Bulgarian Journal of Agricultural Science, 29 (No 6) 2023, 1065–1074

Gas exchange, carbon metabolism and biomass in *Clusia grandiflora* submitted to water deficit and evaluation periods

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Abstract

Ferreira, N. M. M., Ferreira, A. de M., Ribeiro, D. M., de Souza, L. C., do Nascimento, V. R., Nogueira, G. A. dos S., Neto, C. F. de O., Campos, P. S. da S., Filho, B. G. dos S. & Monteiro, G. G. T. N. (2023). Gas exchange, carbon metabolism and biomass in *Clusia grandiflora* submitted to water deficit and evaluation periods. *Bulg. J. Agric. Sci., 29*(6), 1065–1074

Forest species have their growth and metabolism affected, when they are exposed to conditions of water stress and one of the factors that contribute to water scarcity is climate change that increases over time. The objective of this work was to evaluate changes in gas exchange, carbon metabolism and biomass of *Clusia grandiflora* subjected to water deficit and evaluation periods. The experiment was carried out in a completely randomized design, in a 2 × 5 factorial scheme, with five replications, each as specified: two water conditions (control and water deficit) and five evaluation periods (0, 7, 14, 21 and 28 days). The variables related to gas exchange, carbon metabolism and biomass were evaluated. The design of the experiment was completely randomized.

The relative water content did not differ between the control plants and those submitted to water deficit. While stem diameter, adventitious root length, adventitious root diameter and stem dry mass decreased, when plants were exposed to water deficit. The number of leaves, stem height, leaf area and fallen leaves reduced from day 14, in plants submitted to water deficit. There was a reduction in the hydraulic conductivity and in the water potential of the xylem in the leaf from day 7 on in plants under water deficit. Among the biochemical variables, starch and sucrose concentrations increased in plants under water stress from day 14 onwards. Water deficit negatively affected gas exchange, carbon metabolism and *Clusia grandiflora* biomass.

Keywords: carbono assimilation; water stress; forest species; dry mass

Introduction

The forest cover in Brazil represents 56.1% of the Brazilian territorial area, in which about 0.91% of the national area is occupied by forest plantations (Ibá, 2015). According to the Ibá report in 2015, forestry activity in Brazil significantly favored the Brazilian economy, contributing 1.1% of the Brazilian Gross Domestic Product and 5.5% of the Brazilian Gross Domestic Product of the industry, corresponding to 60.7 billion.

This importance of planting forests in Brazilian territory occurs, because the country has a great wealth and greater diversity in forest resources, related both to native species in the region, highlighting the areas with forests belonging to the Legal Amazon, as well as the significant increase in the planting of exotic species, through reforestation (Silva, 2016). However, forest species have their growth and metabolism compromised, when they are exposed to conditions of water stress.

Thus, hot periods and water stress favor a decrease in tree growth during the year (Williams et al., 2010). Thus, trees can lose water, through the soil-plant-atmosphere system that occurs as water and atmospheric deficits grow, but this can increase plant stress (Bréda et al., 2006) and consequently stomata are closed and growth is stopped (Mcdowell et al., 2008). In addition, the response of trees to water deficit can be measured through the leaf water potential (Schäfer et al., 2019), the decrease in cell turgor, resulting in stem shrinkage and changes in radial growth (Daudet et al., 2005; Vieira et al., 2013). The regulation of the stomatal and hydraulic conductance of the plant causes an adjustment of the water use of the trees (Schäfer et al., 2019), allowing the plant not to have excessive water loss and impair its growth.

Given this context, it is essential to obtain information related to the growth and metabolism of trees, when they are exposed to situations of water stress and, in this way, to understand how gas exchange, carbon metabolism and the growth of forest species are affected under conditions of drought, which is a condition that has been getting worse with the severe climate changes on the planet. The objective of this work was to evaluate changes in gas exchange, carbon metabolism and biomass in *Clusia grandiflora* subjected to water deficit and evaluation periods.

Material and Methods

Study location and instalation of experiment

The experiment was initially conducted in a greenhouse at the medicinal plant garden of Embrapa Amazônia Oriental (48°26′45′′W and 1°26′31′′S), under field conditions. The sowing, emergence and potting of the species were carried out in 1.3 dm^{-3} pots, after 4 months, when they were on average 9 cm tall, they were transplanted into 12 L plastic pots. Subsequently, they were taken to the greenhouse of the Soil Laboratory of the Federal Rural University of the Amazon – UFRA (01°28′03′′S, 48°29′18′′W), for acclimatization for 90 days. Seeds were collected from 20 fruits, which showed an average of 121 seeds/fruit, from 10 *C. grandiflora* trees randomly located in the Crispim sandbank (00°37′06′′ to 00°034′42′′S and 47°40′24′′ to 47°38′00′′ W), located near Crispim beach, municipality of Marapanim, 86 km from Belém, capital of Pará, Amazon, Brazil.

