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African Mahogany Under Saline Stress: An Analysis of the Transpiration Response at Different Salinity Levels

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Abstract: Transpiration, being the main water transport mechanism in plants, can be significantly impacted by the concentration of salts in the soil. This study aimed to investigate the influence of soil salinity and sun exposure on the transpiration of African mahogany seedlings in a semi-arid region. The research was conducted using drainage lysimeters, in which African mahogany (*Khaya senegalensis*) seedlings were grown, and different levels of salinity were applied to the irrigation water, ranging from 0.5 $dS.m^{-1}$ to 5 $dS.m^{-1}$ in seven different treatments. Each treatment was replicated three times, totaling 21 experimental units (plants), with the aim of optimizing the management of water resources in semi-arid environments. Relevant environmental data, such as photosynthetically active radiation (Qleaf), water potential and electrical conductivity, were collected directly in the field over four months after planting the seedlings in the lysimeters, located in an experimental field in Bahia. Perspiration assessment was performed using a steady-state diffusion porometer model LCpro-SD. The electrical conductivity of the irrigation water was monitored with a portable conductivity meter, being adjusted with the addition of sodium chloride (NaCl) to achieve different salinity levels. Regression analyzes were applied to understand how environmental variables influence the transpiration of mahogany plants. The results indicate that leaf transpiration decreases as the electrical conductivity of the water increases, especially in periods of water restriction. These findings provide valuable insights into the response of African mahogany seedlings to soil salinity and sun exposure, contributing to a better understanding and management of water resources in semi-arid regions.

Keywords: transpiration; lysimeter; salt stress; water restriction

1. Introduction

Agriculture in semi-arid regions faces complex challenges due to water scarcity and adverse conditions such as high temperatures and intense solar radiation (Tian et al., 2020a). Plant transpiration, crucial for their growth, is strongly influenced by environmental factors such as soil salinity and solar radiation (Xu et al., 2019).

Transpiration plays a vital role in the water balance of plants, affecting their growth, efficient water use and productivity (Singh et al., 2021). Soil salinity, which results in the accumulation of soluble salts, reduces water availability for plants, impairing their transpiration and, consequently, their development. Solar radiation, a source of energy for photosynthesis, influences the rate of transpiration, affecting the metabolism and physiology of plants (Du et al., 2023).

Water restriction decreases daily transpiration and the water potential of plants (Kühnhammer et al., 2023). Irrigation water with high electrical conductivity reduces water potential, making it difficult for plants to absorb water (Carrière et al., 2020), which reduces leaf transpiration due to increased resistance to water penetration in plant tissues (Mehrabi and Sepaskhah, 2019). Water restriction and high electrical conductivity of irrigation water negatively affect plant growth and production, causing atrophy of conducting vessels, reduced nutrient absorption and greater susceptibility to pathogens (Ma et al., 2021).

Plant transpiration depends on water availability, being reduced in conditions of lower water potential (Iwasaki et al., 2019). Transpiration decreases during periods of water restriction, indicating an adaptation of plants to preserve water. Solar radiation remains stable throughout the days, while different water potentials influence transpiration in response to solar radiation. The lower the water potential, the lower the transpiration in response to environmental conditions.

African mahogany (*Khaya senegalensis*), known for its quality wood, faces challenges in cultivation in semi-arid regions due to soil salinity and solar radiation. Soil salinity is a problem in these regions due to inadequate use of irrigation water and intense evaporation, resulting in the accumulation of salts (Liao et al., 2023). High levels of salts impair water availability for plants, causing water stress and reducing the rate of transpiration (Yang et al., 2022). Furthermore, harmful ions accumulated in leaves damage cell membranes and interfere with photosynthesis, reducing transpiration (Gonzalez-Dugo et al., 2019).

Previous studies have investigated the effect of soil salinity on various crops, but little attention has been paid to African mahogany. Understanding its response to soil salinity is crucial for proper management and conservation of water resources in regions affected by salinization.

Solar radiation is essential for plant transpiration (Hochberg et al., 2023). Its intensity directly affects the rate of water evaporation in the leaves and the opening of the stomata, affecting gas exchange. Therefore, understanding the combined effects of soil salinity and solar radiation on African mahogany transpiration is crucial for sustainable agricultural practices.

This study is expected to provide data on the response of African mahogany to soil salinity, contributing to more efficient and sustainable management strategies. This can optimize the use of water resources and increase the productivity of this important crop in semi-arid regions.

2. Material and Methods

The lysimeters were installed in the experimental field of the State University of Southwest Bahia (UESB), located on the Vitória da Conquista campus (Figure 1). This area is located in a region characterized by a tropical high-altitude climate (Cwb), according to the Köppen classification. This indicates that the region experiences a dry season during the winter, with hot and humid summers.

