATERIAL AND METHODS

The experiment was conducted at the Center of Education and Research in Urban Agriculture (NEPAU) of the Plant Science Department of the Federal University of Ceará (UFC), Pici campus, municipality of Fortaleza, Ceará, Brazil, located at the geographic coordinates 03º44'17" S, 38º34'22" W and altitude of 19 m, in the period from September to November 2020.

The experimental design used was a randomized blocks design with four repetitions. The plots were made up of four shading levels: 0 (full sun), 30, 50, and 70%. The subplots were composed of five increasing levels of electrical conductivity of the irrigation water: 0.4, 1.6, 2.8, 4.0 and 5.2 dS m^{-1}, totaling 80 experimental units.

For the conduction of the experiment, three environments built with wooden structures were used, measuring 2.8 m high, 6.1 m wide, and 9.0 m long. Both the roof and the sides of the structures were covered with black screens with shading of 30, 50, and 70%. To compose the treatment in full sun, a

shaded fence was built on the sides to prevent outside interference.

Daily data on average temperature, relative humidity and global solar radiation were collected from the climatological station Fortaleza A305 of the National Institute of Meteorology (INMET, 2020), located at coordinates 03º48'56.5" S, 38º32'16.1" W and altitude of 20 m, approximately 9.56 km from the experimental area. The average temperature during the period was 27.9 ºC and the average relative humidity was 67.5%, while the global solar radiation had a daily average of 224.0 W m^{-2}, for the full sun environment (INMET, 2020). For the other environments, the estimated average values were 156.8, 112.0, and 67.2 W m^{-2}, respectively under 30, 50, and 70% shading.

The seeds of 'angico branco' (*A. colubrina*) came from the Serra das Almas Natural Reserve (RNSA), located on the border between the municipalities of Crateús (CE) and Buriti dos Montes (PI) and implemented by the Caatinga Association. The angico seeds were sown in expanded polystyrene trays of 128 cells, with a volume of 23.60 cm³. The substrate used for sowing was composed of fine sand + vermicompost + soil (classified as Red-Yellow Argissolo) in a 1:1:1 ratio.

At 10 days after sowing (DAS), the seedlings were selected according to the uniformity of height, diameter, and number of leaves, and were transplanted into polyethylene plastic pots, with a volume of 7 L, containing a 3 cm layer of gravel no. 0 on the bottom, in order to facilitate water drainage. The pots were filled with a substrate composed of fine sand, vermicompost, and soil in a 7:1:2 ratio, respectively, and had the following chemical characteristics: pH = 5.7; EC = 0.3 dS m^{-1}; Ca = 3.1 cmolc kg^{-1}; Mg = 0.8 cmolc kg^{-1}; K = 0.39 cmolc kg^{-1}; Na = 0.43 cmolc kg^{-1}; P = 116 mg kg^{-1}. Before the beginning of the salt

treatments, fertilization was performed, according to Gonçalves et al. (2012) with the doses of 50 of N, 150 of P and 50 of K in mg dm^{-3} of substrate.

The levels of electrical conductivity of the irrigation water used to compose the saline treatments were obtained by dissolving the salts sodium chloride (NaCl), calcium chloride (CaCl$_2$.2H$_2$O), and magnesium chloride (MgCl$_2$.6H$_2$O) in a 7:2:1 ratio, added to well water with an initial electrical conductivity of 0.4 dS m^{-1}. The 7:2:1 ratio is a representative approximation for most water sources available for irrigation in the Northeast Region of Brazil (Medeiros, 1992).

The irrigations were done manually, with watering every two days, and the volume was determined by the difference between the volume of water applied, and the volume drained in reference pots previously selected for each treatment. In each irrigation, a leaching rate of 15% was adopted to avoid excessive salt accumulation in the root zone of the plants. At the end of the experimental period, the total volume of water applied in each treatment (shading and salinity) during the entire trial was determined (Table 1).

The determination of the electrical conductivity of the substrate at the end of the experiment was made according to Rhoades and Miyamoto (1990), with the measurement of the electrical conductivity of the substrate: water suspension (1:1 on a volume basis) made with a portable conductivity meter model CD-860, Instrutherm and values expressed in dS m^{-1}.