The average air temperature (T_{ar}), the leaf temperature (T_{fol}), the maximum air temperature (T_{max}), relative humidity (RH), photosynthetically active radiation (PAR) and the leaf-air pressure vapor deficit (DPV_{f-a}) throughout the experiment was 31.48°C, 32.44°C, 33.17°C, 77.79%, 413.39 µmol m^{-2} s^{-1} and 0.505 KPa, respectively. The temperature (T_{ar}), maximum temperature (T_{max}), relative humidity (UR), photosynthetically active radiation (PAR) inside the greenhouse was obtained using a thermohygrometer (MODEL 5203, Incoterm, Rs, Brazil) and water vapor pressure deficit, between leaf-air (DPV_{f-a}) estimated according to Landsberg (1986), taking into account the T_{ar}, UR and leaf temperature (T_{leaf}), in each evaluation period. The leaf temperature (T_{leaf}) was obtained using the IRGA device (Infra-red Gas Analyser/ADC equipaments – mod. LCi 6400, Hoddesdon, UK) from 9:00 am to 10:00 am.

The plants were acclimatized and after acclimatization they were submitted to treatments that consisted of two water conditions: control and water deficit (DH). The experiment was carried out in a completely randomized design, in a 2 x 5 factorial scheme, with five replications, each as specified: two water conditions (control and water deficit) and five evaluation periods (0, 7, 14, 21 and 28 days), totaling 10 treatments, with five repetitions, totaling 50 experimental units. Control plants were irrigated daily, keeping the substrate close to field capacity, and plants in water deficit condition (DH) had the total suspension of irrigation. Five measurements were carried out at 0, 7, 14, 21 and 28 days, with five plants per treatment. All pots were arranged at random, with a distance of 50 cm to avoid possible interactions between plants.

Analyzed variables

The variables photosynthesis (A), transpiration (E), stomatal conductance (gs), and stomatal resistance (Rs) were obtained using the IRGA device (Infra-red Gas Analyser/ ADC equipaments – mod. LCi 6400, Hoddesdon, UK) from 9:00 am to 10:00 am. The water potential before morning (Ψ_{am}) and xylem water potential (Ψ_x) were obtained, respectively, between 4:30 – 5:30 h, and 09:00 – 10:00 h, by means of a Scholander-type pressure pump (m670, Pms Instrument Co., Albany, USA), as described by Pinheiro et al. (2007), obtained from mature and fully expanded leaves, from the third pair counted from the apex. Hydraulic conductivity was calculated according to Hubbard et al. (1999) and Donovan et al. (2000), through the equation: K_L = (gs x DPVfa)/(Ψam – Ψx). The relative water content (RWC) was determined between 04:00 and 05:00, according to Slavick (1979). The results were expressed as a percentage, according to the formula below: RWC = (FM1 – DM/FM2 – DM) × 100 (%), em que: FM1 = Fresh mass 1; FM2 = Fresh mass 2; DM = Dry mass.

To obtain the number of leaves (NL), stem height (SH) in cm, collar diameter (CD) in cm, leaf area (LA) in cm^2, root length (RL) in cm, the length of the adventitious roots (CRa) in cm, the diameter of the adventitious roots (DRa) in cm, the number of fallen leaves (FL) a planimeter with a graduated scale and a digital caliper were used. Root dry mass (RDM), stem dry mass (SDM), leaf dry mass (LDM) and total dry mass (TDM) were obtained using the weight difference method after drying in an oven at 65°C for 72 h, with values expressed in grams per plant.

Starch concentrations were determined using the method described by Dubois et al. (1956). The determination of sucrose concentrations was performed according to the method of Van Handel (1968) and the concentrations of total soluble carbohydrates were orbited using the method of Dubois et al. (1956).

The design of the experiment was completely randomized, the data were submitted to analysis of variance (ANOVA), the means were compared by Tukey's test at the level of 5%, using the Agroestat program (Barbosa; Maldonado Junior, 2015).

Results and Discussion

According to the results of the analysis of variance presented in Table 1, there was no significant difference in the relative water content in relation to the water condition. Probably, this species may have maintained its water potential for a longer time even under stress conditions, demonstrating that it is a species that can tolerate a short period of water scarcity. Because normally, plants tend to reduce the relative water content, when they are exposed to water deficit, causing a decrease in water absorption. Brito et al. (2018), found a decrease in relative water content in *Clusia grandiflora* plants with water deficit, when related to control plants, in which plants subjected to water deficit showed a decrease of 0.49% on the 7^{th} day, 0.51% on the 14^{th} day, 0.37% on the 21^{st} day and 2.54% on the 28^{th} day. Likewise, França et al. (2017), found a decline in water content in guanandi plants under water deficit, when compared to plants in which they received daily watering.