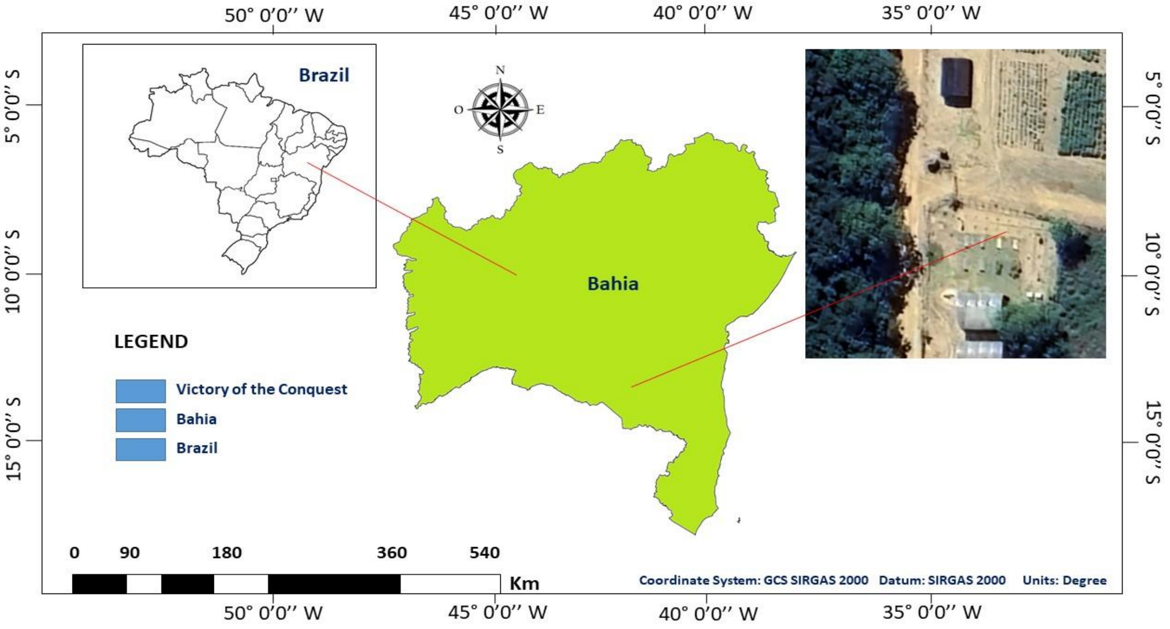

Figure 1. Location of the study area: Vitória da Conquista – BA, northeast of Brazil.

The geographic coordinates of the site are approximately 14° 53' 08'' south latitude and 40° 48' 02'' west longitude of Greenwich, with an altitude of 881 meters. In the region, the rainy season occurs from November to March, with a total annual rainfall of around 700 mm. Thermal averages indicate

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maximum temperatures of 26.4°C and minimum temperatures of 16.1°C, resulting in an annual average of 20.2°C, according to INMET data from 2018.

2.1. Lysimeters

The lysimeters used were made of polyethylene (canisters), with a cylindrical shape, one meter high and a total volume of 0.2 m^3. They were placed at ground level, in an open area. In the center of each lysimeter, a PVC tube 75 inches in diameter and 1.6 meters long was inserted. This tube was positioned so that water could be stored in it and flow to the lysimeter's soil storage area, through holes located along the tube. The part of the tube that protruded outside the lysimeter was approximately 0.6 meters.

To fill the lysimeters, the following procedure was followed: an initial layer of crushed stone was added to completely cover the drainage tube holes, corresponding to a 20 cm thick layer. Then, a 5 cm layer of coarse sand was placed. Finally, the inside of the lysimeter was completely filled with soil, to a depth of 40 cm.

After planting the African mahogany seedlings, the lysimeters were covered with a thin layer of cement to prevent water evaporation from the soil. Finally, they received a layer of white paint to reduce the soil temperature inside the lysimeters (Figure 2).

Figure 2. Field experiment with distribution of drainage lysimeters in the experiment area.

2.2. Leaf Transpiration

To evaluate the transpiration (E) of plants, the steady-state diffusion porometer, model LCpro-SD, was used. During the measurements, the plants were exposed to a certain photon irradiance (μmol. m^{-2} s^{-1} of CO_2), according to a light saturation curve.

The experiment was conducted during the first nine months of crop development, with transpiration data collection occurring in three subsequent months: January, February and March 2022. A total of 21 plants (experimental units) were evaluated in seven different treatments electrical conductivity: 0.5 $dS.m^{-1}$; 1.25 $dS.m^{-1}$; 2 $dS.m^{-1}$; 2.75 $dS.m^{-1}$; 3.5 $dS.m^{-1}$; 4.25 $dS.m^{-1}$ and 5 $dS.m^{-1}$, with three repetitions.

The plants were randomly distributed in the field, each one in its own lysimeter, ensuring that there was no interference between them. The determination of leaf transpiration was carried out at the leaf level, with individuals kept under water restriction conditions, resulting in different water potentials.

To measure transpiration behavior, three healthy and fully expanded leaves were selected from each plant, located in the middle third of the canopy and exposed to solar radiation throughout the evaluation period. Readings were taken at hourly intervals throughout the day, from 7 am to 5pm, for five consecutive days, without applying water to the lysimeters, thus increasing water restrictions to observe the effect on leaf transpiration. At the end of the five-day period, the plants were maintained under normal irrigation conditions, restoring the maximum water level in the lysimeters.

2.3. Leaf Water Potential (Ψw)

During the experimental period, three leaves were collected from each plant, located in the middle third of the shoot, to evaluate leaf water potential. Leaves were collected during the morning and leaf water potential was determined using a pressure chamber, following the method described by Scholander et al. (1965).

2.4. Climate Factors

During transpiration measurements (E), photosynthetically active radiation (Qleaf) was determined simultaneously using a sensor coupled to the porometer chamber. This sensor was positioned perpendicular to the sunlight incident on the leaf surface throughout each working day.

Furthermore, complementary data on air temperature and relative humidity, specific to the measurement days, were obtained from the meteorological station of the National Institute for Space Research (INPE). This station is located in the UESB experimental area, at a distance of 300 meters from the place where the lysimeters were installed.

2.5. Relationship Between e, ψpd and Wleaf

With the help of SISVAR 5.6 software, regression models were developed to better explain transpiration (E) in relation to photosynthetically active radiation (Qleaf) for each class of plant water potential (Ψpd) at different levels of electrical conductivity.

From the models' response curves, it was possible to determine the light saturation point for each situation, providing a more detailed understanding of the relationship between radiation and transpiration in different soil moisture and salinity conditions.

2.6. Analysis of Variance and Regression Analysis

The results were subjected to analysis of variance (ANOVA) using the F test to compare means and regression analysis to quantitatively study the characteristics evaluated. These analyzes were carried out using the statistical programs SISVAR 5.6 and STATISTICA. Subsequently, a regression analysis was conducted between each treatment, excluding the control treatment, and the others, using the Dunnett test ($p < 0.05$).

The regression equations were generated using the least squares method, which seeks to minimize the sum of squares of the differences between the values estimated by the regression equation and the observed transpiration data from the mahogany crop. These differences are called residuals.

To evaluate the quality of the model in correctly estimating the values of the response variable (crop transpiration - E) as a function of environmental variables (global radiation (Rg), photosynthetically active radiation (Qleaf) and water potential - independent variables), the correlation coefficient R^2. This coefficient varies from 0 to 1 and indicates how well the model fits the observed data, with values closer to 1 indicating a better fit of the model to the data.

$$R^2 = 1 - (QRes / SQTot)$$

Where: SQRes = sum of squares of the residue;

SQTot = total sum of squares.