At 30 days after the beginning of the salt treatments, the rates of net photosynthesis (*A*, in μmol m^{-2} s^{-1}), stomatal conductance (*gs*, in mol m^{-2} s^{-1}), transpiration (*E*, in mmol m^{-2} s^{-1}), and internal CO$_2$ concentration (*Ci*, in μmol mol^{-1}) were measured with a portable infrared gas analyzer, model LI-

Table 1 – Total volume of water consumed (average ± standard error) by (*A. colubrina*) plants as a function of shading and electrical conductivity of irrigation water.
Tabela 1 – *Volume total de água consumido (média ± erro padrão) pelas plantas de (**A. colubrina**) em função dos níveis de sombreamento e condutividade elétrica da água de irrigação.*

ECw (dS.m^{-1})	Water Consumption (L)			
	70%	50%	30%	Full Sun
0,4	5,624 ± 0,33	6,254 ± 0,49	7,740 ± 0,32	8,656 ± 0,81
1,6	5,489 ± 0,22	6,033 ± 0,34	6,571 ± 0,27	7,758 ± 0,29
2,8	4,211 ± 0,19	4,622 ± 0,28	5,630 ± 0,34	6,822 ± 0,36
4,0	4,132 ± 0,61	4,557 ± 0,16	5,166 ± 1,17	6,249 ± 1,25
5,2	3,483 ± 0,27	3,976 ± 0,29	4,675 ± 0,66	5,941 ± 0,58

6400XT, Licor, USA, with a light intensity of 1,800 $\mu mol\ m^{-2}\ s^{-1}$. The readings were taken in the morning, between 08:00 and 10:00 am, on the fully expanded leaves of each plant and under ambient conditions of air temperature and relative humidity, with constant CO_2 concentration. Using the gas exchange data, the carboxylation efficiency ($A\ Ci^{-1}$) was calculated.

At 40 days after the beginning of the salt treatments, plant height and stem diameter were determined with a graduated ruler and digital caliper, respectively. Then, the plants were then divided into roots, stems and leaves and placed in paper bags to be dried in an oven with forced air circulation, maintaining the temperature around 65 ºC until they reached a constant weight.

To determine the quality of the plants, Dickson quality index (DQI) was calculated (Equation 1), according to Dickson et al. (1960), in which:

$$DQI = \frac{TDB}{\frac{PH}{SD} + \frac{SDB}{RDB}}$$ Eq.1

where: DQI – Dickson quality index; TDB – total dry biomass (g); PH – plant height (cm); SD – stem diameter (mm); SDB – shoot dry biomass (g); RDB – root dry biomass (g).

The data obtained were submitted to variance analysis and when significant by the F test (p ≤ 0.05), the qualitative data (shading factor alone) were submitted to the Tukey test and the quantitative data were submitted to regression analysis, admitting error up to 5% probability and adopting the mathematical model based on the significance and the determination coefficient, using the statistical software SISVAR version 5.7 (Ferreira, 2014).