It is observed that the stem diameter, the adventitious root length, the adventitious root diameter and the stem dry mass reduced 8.33%, 33.85%, 28.57% and 9.56%, respectively, in the plants submitted to water deficit (Table 2), when compared to control plants. Possibly these reductions are the

Table 1. Analysis of variance (ANOVA) of the variable relative water content subjected to water conditions (control and water deficit) and evaluation periods in *Clusia grandiflora* plants

Variables	Causes of variation					
	WC	EP	CH x PA	General Mean	EPM	CV
RWC	0.0759NS	0.9543NS	0.8315NS	86.62	4.57	11.80

* = significant ($p < 0.0005$), ** = significant ($p < 0.0001$), NS = not significant, CV = Coefficient of variation; EPM = Standard error of the mean; RWC = relative water content. WC= Water condition; EP = Evaluation periods

consequences generated by the low availability of water in the soil, which affected the formation of a concentration gradient that would improve the absorption of water by plants. The reduction of the stem diameter, the length of the adventitious roots and the diameter of the adventitious roots reflected in the reduction of the dry mass of the stem. Water shortage also negatively affected stem diameter and stem dry mass in Craibreira seedlings, when compared to control plants (Nascimento et al., 2018).

Table 2. Stem diameter (DC), adventitious root length (CRa), adventitious root diameter (Dra) and stem dry mass (MSC) as a function of water conditions in *Clusia grandiflora* plants

LA	DC	CRa	Dra	MSC
CO	1.08A	12.94A	0.70A	5.65A
DH	0.99B	8.56B	0.50B	5.11B
CV	9.19	57.31	53.64	17.24
p	< 0.0025	< 0.0160	< 0.0361	< 0.0444

*Means followed by the same letter do not differ from each other by Tukey's test, at the 5% probability level

Stem diameter and stem dry mass increased according to the evaluation periods (Table 3), with more expressive increases at 28 days of evaluation, in which for DC and MSC there was an increase of 13.76% and 30.51%, respectively, from day 0 to day 28. This result is due to the fact that the plants are in ample development, and as time passes the trend and their metabolism is more activated.

Table 3. Stem diameter (DC) and stem dry mass (MSC) as a function of evaluation periods in plants of *Clusia grandiflora*

Evaluation period (EP)	DC	MSC
0	0.94b	4.10b
7	1.02ab	5.72a
14	1.05ab	5.42a
21	1.08a	5.77a
28	1.09a	5.90a
CV	9.19	17.24
p	< 0.0048	< 0.0005

*Means followed by the same letter do not differ from each other by Tukey's test, at the 5% probability level

It is observed that in relation to the water condition there was a reduction in the number of leaves, stem height, leaf area and fallen leaves from day 14, when the plants were submitted to water deficit (Tabela 4). From day 7 onwards, root length, leaf dry mass and total dry mass also decreased under stress conditions. The root dry mass showed a decrease on days 7, 21 and 28 of 18.48%, 35.85% and 24.27%, respectively, in plants with deficit. The reduction of these variables occurs, because if the plant is in a condition of water stress, its turgidity is affected and consequently the expansion of the cells is also compromised, since the expansion is dependent on the turgidity. Martins et al. (2010), evaluating during a period of 60 days the young plants of *Azadirachta indica,* submitted to different water regimes, verified that the lack of water reduced parameters, such as plant height, the number of leaves and also the stem diameter, when subjected to a 20% water regime.

When verifying the evaluation period, it was found that there was no significant difference in the number of leaves (NL), leaf area (LA), root length (RL), root dry mass (RDM), leaf dry mass (LDM) and total dry mass (TDM), when submitted to water deficit (Table 4). The absence of significance can be explained by the fact that the evaluation period was too short for the species under study to show any change in these variables. For stem height (SH) there was growth between days 7 and 21 of 12.61% and 4.88%, respectively, in plants submitted to HD. On days 14, 21 and 28 the amounts of fallen leaves increased by 100%, 53.33% and 28.57%, respectively, when compared to day 0 (zero) of evaluation in plants that were subjected to water stress. The increase in stem height occurred, because the plant expands its cells as time passes, which led to an increase in stem height. The increase in the number of fallen leaves in plants under water stress also increased, because probably the nitrogen content was affected, and its deficiency favors the fall of older leaves on the plant.

The results, observed in this work are similar to the results found by Ramos et al. (2020), in which they identified a decrease in the height of Craibeira plants, when analyzed in three treatments (100%, 60% and 40% of water availability). These authors found that plants, in which they received 60% and 40% of water availability decreased height by 33.2% and 56.5%, respectively, when compared to the 100% treatment. Likewise, the authors also noticed that in the treatment of 40% water availability, the number of leaves decreased when compared to the other treatments (Ramos et al., 2020).