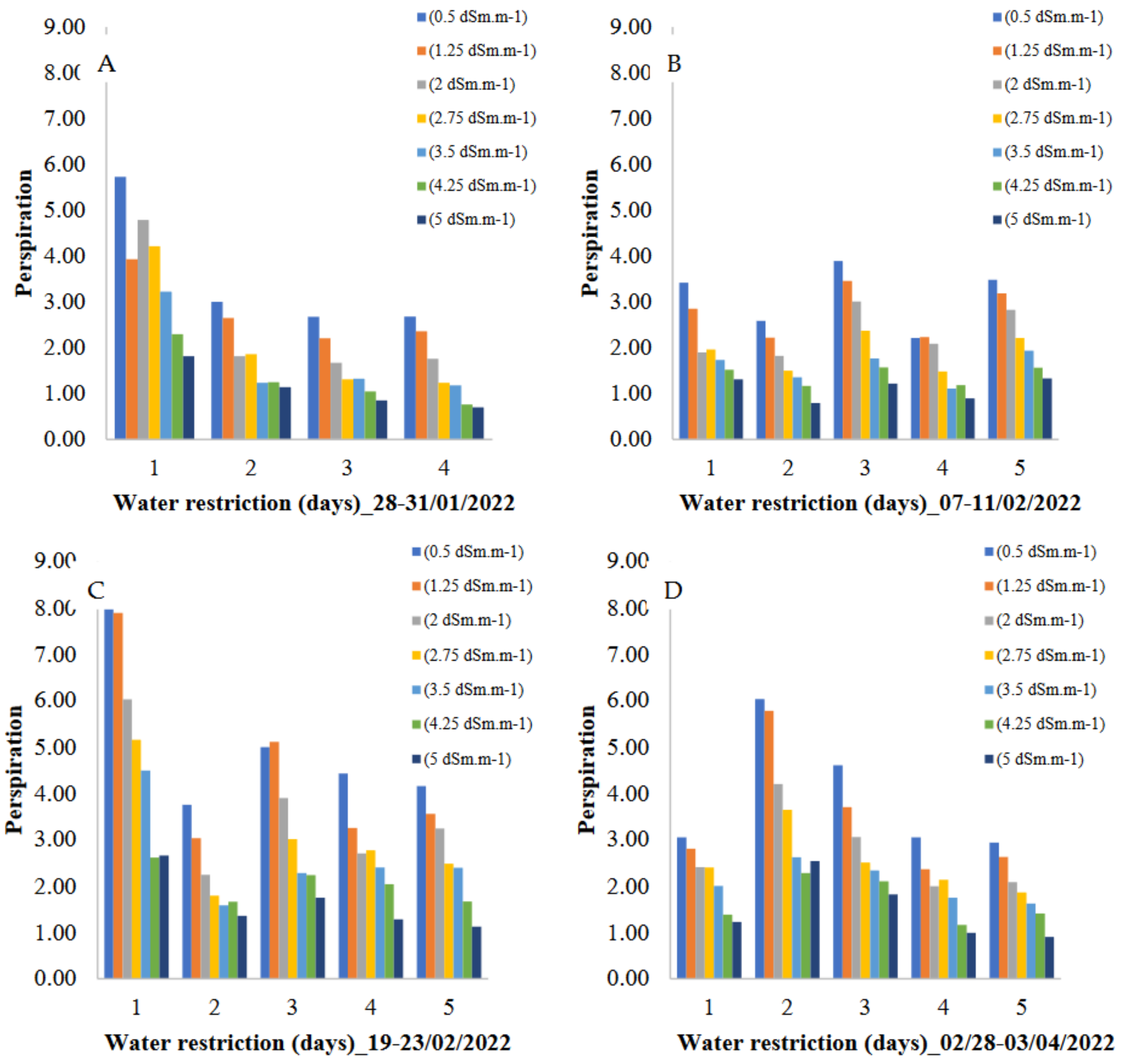
3. Results

Tables 1–3 display measurements of environmental parameters in the control treatment, including photosynthetically active radiation (Qleaf), leaf temperature (Tleaf), leaf transpiration (E), stomatal conductance (Gs) and photosynthesis (A) throughout the day for the three different repetitions. According to these tables, measurements of environmental parameters occur every 21 minutes. This interval was determined based on the time needed to carry out the measurements of the repetitions, totaling 21 experimental units in the seven treatments, which took 21 minutes. Each measurement per experimental unit (plant) lasted one minute, resulting in 28 measurements during the day for each plant, carried out from 7:49 am to 5:59 pm.

The values of environmental parameters, such as photosynthetically active radiation, leaf temperature, leaf transpiration and stomatal conductance, show an oscillation pattern with higher amplitudes at noon, around 12 o'clock, and lower values at the beginning, at 7 o'clock: 50 hours, and at the end of the day, at 5:50 pm. This oscillation follows a normal distribution pattern, resembling a trigonometric distribution in the shape of a parabola.

In the control treatment, in repetition one of Table 1, the environmental parameters have their maximum values at 11:19 am, with photosynthetically active radiation reaching 1986 W m-2 s-1, leaf temperature reaching 42.6 °C at 2 pm :07 hours, leaf transpiration of 16.3 mmol.m-2.s-1 at 11:40 hours and stomatal conductance with the highest value of 1.6 mmol.m-2.s-1 also at 11:40 hours. However, for photosynthesis, the oscillatory behavior does not follow a standard parabolic variation, presenting higher values at noon and lower values at the beginning, at 7:50 am, and the end of the day, at 5:50 pm, following a pattern of more random data distribution throughout the day.

Figure 3 shows the relationship between leaf transpiration over the days of the week for the seven treatments throughout the evaluation period in the field experiment. As shown in Figure 3, six evaluation periods were carried out, corresponding to six weeks, during which the plants were subjected to water restriction. At the end of each week, the water supply to the African mahogany plants was restored to avoid damage caused by excessive reduction in water potential, which could result in the death of the plants.