3. RESULTS

The substrate electrical conductivity ($EC_{1:1}$), net photosynthesis (A), carboxylation efficiency ($A\ Ci^{-1}$), plant height (PH), root dry biomass (RDB), shoot dry biomass (SDB) and Dickson quality index (DQI) were significantly influenced by the interaction between the
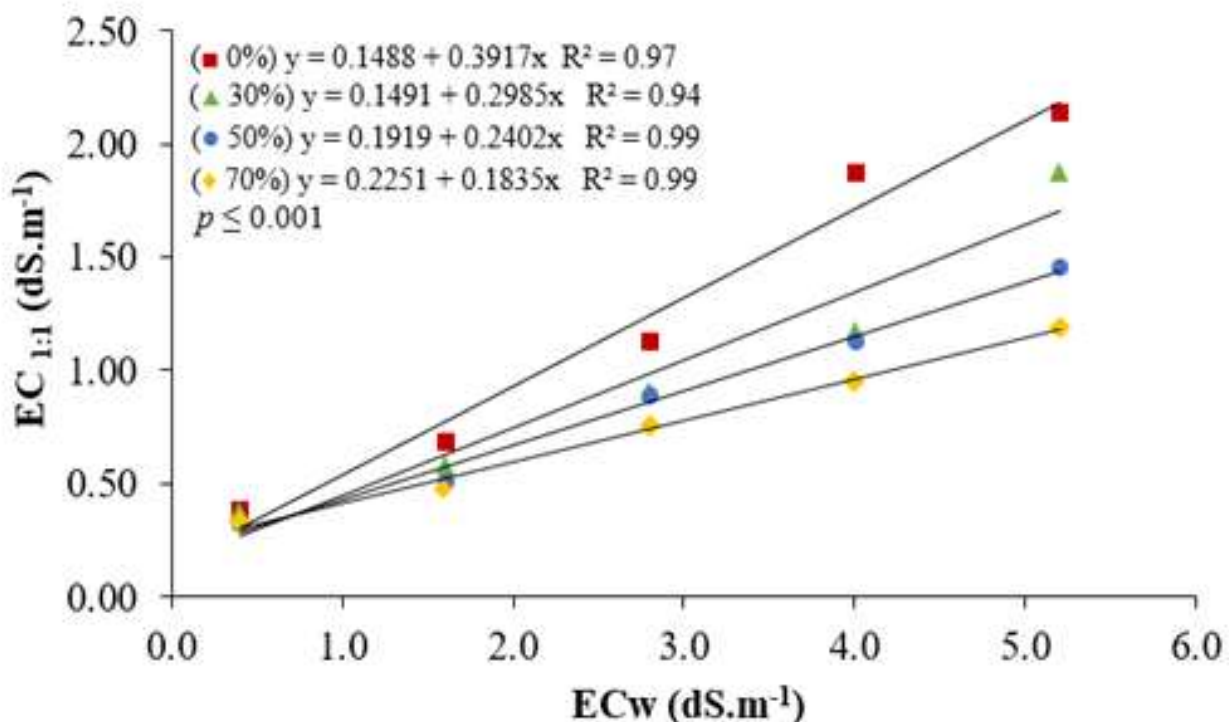

Figure 1 – Electrical conductivity of the substrate ($EC_{1:1}$) grown with (*A. colubrina*) plants under shading levels and electrical conductivity of irrigation water (ECw) at 40 days after planting in Fortaleza, CE, Brazil.
Figura 1 – *Condutividade elétrica do substrato (CE1:1) cultivado com plantas de (**A. colubrina**) sob níveis de sombreamento e condutividade elétrica da água de irrigação (CEa) aos 40 dias após o plantio em Fortaleza, CE, Brasil.*

factors studied (p < 0.05). Stomatal conductance (gs), transpiration (E) and internal CO_2 concentration (Ci) were influenced by shading and salinity factors alone (p < 0.05).

The electrical conductivity of the substrate, in the substrate:water extract (1:1) increased linearly with the levels of electrical conductivity of the irrigation water, and the greatest accumulation of salts was observed in the full sun environment (Figure 1). Increases in $EC_{1:1}$ values of 0.39, 0.29, 0.24, and 0.18 dS m^{-1} were found in the full sun, 30, 50, and 70% shaded environments, respectively, for each increase in the electrical conductivity of the irrigation water (Figure 1).

Stomatal conductance was significantly influenced by the isolated effects of shading and irrigation water electrical conductivity (Figure 2). In relation to the levels of shading, it was observed that the use of shading screens provided greater stomatal conductance of *A. colubrina* plants, with the highest values of gs observed in the environment with 50% shade (0.25 mol m^{-2} s^{-1}), which presented statistically superior mean values than plants in full sun (0.16 mol m^{-2} s^{-1}) (Figure 2A). On the other hand, the electrical conductivity of the irrigation water caused a linear decreasing response in gs, with a reduction rate of 0.0324 mol m^{-2} s^{-1} per unit dS m^{-1} (Figure 2B).