Silva et al. (2019) found decreases in the diameter of the collar, when subjected to treatment under water stress (10% of ET0), in mahogany, umbu, eucalyptus, cedar and angico around 67.5%, 73.8%, 76%, 78.1% and 85.9%, respectively, when compared to the treatment of 150% of the irrigation depth. In the evaluation of leaf area, Brito et al. (2018) found a reduction of 10.45% on the twenty-eighth day of area evaluation in plants and *Clusia grandiflora*, when compared to control plants. Distinctively from the result obtained, Nascimento et al. (2018) observed root growth in Craibeira, being stimulated by water deficit, when compared to control plants. Oliveira et al. (2019) observed in ipê roxa and rosa, sub-

Table 4. Number of leaves (NF), Stem height (SH), Collect diameter (CD), Leaf area (LA), root length (RL), Fallen leaves (FL), RDM = root dry mass, MLD = mass leaf dryness and TDM = total dry mass as a function of the interaction of water condition (control and water deficit) and evaluation periods in *Clusia grandiflora* plants

LA	Evaluation periods (EP)				
	0	7	14	21	28
			NF		
CO	17.60Ad	22.40Acd	25.60Abc	29.20Aab	32.40Aa
DH	17.20Aa	20.00Aa	21.40Ba	20.40Ba	20.60Ba
CV			13.48		
p			< 0.0008		
			HC		
CO	23.20Ad	29.44Ac	36.22Ab	38.54Ab	44.08Aa
DH	23.42Ab	26.80Aab	27.08Bab	28.47Ba	28.82Ba
CV			7.74		
p			< 0.0001		
			AF		
CO	1308.51Ac	1689.93Abc	2268.50Aab	2429.42Aa	2647.59Aa
DH	1314.18Aa	1535.36Aa	1589.46Ba	1574.92Ba	1588.61Ba
CV			21.52		
p			< 0.0154		
			CR		
CO	36.08Ac	43.65Ab	46.34Aab	47.70Aab	51.38Aa
DH	35.39Aa	38.13Ba	36.32Ba	36.11Ba	33.79Ba
CV			8.24		
p			< 0.0001		
			FC		
CO	0.00Aa	0.00Aa	0.00Aa	0.00Aa	0.00Aa
DH	0.00Ad	0.00Ad	1.40Bc	3.00Bb	4.20Ba
CV			45.03		
p			< 0.0001		
			MSR		
CO	14.88Ac	15.96Abc	17.10Abc	19.03Aab	22.01Aa
DH	15.24Aa	13.01Ba	14.92Aa	14.41Ba	14.12Ba
CV			12.56		
p			< 0.0009		
			MSF		
CO	16.88Ac	17.79Abc	22.35Aab	23.06Aa	23.50Aa
DH	15.90Aa	14.02Ba	15.19Ba	14.07Ba	13.65Ba
CV			14.55		
p			< 0.0017		
			MST		
CO	35.73Ad	39.38Acd	45.02Abc	48.42Aab	52.28Aa
DH	35.38Aa	32.84Ba	35.37Ba	33.68Ba	32.81Ba
CV			9.91		
p			< 0.0001		

*Means followed by the same letter (capital letters for water condition and lowercase letters for evaluation periods) do not differ from each other by Tukey's test, at the 5% probability level jected to water stress, that there was no significant change in relation to shoot dry matter in either of the two species. However, it was verified that purple ipê suffered decreases in its amount of root dry matter and total dry matter due to water deficit.

For hydraulic conductivity from day 7 on, there was a reduction in plants submitted to water deficit (Figure 1). For the evaluation periods, it is observed that on day 7 the control plants showed a reduction in hydraulic conductivity, when compared to the other evaluation days, while for the plants submitted to water deficit the reduction occurred on days 14, 21 and 28 in 33.33%, 50% and 96.66%, respectively (Figure 1). The sharp decrease in hydraulic conductivity is possibly related to low water availability, since the lower the amount of water in the plant, the lower the transport capacity to the area. Likewise, Teixeira et al. (2018) observed a decrease in the hydraulic conductivity of *Clusia grandiflora* plants with water deficit of -32.44%, -54.07%, and -78.90% on days 14, 21 and 28, respectively.

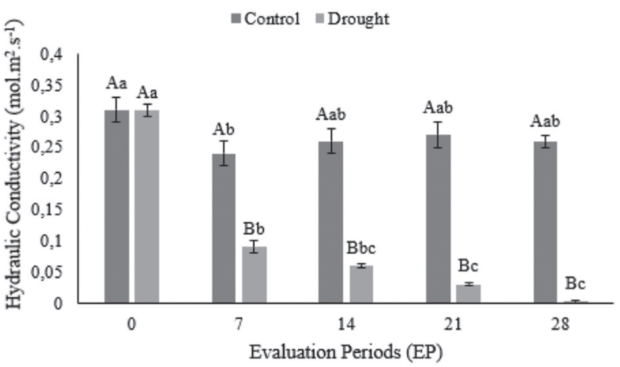


Fig. 1. Leaf hydraulic conductivity as a function of the interaction of two water conditions (control and water deficit) and five evaluation periods (days) in *Clusia grandiflora* plants. CV = 16.57, p < 0.0001

*Means followed by the same letter (capital letters for water conditions and lowercase letters for periods) do not differ from each other by Tukey's test, at the 5% probability level

It can be seen in Figure 2A that the water potential before morning did not show a marked variation in the control plants, however, in the plants under water deficit the variation occurred from day 14. For the evaluation period, the plants with water deficit, reduced significantly between the day 0 and 28 at 37.15%. The reduction of the water potential in the morning may have occurred, because the amount of water in the soil has decreased, which provided a reduction in the water potential developed by the roots, making it more negative. Reductions were also observed by Teixeira et al. (2018) and Brito et al. (2018) that as the evaluation days increased, the water potential before morning was decreasing, in the same species with water deficit, when related to the control plants.