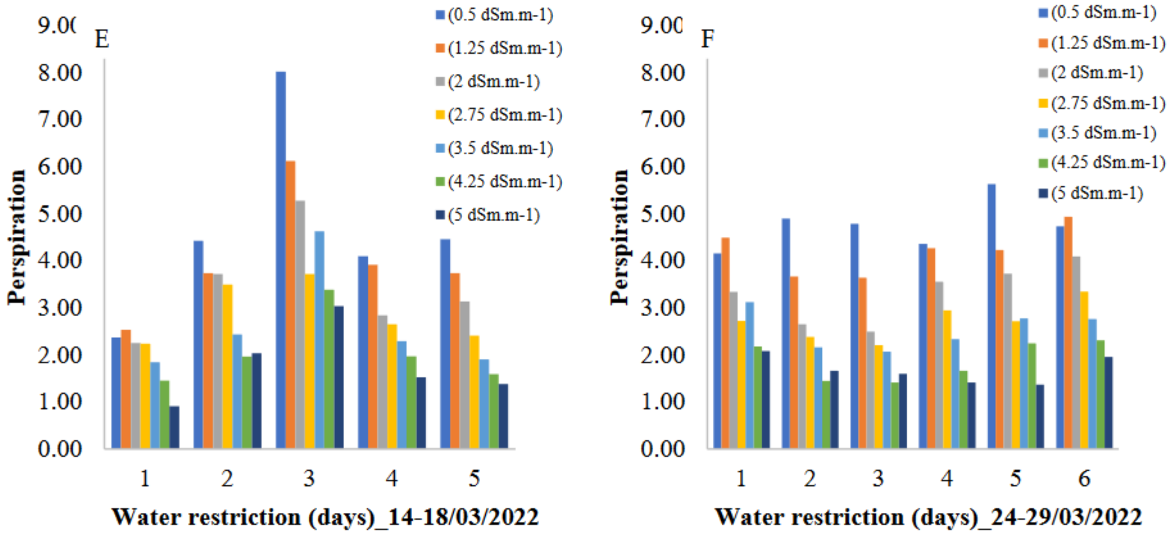


Figure 3. A, B, C, D, E, F - Leaf transpiration throughout the days of the week, from 6:00 am to 6:00 pm, in plants under different electrical conductivities of irrigation water for the period from january 28 th to march 29 th from 2022.

It can be seen in Figure 3 that, for the first day of each week, leaf transpiration decreases as the electrical conductivity of the irrigation water increases. This pattern is repeated over the days of the week, from day 1 to day 4, and it is also observed that the average leaf transpiration for all treatments decreases over the days of the week during the water restriction period from the 28th to the 31st of January 2022.

Table 1. Environmental parameters in the control treatment, including photosynthetically active radiation (Qleaf), leaf temperature (Tleaf), leaf transpiration (E), stomatal conductance (Gs) and photosynthesis (A) throughout the day for replication 1.

CONTROL TREATMENT – REPETITION 1							
Record (1-28)	**Date (day month year)**	**Time (hs:m:s)**	**Qleaf (W m $^{-2}$ s $^{-1}$)**	**Tleaf (°C)**	**AND (mmol.m $^{-2}$ .s- ^{1})**	**Gs (mmol.m $^{-2}$ .s- ^{1})**	**A (mmol.m $^{-2}$ .s $^{-1}$)**
1	03/01/2022	07:49:31	66.0	23.2	0.4	0.1	4.0
two	03/01/2022	08:10:31	72.0	22.3	0.6	0.1	2.7
3	03/01/2022	08:31:31	79.0	22.9	0.6	0.1	2.5
4	03/01/2022	08:52:30	120.0	23.8	1.0	0.1	3.7
5	03/01/2022	09:13:30	1326.0	28.8	10.9	1.1	4.4
6	03/01/2022	09:34:30	1364.5	36.4	11.2	1.1	5.5
7	03/01/2022	09:55:30	135.5	33.6	1.1	0.1	6.9
8	03/01/2022	10:16:30	1078.5	34.9	8.8	0.9	6.5
9	03/01/2022	10:37:30	1823.5	41.4	15.0	1.5	2.5
10	03/01/2022	10:58:30	1463.0	41.6	12.0	1.2	1.1
11	03/01/2022	11:19:30	1986.0	37.7	16.3	1.6	16.6
12	03/01/2022	11:40:30	1983.5	40.5	16.3	1.6	3.5
13	03/01/2022	12:01:30	1933.0	39.3	15.9	1.5	5.1
14	03/01/2022	12:22:30	297.0	40.3	2.4	0.2	1.1
15	03/01/2022	12:43:30	1242.5	41.8	10.2	1.0	1.1
16	03/01/2022	13:04:30	305.5	33.7	2.5	0.2	6.8
17	03/01/2022	13:25:30	1647.5	35.7	13.4	1.3	6.6
18	03/01/2022	13:46:29	315.5	35.4	2.6	0.3	5.9
19	03/01/2022	14:07:29	1304.0	42.6	10.7	1.0	2.6

20	03/01/2022	15:05:03	103.5	32.4	0.8	0.1	0.9
21	03/01/2022	15:26:03	150.5	32.7	1.2	0.1	1.3
22	03/01/2022	15:47:03	281.5	34.3	2.3	0.2	2.4
23	03/01/2022	16:12:57	761.0	36.8	6.2	0.6	4.6
24	03/01/2022	16:33:57	243.0	34.3	2.0	0.2	3.4
25	03/01/2022	16:54:57	173.5	32.6	1.4	0.1	3.0
26	03/01/2022	17:15:56	145.5	31.7	1.2	0.1	2.7
27	03/01/2022	17:36:56	76.0	30.7	0.6	0.1	1.2
28	03/01/2022	17:57:56	25.0	29.2	0.2	0.0	3.4

This pattern of variation in leaf transpiration is repeated during the period from February 19 to 23, 2022 (Figure 3.C). For example, on the first day of the week, leaf transpiration reaches 8.5 mmol.m-2.day-1 for the control treatment of 0.5 dSm.m-1, while for the treatment with the highest electrical conductivity of the water of irrigation (5 dSm.m^{-1}), leaf transpiration is 2.5 mmol.m^{-2}.day^{-1}. This variation is observed on days 2, 3, 4 and 5, with the average leaf transpiration decreasing over the days of the week with water restriction.