Photosynthetic rates were influenced by the association of the effects of solar radiation and salinity (Figure 2C). In general, reductions in photosynthetic rates occurred in all environments with increasing levels of electrical conductivity of the water. The most pronounced reductions occurred in full sun, due to the more depressive action of the combination between the factors analyzed, expressing more intense reductions when compared to the other environments (Silva et al., 2017).

By deriving the equations of the regression curves, the maximum values of A were obtained at 0.52, 1.99, and 2.61 dS m^{-1} for the full sun, 50 and 70% shaded environments respectively, showing that shading attenuates the effect of salt stress. In the treatments with higher salt concentrations, in full sun, the values were lower than in the other treatments (Figure 2C).

Carboxylation efficiency was reduced at all shading levels with increasing water conductivity (Figure 2D), with greater reductions in the full sun environment and with the lowest A Ci^{-1} ratios. The maximum values of the A Ci^{-1} ratio were estimated at salinity levels of 1.19, 1.81, 2.38, and 3.5 dS m^{-1} in full sun, 30, 50 and 70% shade, respectively. These results indicate that plants that were exposed to the highest radiation levels showed greater CO_2 losses with increasing salt stress.

Transpiration was significantly influenced by the isolated effects of the shading and salinity factors. It can be seen that the shading screens promoted a higher transpiration rate in *A. colubrina* plants, and the environment with 50% shading provided the highest averages (5.5 mmol m^{-2} s^{-1}), not differing from the other shading levels, but being statistically higher than plants that were in full sun (3.58 mmol m^{-2} s^{-1}) (Figure 2E). In relation to salinity, the averages fitted a decreasing linear model, showing that transpiration decreased in plants that were subjected to the highest salinity levels, with decreases of 0.65 mmol m^{-2} s^{-1} for each increase in water electrical conductivity (Figure 2F).

The plant height data (Figure 3A) indicate that there was solar radiation stress on the plants in the full sun environment, which showed smaller heights, even under non-saline conditions, but with a reduction in height as the electrical conductivity of the water increased. It is possible then to infer that in full sun, the higher level of incident solar radiation promotes interference in the height growth of the Angico plants, as well as the increase in the levels of electrical conductivity of the irrigation water.

The relative reductions in plant height, comparing the lowest and highest salinity treatments, were 52.3, 70.8, 51.7, and 45.2% in the full sun, 30, 50, and 70% shading environments, respectively. There was a greater reduction in height, in relation to salinity in the 30% shaded environment, showing that the 30% shading is not enough to neutralize the harmful effects of salinity, since the treatment in full sun, also since the lowest dosages, had the lowest values of plant height.