The xylem water potential in the leaf (Figure 2B) decreased in plants submitted to water deficit from day 7 onwards. While for the evaluation periods the plants submitted to water deficit varied between days 0 and 28 by 55.91%. Probably due to the low water availability in the plant, the movement of water through the xylem is also reduced. Brito et al. (2018) also observed, in the same species, a decrease in the water potential of the leaf xylem in plants under water deficit. As in guanandi plants, significant reductions

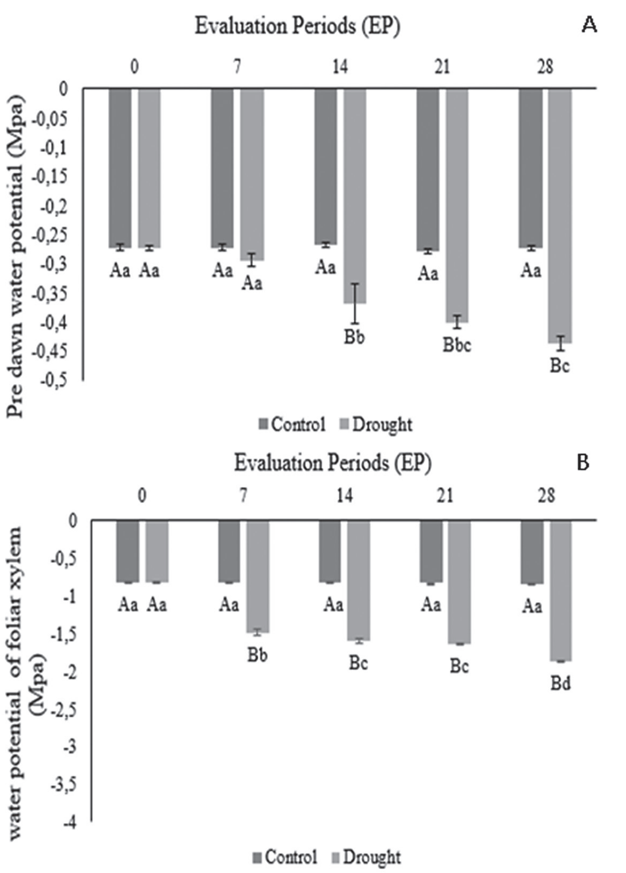


Fig. 2. Early morning water potential (A) and leaf xylem water potential (B), as a function of the interaction of two water conditions (control and water deficit) and five days of evaluation in plants of *Clusia grandiflora*. ψam = early morning water potential (CV = -9.23, p < 0.0001), ψx = leaf xylem water potential (CV = -3.47, p < 0.0001)

*Means followed by the same letter (capital letters for water conditions and lowercase letters for periods) do not differ from each other by Tukey's test, at the 5% probability level were also observed in relation to their leaf water potential, in plants that suffered water restrictions, when compared to those that received daily watering (França et al., 2017).

Transpiration decreased from day 7, in plants submitted to water deficit, when evaluated the water condition. For the evaluation period, there was a statistical difference for transpiration in plants subjected to water deficit, where the highest value was observed on day 0 and the lowest value on day 28, varying by 56.25% (Figure 3).