Table 2. Environmental parameters in the control treatment, including photosynthetically active radiation (Qleaf), leaf temperature (Tleaf), leaf transpiration (E), stomatal conductance (Gs) and photosynthesis (A) throughout the day for repetition 2.

CONTROL TREATMENT – REPETITION 2							
Record (1-28)	**Date (day month year)**	**Time (hs:m:s)**	**Qleaf (W m $^{-2}$ s $^{-1}$)**	**Tleaf (°C)**	**AND (mmol.m $^{-2}$ .s- ^{1})**	**Gs (mmol.m $^{-2}$ .s- ^{1})**	A (mmol.m $^{-2}$ .s $^{-1}$)
1	03/01/2022	07:50:31	66.0	23.2	0.4	0.1	3.6
2	03/01/2022	08:11:31	72.0	22.3	0.6	0.1	2.8
3	03/01/2022	08:32:31	79.0	22.9	0.6	0.1	2.5
4	03/01/2022	08:53:30	117.0	23.8	1.0	0.1	3.8
5	03/01/2022	09:14:30	1320.5	28.9	10.8	1.1	4.4
6	03/01/2022	09:35:30	1363.8	36.5	11.2	1.1	5.6
7	03/01/2022	09:56:30	136.8	33.6	1.1	0.1	6.8
8	03/01/2022	10:17:30	711.3	34.7	5.8	0.6	6.6
9	03/01/2022	10:38:30	1835.3	41.3	15.1	1.5	2.7
10	03/01/2022	10:59:30	1666.0	41.7	13.7	1.3	1.4
11	03/01/2022	11:20:30	1983.5	37.7	16.3	1.6	16.1
12	03/01/2022	11:41:30	1988.8	40.6	16.4	1.6	3.3
13	03/01/2022	12:02:30	1916.5	39.4	15.7	1.5	5.1
14	03/01/2022	12:23:30	295.5	40.2	2.4	0.2	0.8
15	03/01/2022	12:44:30	900.3	41.4	7.4	0.7	1.7
16	03/01/2022	13:05:30	301.3	33.6	2.5	0.2	6.6
17	03/01/2022	13:26:30	1650.3	35.8	13.5	1.3	6.5
18	03/01/2022	13:47:29	317.8	35.4	2.6	0.3	6.1
19	03/01/2022	14:08:29	1302.0	42.6	10.7	1.0	2.4
20	03/01/2022	15:06:03	98.8	32.4	0.8	0.1	1.2
21	03/01/2022	15:27:03	145.3	32.7	1.2	0.1	1.9
22	03/01/2022	15:48:03	270.8	34.3	2.2	0.2	2.2
23	03/01/2022	16:13:57	768.0	36.8	6.2	0.6	4.5
24	03/01/2022	16:34:57	220.5	34.3	1.8	0.2	3.4
25	03/01/2022	16:55:57	176.3	32.5	1.4	0.1	3.0
26	03/01/2022	17:16:56	132.3	31.7	1.1	0.1	2.7
27	03/01/2022	17:37:56	74.5	30.6	0.6	0.1	1.0
28	03/01/2022	17:58:56	24.5	29.1	0.2	0.0	2.9

The variation in leaf transpiration during the period from February 7 to 11, 2022 (Figure 3.B) shows similar average oscillation values between days of the week, with variation between treatments on each day. For example, on the first day of the week, treatments with lower electrical conductivity of irrigation water show higher leaf transpiration values, while values decrease linearly with increasing electrical conductivity.

Table 3. Environmental parameters in the control treatment, including photosynthetically active radiation (Qleaf), leaf temperature (Tleaf), leaf transpiration (E), stomatal conductance (Gs) and photosynthesis (A) throughout the day for repetition 3.

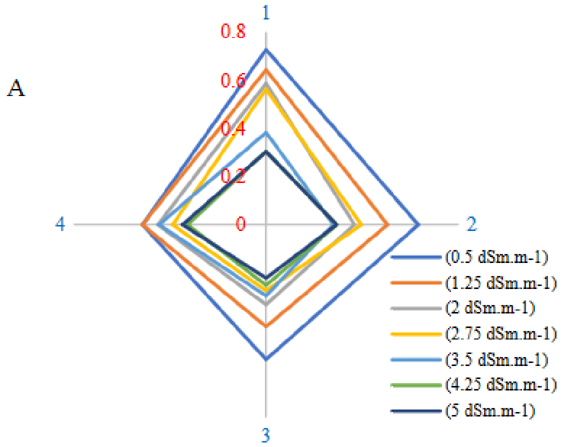
CONTROL TREATMENT – REPETITION 3							
Record (1-28)	**Date (day month Year)**	**Time (hs:m:s)**	**Qleaf (W m $^{-2}$ s $^{-1}$)**	**Tleaf (°C)**	**AND (mmol.m $^{-2}$ .s- ^{1})**	**Gs (mmol.m $^{-2}$ .s- ^{1})**	**A (mmol.m $^{-2}$ .s $^{-1}$)**
1	03/01/2022	07:51:31	66.0	23.2	0.4	0.1	3.2
2	03/01/2022	08:12:31	72.0	22.3	0.6	0.1	2.8
3	03/01/2022	08:33:31	79.0	22.9	0.6	0.1	2.5
4	03/01/2022	08:54:30	114.0	23.8	0.9	0.1	3.9
5	03/01/2022	09:15:30	1315.0	29.0	10.8	1.1	4.4
6	03/01/2022	09:36:30	1363.0	36.6	11.2	1.1	5.6
7	03/01/2022	09:57:30	138.0	33.5	1.1	0.1	6.8
8	03/01/2022	10:18:30	344.0	34.5	2.8	0.3	6.6
9	03/01/2022	10:39:30	1847.0	41.1	15.2	1.5	2.9
10	03/01/2022	11:00:30	1869.0	41.8	15.4	1.5	1.7
11	03/01/2022	11:21:30	1981.0	37.7	16.3	1.6	15.5
12	03/01/2022	11:42:30	1994.0	40.7	16.4	1.6	3.1
13	03/01/2022	12:03:30	1900.0	39.4	15.6	1.5	5.2
14	03/01/2022	12:24:30	294.0	40.0	2.4	0.2	0.4
15	03/01/2022	12:45:30	558.0	41.0	4.6	0.4	2.2
16	03/01/2022	13:06:30	297.0	33.5	2.4	0.2	6.4
17	03/01/2022	13:27:30	1653.0	35.9	13.5	1.3	6.4
18	03/01/2022	13:48:29	320.0	35.3	2.6	0.3	6.3
19	03/01/2022	14:09:29	1300.0	42.7	10.6	1.0	2.3
20	03/01/2022	15:07:03	94.0	32.4	0.8	0.1	1.6
21	03/01/2022	15:28:03	140.0	32.7	1.1	0.1	2.5
22	03/01/2022	15:49:03	260.0	34.3	2.1	0.2	1.9
23	03/01/2022	16:14:57	775.0	36.8	6.3	0.6	4.4
24	03/01/2022	16:35:57	198.0	34.2	1.6	0.2	3.4
25	03/01/2022	16:56:57	179.0	32.5	1.4	0.1	2.9
26	03/01/2022	17:17:56	119.0	31.6	1.0	0.1	2.8
27	03/01/2022	17:38:56	73.0	30.6	0.6	0.1	0.8
28	03/01/2022	17:59:56	24.0	29.1	0.2	0.0	2.4