Root dry biomass showed linear reductions with increasing irrigation water conductivity (Figure 3B). Reductions of 86.7, 56.4, 54.0, and 63.2% occurred between the salinity extremes (0.4 and 5.2 dS m^{-1}) in full sun, 30, 50, and 70% shade, respectively. The
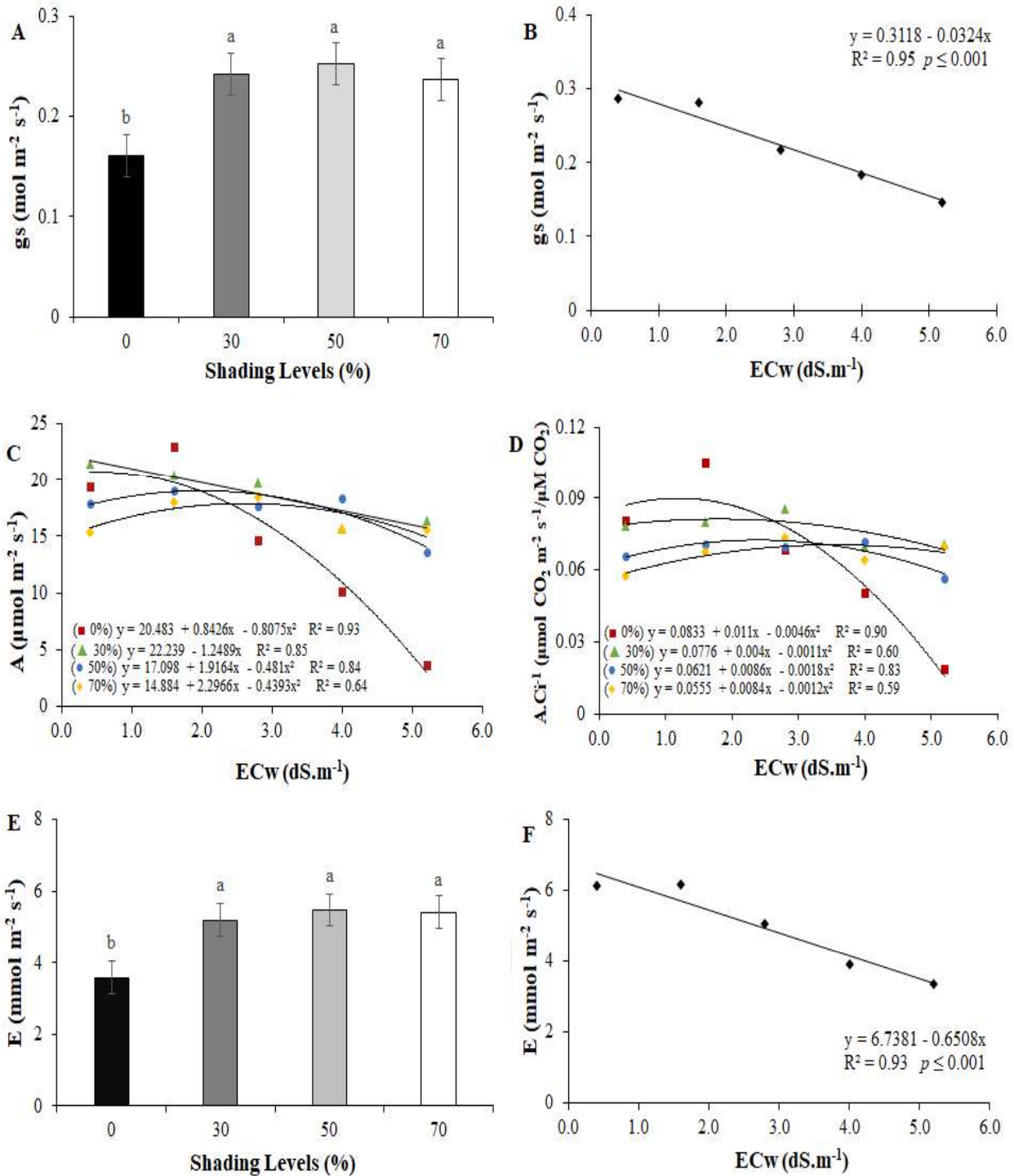
Figure 2 – Stomatal conductance (A and B), net photosynthesis (C), carboxylation efficiency (D) and transpiration (E and F) of (*A. colubrina*) plants under shading levels and electrical conductivity of irrigation water (ECw).
*Figura 2 – Condutância estomática (A e B), fotossíntese líquida (C), eficiência de carboxilação (D) e