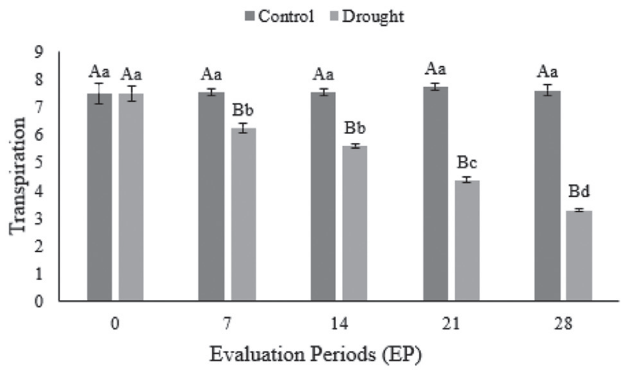


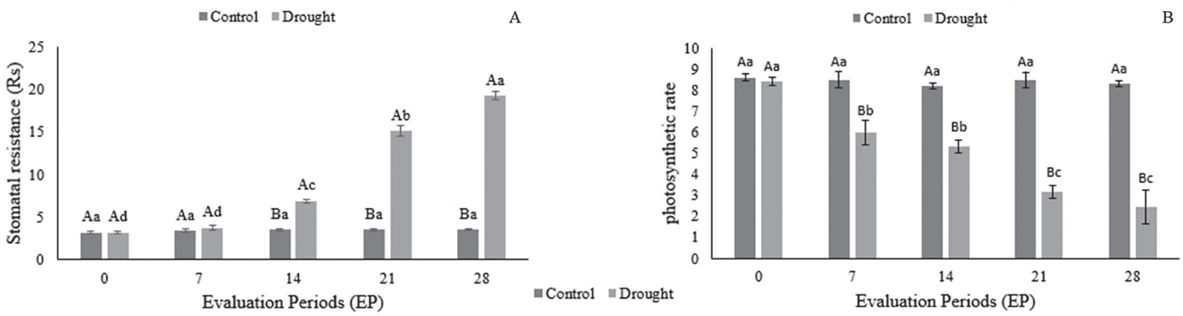
Fig. 3. Transpiration as a function of the interaction of two water conditions (control and water deficit) and five days of evaluation in *Clusia grandiflora* plants. CV = 6.46, p < 0.0001

*Means followed by the same letter (capital letters for water conditions and lowercase letters for periods) do not differ from each other by Tukey's test, at the 5% probability level

The decrease in transpiration is probably a consequence of the closing of the stomata, since most of the transpiration takes place in the leaves, where its presence is more pronounced and as this process leads to water loss, it also consists of a survival mechanism to avoid causing the plant to become even more dehydrated. Young African mahogany plants that were not irrigated showed a 93% reduction in their transpiration rate, when compared to control plants (Albuquerque et al., 2013). Decreases in transpiration were also observed by Fernandes et al. (2015) in eucalyptus clones under water deficit.

For the water condition, stomatal resistance in plants submitted to water deficit increased from day 14 onwards. While for the evaluation periods it is observed that plants subjected to water deficit increased their resistance on days 14, 21 and 28 by 45.98 %, 54.29% and 21.55%, respectively (Figure 4A). The increase in stomatal resistance is possibly a plant mechanism to maintain, for as long as possible, the available water content in the tissues. On days 14 and 21, *Clusia grandiflora* plants under water stress showed values of 85.26% and 118.73%, respectively, for stomatal resistance, practically twice the observed result (Teixeira et al., 2018).

The photosynthetic rate in plants with water deficit decreased significantly from day 7, where its strongest decrease occurred on day 28 at 70.53%, when compared to control plants. For the evaluation periods, the photosynthetic rate of plants submitted to water deficit was higher on day 0 and lower on days 21 and 28 (Figure 4B). The decrease in photosynthetic rate is probably related to the increase in sto-



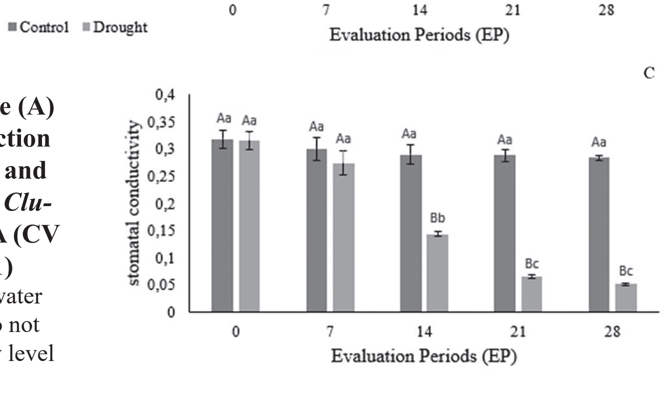


Fig. 4. Stomatal resistance (Rs), photosynthetic rate (A) and stomatal conductivity (Gs) in the leaf as a function of the interaction of two water conditions (control and water deficit) and five evaluation periods (days) in *Clusia grandiflora* plants.Rs (CV = 10.08, p < 0.0001), A (CV = 13.08, p < 0.0001), Gs (CV = 13.36, p < 0.0001)

*Averages followed by the same letter (capital letters for water conditions and lowercase letters for evaluation periods) do not differ from each other by Tukey's test, at the 5% probability level matal closure, where the decrease in stomatal pores prevents gas exchange between the interior of the leaf and the atmosphere, reducing the assimilation of CO_2, a very important gas in the photosynthetic process. Nascimento et al. (2019) observed variations in the photosynthetic rate of 0.4 μmol m^{-2} s^{-1} in young rubber trees under water deficit, where according to the authors, water availability greatly influenced photosynthesis. In guanandi plants, photosynthesis was reduced by 66% and 77% in treatments that were irrigated every 5 days (5D SR) and watered every 15 days (15D SR), respectively, when compared to those that were irrigated daily (RD) (França et al., 2017).