In Figure 3.D, the second day of the week (day 2) presents the highest leaf transpiration values for all treatments. Analyzing day 2 of the period from February 28th to March 4th, 2022 in isolation, the same pattern of reduction in leaf transpiration is observed between treatments, with treatments having lower electrical conductivity (0.5 dSm.m^{-1}) presenting higher values (6 mmol.m^{-2}.day^{-1}) and treatments with higher electrical conductivity (5 dSm.m^{-1}) with lower values (2.5 mmol.m^{-2}.day^{-1}).

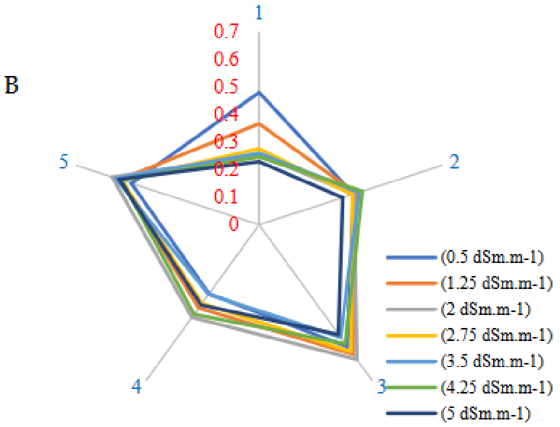
Figure 4 shows the relationship of stomatal conductance over the days of the week for the seven treatments throughout the evaluation period in the field experiment. By analyzing Figure 4.A, it is observed that, for the first day of the week (day 1) of the period from january 28 to 31, 2022, the stomatal conductance values vary according to the electrical conductivity of the irrigation water, decreasing as the conductivity increases.

This pattern of oscillation in stomatal conductance values is repeated on the 2nd, 3rd and 4th of the week, with a gradual decrease over the days of the week. On day 4, for example, stomatal conductance reaches 0.4 mmol.m^{-2}.day^{-1} for the control treatment of 0.5 dSm.m^{-1}.

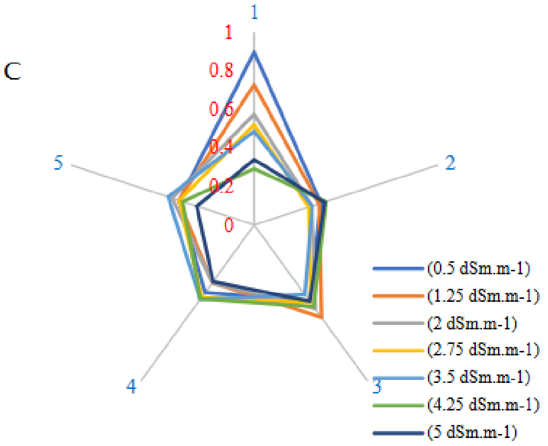
The observation in Figure 4.B shows a variation behavior similar to that observed in the period from january 28 to 31, 2022, with a pronounced variation in stomatal conductance values for the first day of the week. The highest values are observed for the control treatment of 0.5 dSm.m^{-1}, while these values decrease with the increase in the electrical conductivity of the irrigation water.



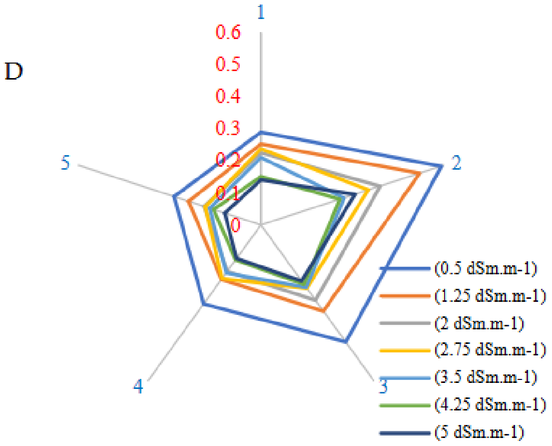
Time with water restriction (days)_28-31/01/2022
mmol.m$^{-2.}$ Day^{1} (Stomatal Conductance)