transpiração (E e F) das plantas de (**A. colubrina**) sob níveis de sombreamento e condutividade elétrica da água de irrigação (CEa).*
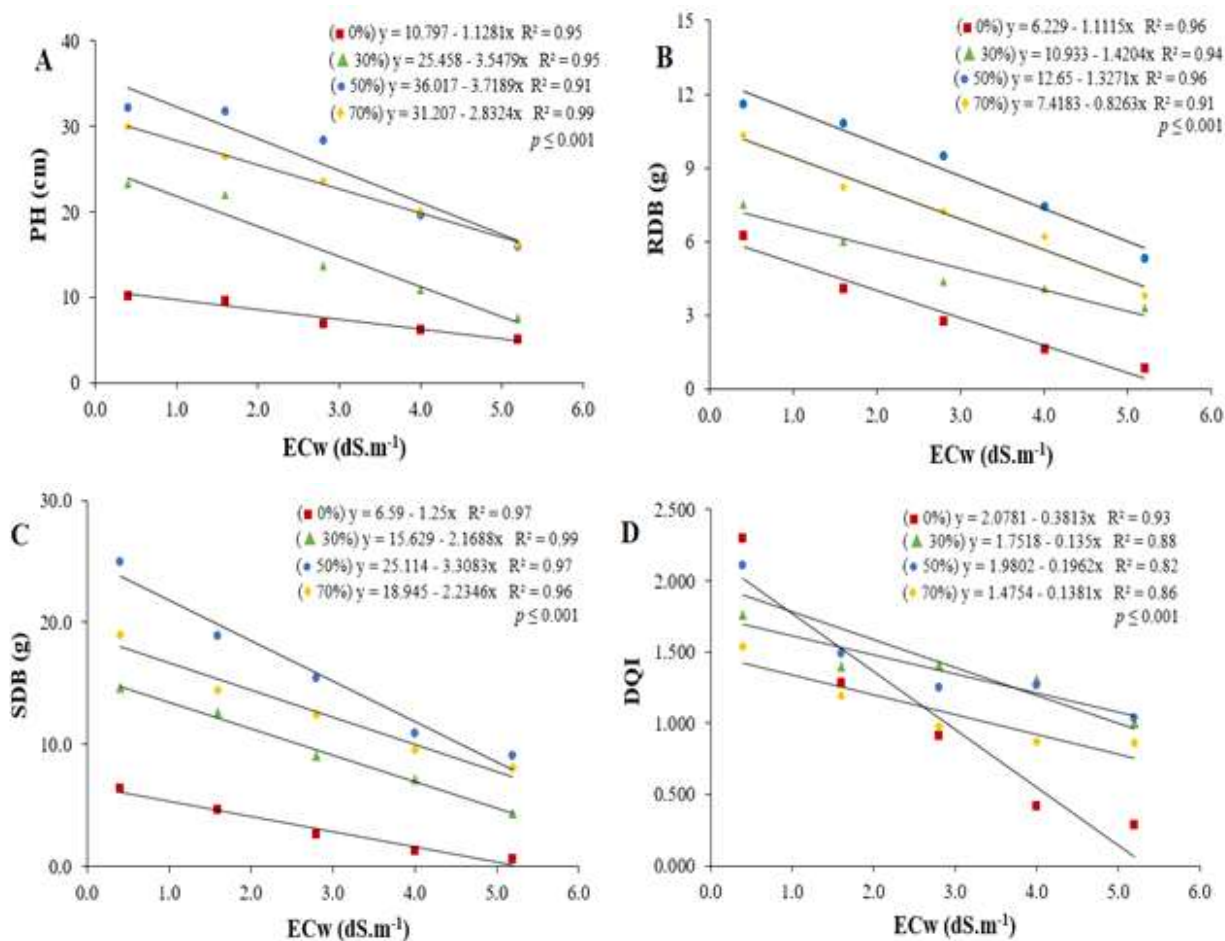
Figure 3 – Plant height (A), root dry biomass (B), shoot dry biomass (C) and Dickson quality index (D) of (*A. colubrina*) plants under shading levels and electrical conductivity of irrigation water (ECw).
Figura 3 – *Altura de plantas (A), biomassa seca das raízes (B), biomassa seca da parte aérea (C) e índice de qualidade de Dickson (D) das plantas de (**A. colubrina**) sob níveis de sombreamento e condutividade elétrica da água de irrigação (CEa).*