The stomatal conductivity differed statistically from day 14 for the water condition, where the plants submitted to water deficit presented lower values in relation to the control plants. There was a significant difference between the evaluation days for the plants submitted to water deficit, in which the highest value presented was on day 0 and the lowest value on day 28, where it decreased by 83.54%, when compared to the first and last day of evaluation (Figure 4C). Possibly because the plant is undergoing stress and as a safety measure, the plant itself begins to close its stomata, because of this its stomatal resistance will be high, to prevent water vapor from being released and its photosynthetic rate low, because with the stomata closed, carbon dioxide is prevented from entering and thus the photosynthetic process takes place. Albuquerque et al. (2013) found that in African mahogany plants that were not irrigated, stomatal conductance was reduced by 93%, when compared to control plants, as well as stomatal conductance significantly reduced in eucalyptus clones under water stress (Fernandes et al., 2015).

It can be seen in Figure 5A, for water condition, on day 0 the amount of starch concentration in the leaves of plants subjected to water deficit was higher, when compared to control plants and decreased significantly from day 14 onwards. evaluation, there was a significant reduction in the concentration of plants with water deficit on day 28, but without differing between days 14 and 21.

For root starch concentration (Figure 5B) the decrease also occurred from day 14, in plants exposed to stress. While for the evaluation days, the highest concentration of starch occurred on day 0 and the lowest on day 28th, with a reduction of 66.66% in plants with deficit. The increase in starch in plants with water deficit may be an attempt to store energy and its subsequent decrease is probably due to the low occurrence of the photosynthetic process and its degradation by the plant, in order to obtain an osmotic adjustment to try to maintain its water potential. Nascimento et al. (2019) observed similar results in plants of *Hevea brasiliensis* that showed, after 32 days, a decrease in starch in the leaves, in plants, in which they were not irrigated. Likewise, Maltarolo et al. (2015) found reductions in starch concentrations in leaves and roots in young Noni plants by 38.23% and 25%, respectively, after 10 days of evaluation.

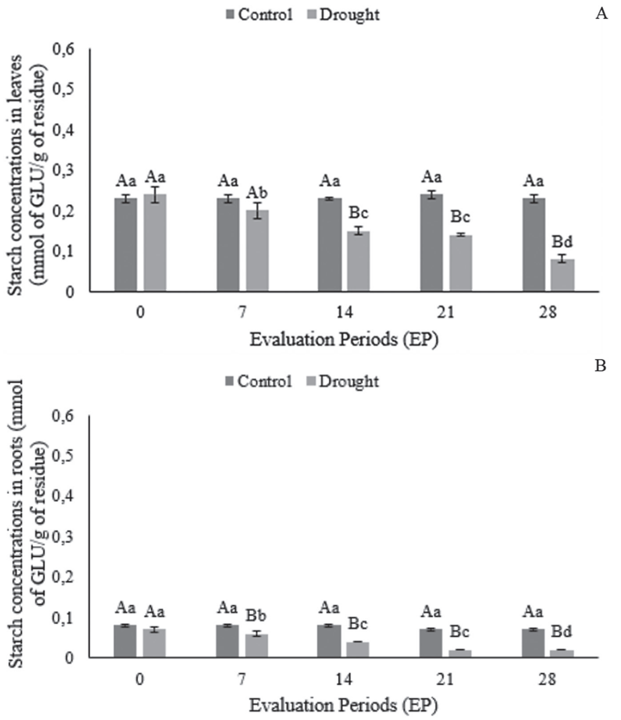


Figure 5. Starch concentrations in leaves (A) and roots (B), as a function of the interaction of two water conditions (control and water deficit) and five days of evaluation in *Clusia grandiflora* plants

Leaf starch concentrations (CV = 10.60, $p < 0.0001$), root starch concentrations (CV = 13.17, $p < 0.0001$). *Averages followed by the same letter (capital letters for water conditions and lowercase letters for evaluation periods) do not differ from each other by Tukey's test, at the 5% probability level

For water condition the sucrose concentration in the leaf increased considerably, in plants under water stress, on days 14, 21 and 28 by 21.49%, 31.52%, and 33.79%, respectively, when compared to the control plants. For the evaluation days, the sucrose concentration in the leaves of the plants with deficit did not differ on days 0 and 7 and increased from day 14 onwards (Figure 6 A).

Sucrose in the roots of plants with water deficit differed from day 0, when compared to control plants for water condition (Figure 6 B). While for the evaluation days, its concentration did not differ on days 0 and 7, and increased on days 14, 21 and 28 by 20.09%, 16.48% and 9.82%, respectively. Likewise, Oliveira et al. (2015) observed an increase in sucrose concentration in the root and leaf by 42% and 43.39%, respectively, in *Parkia pendula* (Willd.) Benth with water deficit, when related to plants control.