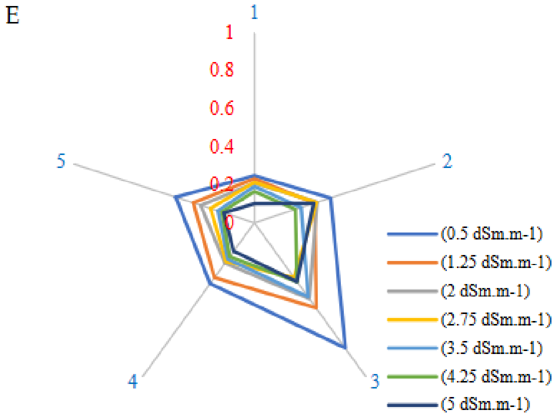
Time with water restrictions (days)_07-11/02/2022
mmol.m$^{-2.}$ Day^{1} (Stomatal Conductance)



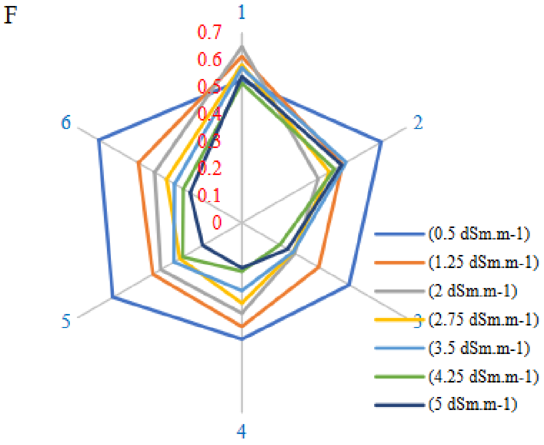
Time with water restrictions (days)_19-23/02/2022
mmol.m$^{-2.}$ Day^{1} (Stomatal Conductance)



Time with water restriction (days)_28/2-04/03/2022
mmol.m$^{-2.}$ Day^{1} (Stomatal Conductance)



Time with water restrictions (days)_14-18/03/2022
mmol.m$^{-2.}$ Day^{1} (Stomatal Conductance)



Time with water restrictions (days)_24-29/03/2022
mmol.m$^{-2.}$ Day^{1} (Stomatal Conductance)

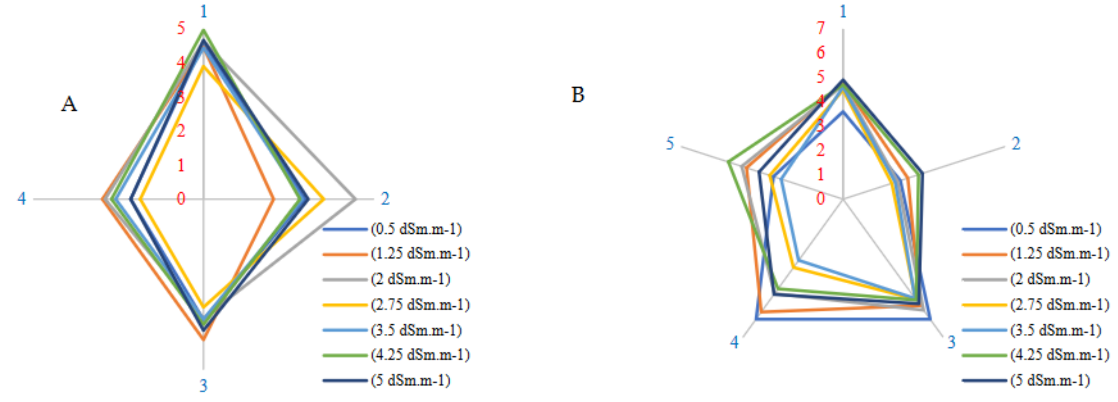
doi:10.20944/preprints202411.0079.v1

Figure 4. A, B, C, D, E, F - Stomatal conductance throughout the days of the week, from 6:00 am to 6:00 pm, in plants under different electrical conductivities of irrigation water for the period from january 28 th to march 29 th from 2022.

During the period from march 14 to 18, 2022 (Figure 4.C), the third day of the week presented the highest stomatal conductance values, highlighting the control treatment with a stomatal conductance of 0.8 mmol.m^{-2}.day^{-1}, followed by lower values of the other treatments subjected to lower electrical conductivities of the irrigation water.

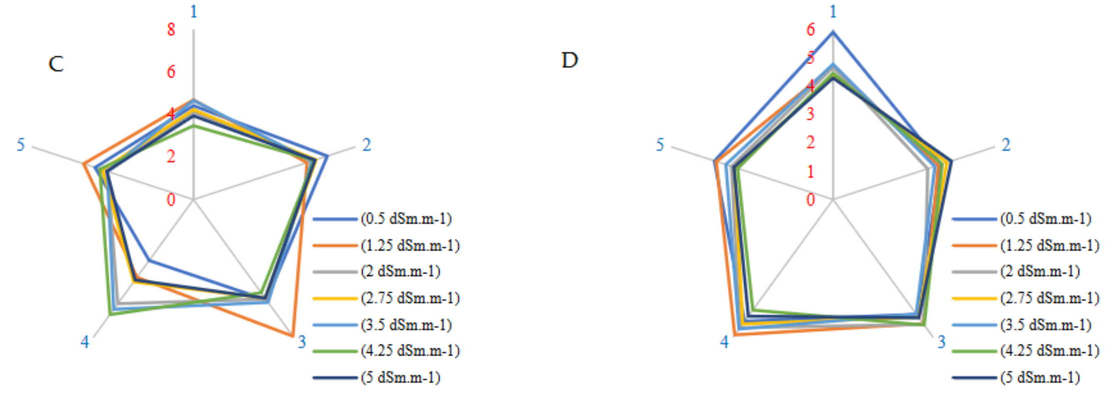
For the control treatment subjected to electrical conductivity of the irrigation water of 0.5 dSm.m^{-1} (Figure 4.F), it is observed that the stomatal conductance values are higher than those of the other treatments on all days of the week. However, on the first day of the week, these values are the lowest among the other treatments.

Figure 5 graphically presents the distribution of the photosynthetic rate over the days of the week for all seven electrical conductivity treatments. It is observed that photosynthesis does not present a linear trend in relation to the increase in the electrical conductivity of irrigation water. For all periods of analysis, photosynthesis presents similar values throughout all days of the week, not being influenced by water restriction or variations in the electrical conductivity of irrigation water. In Figure 5.E, for example, the photosynthesis values for all treatments on all days of the week are very close, around 6 mmol.m^{-2}.day^{-1}, during the period from march 14 to 18 2022.