highest values in the percentage reduction of the RDB of the plants occurred under 70% shading and in full sun.

In all environments studied, *A. colubrina* plants had marked reductions in shoot dry biomass in increasing treatments of irrigation water salinity (Figure 3C). The percentage reductions between the highest and lowest salinity levels in each environment were 79.5, 70.1, 63.6, and 57.6% in full sun, 30, 50, and 70% shade, respectively.

The Dickson quality index (DQI) decreased linearly in all environments studied with increasing salinity of irrigation water, with this reduction being accentuated in plants in full sun (Figure 3D). In this environment, the reductions reached 47.5 and 95.0% at salinities of 2.8 and 5.2 dS m^{-1}. The environments with intermediate shading levels (30 and 50%) were those that presented the highest average DQI values, indicating greater potential for establishment in the field. On the other hand, the 70% environment was the one that presented the lowest average DQI values under low salinity conditions, surpassing the full sun environment only at salinities higher than 3.0 dS m^{-1}.

4. DISCUSSION

The increase in $EC_{1:1}$ values can be attributed to the higher incidence of solar radiation in environments with less shading, causing greater absorption of thermal energy by the substrate surface, consequently increasing temperature values and water consumption

(Yuan et al., 2019), as observed in the present study (Table 1), favoring greater contribution of salts to the system.

The variations in stomatal conductance values (Figure 2A and 2B) are due to the fact that the shadier environments tend to be more humid, since the substrate surface has less evaporation, which keeps the stomata open longer, since the stomatal response is related to the plant's water dynamics (Freitas et al., 2020). On the other hand, the increase in the concentration of salts in the substrate causes a reduction in the water potential, compromising water uptake by the roots and causing stomatal closure as a stress tolerance mechanism, reducing water losses (Silva et al., 2014).

The behavior of gs with respect to shading can be attributed to the greater thermal comfort provided by the screens, demonstrating that there is sensitivity of gs with increasing temperature, since high temperatures increase the effect of vapor pressure deficit (VPD) and can lead to stomatal closure, minimizing water loss (Taiz et al., 2017). They also mention that in most C3 plants, stomatal closure is associated with high VPD values, especially when growing in environments with low soil water availability. Thus, these limitations in stomatal conductance can protect plants by preventing excessive water loss and enabling survival under stress conditions (Urban et al., 2017).

The reduced photosynthetic performance (Figure 2C) in the environments with higher incident radiation levels and the higher salinity levels can also be attributed to the indirect effects of high temperatures, causing both inhibition of photosynthetic enzyme activity and limitations in stomatal conductance, reducing the assimilation of atmospheric CO_2 and consequently restricting the photosynthetic rate (Tan et al., 2017; Silva et al., 2019). In addition, because it is considered a C3 plant, angico adapts better to low-light conditions than C4 or CAM plants, as well as being an early secondary species, explaining why there were no marked reductions in photosynthetic rates in plants that were in shaded environments (Taiz et al., 2017).

Regarding carboxylation efficiency (figure 2D), shading partially attenuated the effects of salt stress. In the three levels of shading used, there was a greater efficiency of carboxylation, even with the increase in

the electrical conductivity of the irrigation water, while in the full sun environment, the reduction was more pronounced. The greater reductions in the full sun environment may indicate the possibility of inhibition of the RuBisCo enzyme due to heat stress, which will also cause biochemical limitations on photosynthesis, decreasing carboxylation efficiency (Campelo et al., 2015; Perdomo et al., 2017; Silva et al., 2019). The high values of internal CO_2 concentration associated with the increase in stomatal conductance at the higher levels of shading, can justify the higher instantaneous carboxylation efficiency, which occurred due to the availability of ATP and NADPH and substrate for RuBisCo (Silva et al., 2015; Tan et al., 2017).

Similar results were observed by Andrade et al. (2019), who observed reductions in carboxylation efficiency in *Eucalyptus* spp. clones with increasing soil salinity levels, observing strong correlation with photosynthesis data, which was also observed in the present study. Scalon et al. (2015) also observed reductions in instantaneous carboxylation efficiency in Hancornia speciosa seedlings as a result of limitations in RuBisCo enzyme activity caused by water deficit. The authors state that after the reduction in stomatal conductance the efficiency of carboxylation is affected, pointing out that under conditions of low water potential, with the decrease in stomatal conductance, the rate of CO_2 assimilation and transpiration are also reduced.

The behavior of transpiration followed the same trend as stomatal conductance (Figure 2A), showing the reduction of plant water loss through stomatal closure, according to the conditions of water availability. Under conditions of water availability, plants generally exhibit high transpiration rates, while as water availability reduces, the plant closes stomata to reduce water loss, also reducing transpiration (Felsemburgh et al., 2016). Similarly, it happens with respect to the increase in salinity, since the absorption of water is restricted by the osmotic effect, leading to stomatal closure not only to reduce water loss, but also as a way to regulate the amount of water absorbed, also reducing the absorption of salts and consequently reducing the transpiration rate (Freire et al., 2021).