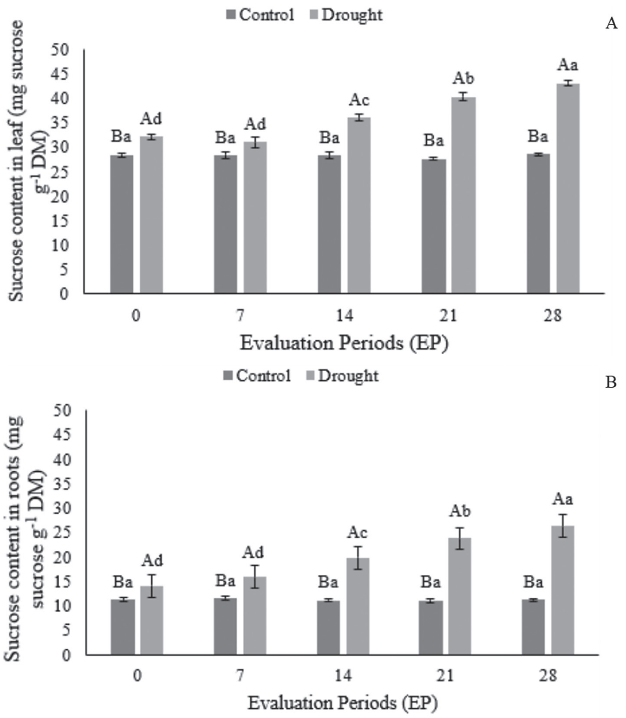


Fig. 6. Sucrose concentrations in leaf (A) and roots (B), as a function of the interaction of two water conditions (control and water deficit) and five days of evaluation in *Clusia grandiflora* plants

Sucrose concentrations in the leaf (CV = 4.52, $p < 0.0001$), Sucrose concentrations in the root (CV = 7.50, $p < 0.0001$) *Averages followed by the same letter (capital letters for water conditions and lowercase letters for evaluation periods) do not differ from each other by Tukey's test, at the 5% probability level

The concentration of total soluble carbohydrates in the leaf increased significantly in plants with water deficit from day 14, when analyzed the water condition. For the evaluation days, we observed that there was no significant change between days 0 and 7, whereas on days 14, 21 and 28, its concentration increased by 38.68%, 17.72% and 15.69%, respectively (Figure 7A). Possibly increasing the concentration of carbohydrates in the leaf is a way of conserving the water level in the leaf and leading to an osmotic adjustment.

For water condition, the amount of total soluble carbohydrates in the root increased from day 7 onwards (Figure 7B). For the evaluation days, it was observed that its increase occurred from the 14th, with its lowest amount on day 0 and its highest amount on day 28, varying by 67.29%. Similarly Oliveira et al. (2015) verified in *Parkia pendula* (Willd.) Benth, submitted to water deficit, an increase of soluble carbohydrates in the leaf and in the root of about 53% and 70%, respectively, in relation to the control plants.

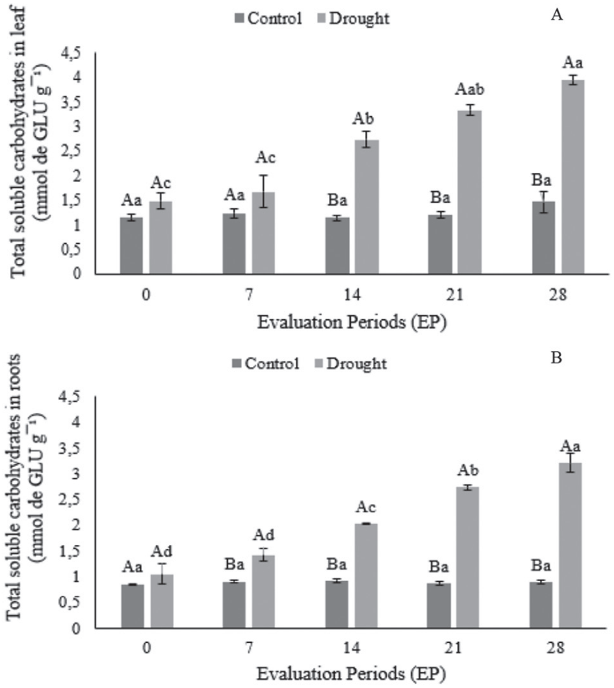


Fig. 7. Total soluble carbohydrates in leaf (A) and roots (B), as a function of the interaction of two water conditions (control and water deficit) and five days of evaluation in *Clusia grandiflora* plants

Total soluble carbohydrates in the leaf (CV = 17.96, $p < 0.0001$), Total soluble carbohydrates in the root (CV = 14.93, $p < 0.0001$). *Averages followed by the same letter (capital letters for water conditions and lowercase letters for evaluation periods) do not differ from each other by Tukey's test, at the 5% probability level

Conclusion

The forest species Clusia grandiflora demonstrated tolerance to water deficiency of 28 days, with growth at lower levels than plants without stress.

Water deficiency negatively affected gas exchange, carbon metabolism and Clusia grandiflora biomass.

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Received: **August, 04, 2022**; *Approved*: **June, 12, 2023;** *Published:* **December, 2023**