The reduction in RDB production, with increasing salinity, is due to the fact that the roots are the plant organs that have direct contact with the salts present in the soil and need to adapt to maintain

growth and the absorption of water and nutrients. With increasing soil salt concentration the root mass is reduced, affecting the growth rate of the main root and lateral roots and inhibiting the formation of new lateral roots (Zelm et al., 2020). Corroborating with the results obtained, Lima et al., (2018b) observed that, dry matter accumulation in *Hazel sterculia* seedlings was negatively affected by increasing salinity levels, showing relative losses of up to 53% between the control treatment (1.0 dS m^{-1}) and the one with the highest saline level (5.1 dS m^{-1}). As for the shading levels, the high percentage of reduction in the 70% environment was due to the fact that the shading level was very high, promoting limitations in photosynthetic activity and consequently lower increase in RDB (Ballaré and Pierik, 2017).

The lower SDB values in the treatments with higher salinity, are attributed to the decrease in turgidity caused by water deficit and changes in cell wall properties, which is accentuated when the plants are in environments with higher levels of incident solar radiation, decreasing cell expansion and plant growth. In addition, the photosynthetic limitations observed previously, may also be contributing to such results, since with the stomatal closure observed at higher salt concentrations, there is less CO_2 assimilation, affecting the production of photoassimilates by the plant (Freitas et al., 2014).

In general, the reduction in plant growth, measured by height (Figure 3A) and biomass production (Figure 3B and 3C) may have been caused by stomatal closure, caused by the osmotic effect of irrigation water salts, as a way to reduce water loss by transpiration since water uptake is reduced, restricting the photosynthetic capacity of the plant, consequently limiting development (Taiz et al., 2017; Kumar et al., 2018). Another factor that may have contributed to the reduction in plant height, under higher salinity levels, is the toxicity by Na^+ and Cl^- ions, causing nutritional imbalance (Araújo et al., 2018).

The presence of high levels of radiation and high temperatures, intensify the effects of salt stress on the growth and development of plants, since the assimilation of CO_2 is directly related to higher water availability, which is affected by high exposure to solar radiation and the osmotic effect of salt, and may even compromise the establishment of plants under field conditions (Long et al., 1994; Morais et

al., 2017). The milder temperatures, provided by the environments with higher levels of shading, favored the water status of the plants, enabling improvement in photosynthetic activity and turgidity, parameters that are necessary for growth (Pacheco et al., 2013).

The reduction in DQI with increasing salinity may have occurred due to reduced water uptake by plants as a result of the osmotic effect, affecting development and reflecting on height, diameter, and biomass production, which are used in determining DQI (Alves et al., 2019). Similarly, plants grown in full sun had their development influenced by the environmental conditions that influenced water availability, while at extreme levels of shading (70%), there was a reduction in the production of photo-assimilates used for development and reflected in the seedling quality index.

According to the results obtained, it was observed that the angico plants presented variations in their development depending on the level of shade provided, where they showed better development in intermediate light conditions. These results are in accordance with the species' classification in the successional group, which is classified as early secondary (Carvalho, 2003), that is, it needs less light than pioneer species, tolerating partial shading in the juvenile phase (Almeida, 2016).

5. CONCLUSIONS

The use of artificial shading favored the initial development of *A. colubrina* plants, with greater growth and higher photosynthetic rates at moderate and high salinity levels, when compared to the full sun environment.

At 40 days of *A. colubrina* plants in nursery, the conditions for production were evidenced by physiological responses, growth, quality index and with intermediate shading (30 or 50%), tolerating irrigation with brackish water with electrical conductivity up to 2.8 dS m^{-1}.

AUTHOR CONTRIBUTIONS

All authors made essential contributions to the elaboration of this work. PINHO LL was responsible for conducting the experiment and the initial writing of the manuscript. CAVALCANTE ES and SALES JRS

assisted in conducting the experiment and to review and correct the work. SANTOS AM contributed with the supervision of the methodology and correction. LACERDA CF, SOUSA JA and BEZERRA AME contributed to the provision of resources and acted in the supervision, validation and review of the work as a whole.

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