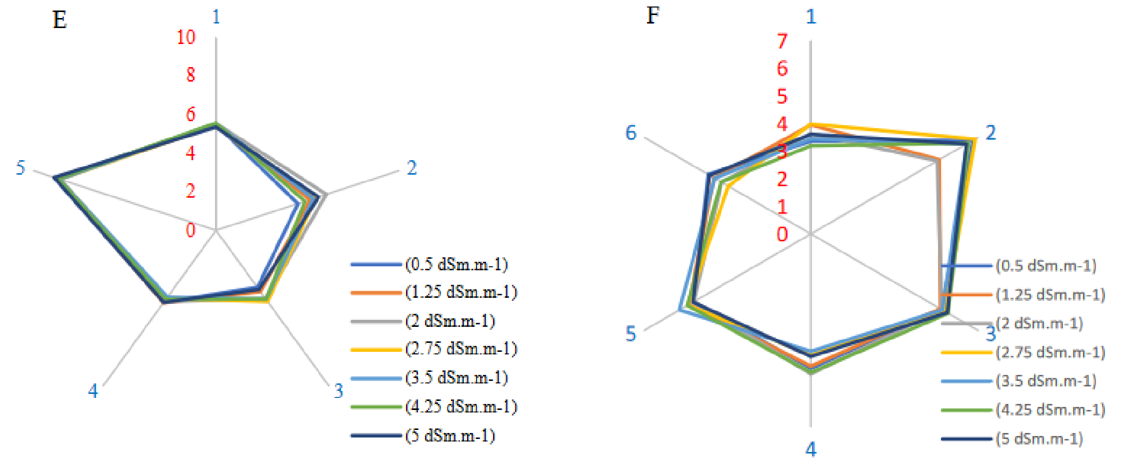
Time with water restriction (days)_28-31/01/2022
mmol.m $^{-2}$ Day ^{1} (Photosynthesis)

Time with water restrictions (days)_07-11/02/2022
mmol.m $^{-2}$ Day ^{1} (Photosynthesis)



Time with water restrictions (days)_19-23/02/2022
mmol.m $^{-2}$ Day ^{1} (Photosynthesis)

Time with water restriction (days)_28/2-04/03/2022
mmol.m $^{-2}$ Day ^{1} (Photosynthesis)



Time with water restrictions (days)_14-18/03/2022
mmol.m $^{-2.}$ Day ^{1} (Photosynthesis)

Time with water restrictions (days)_24-29/03/2022
mmol.m $^{-2.}$ Day ^{1} (Photosynthesis)

Figure 5. A, B, C, D, E, F - Photosynthesis throughout the days of the week, from 6:00 am to 6:00 pm, in plants under different electrical conductivities of irrigation water for the period from january 28 th to march 29 th, 2022.

4. Discussion

The results obtained from measurements of environmental parameters in the control treatment provide valuable insights into the physiological behavior of plants throughout the day. The frequency of measurements every 21 minutes allowed a detailed analysis, revealing notable oscillatory patterns in the values of photosynthetically active radiation (Qleaf), leaf temperature (Tleaf), leaf transpiration (E), stomatal conductance (Gs) and photosynthesis (A).

The oscillation of these parameters, with higher values at midday and lower values at the beginning and end of the day, is consistent with findings from other studies, indicating an adaptive response of plants to the diurnal cycle. The normal distribution pattern, resembling a trigonometric parabola, is consistent with physiological regulation to optimize metabolic efficiency.

When comparing the results with other studies, we observed that the amplitude and timing of the oscillations can vary depending on the plant species, specific environmental conditions and experimental methods. Previous studies, as mentioned by Tian et al., 2020b ; Page et al., 2018 corroborate the general trend of midday highs, but specific divergences may occur.

Repetition one of the control treatment, as highlighted in Table 1, revealed significant peaks in photosynthetically active radiation, reaching 1986 W $m^{-2}.s^{-1}$ at 11:19. This can be compared with similar studies by Y. Wu et al., 2021b and Lyu et al., 2022, which also identified high values during this period, indicating the plant's effectiveness in taking advantage of available sunlight.

Leaf temperature reaching 42.6 °C at 2:07 pm indicates thermal adaptation, but this increase can influence photosynthesis and transpiration rates. Dauzat et al., 2001 and Ben-Asher et al., 2006 suggest that extreme leaf temperatures can have significant effects on plant physiology, highlighting the importance of considering this factor in comparative studies.

The more random variation observed in photosynthesis throughout the day, in contrast to a parabola pattern, suggests that this process may be more influenced by specific factors, such as availability of water, nutrients or other elements not considered in this study.

These results reinforce the complexity of plants' physiological response to environmental factors, highlighting the continued need for in-depth studies to understand the nuances of these processes. By contextualizing the results within the existing body of scientific literature, we contribute to the global understanding of diurnal patterns in plant physiological responses.

Analysis of Figure 3 reveals interesting patterns in leaf transpiration in response to the water restriction imposed by the different treatments. Observing the six assessment periods, each representing a week of water restriction, provides valuable insights into how plants respond to water deficit conditions over time.

A clear trend is the reduction of leaf transpiration with the increase in the electrical conductivity of irrigation water. This pattern is consistent throughout the different periods evaluated and is observed on all days of the week, indicating a consistent response of plants to water availability. This inverse relationship between electrical conductivity and leaf transpiration is corroborated by previous studies, as mentioned by Miyoshi et al., 2023; Cao et al., 2022 and Zhu et al., 2022a , which highlight the importance of irrigation water quality in plant physiology.

A general decrease in leaf transpiration was also observed over the days of the week within each evaluation period. This suggests an adaptation of plants to water stress over time, possibly as a water conservation mechanism during periods of scarcity. This dynamic adaptation is fundamental for the survival of plants in environments subject to variations in water availability.

However, it is worth highlighting that the magnitude of the reduction in leaf transpiration may vary between different treatments, as evidenced by the variation in average values over the days of the week. This variation can be attributed to different plant tolerances to water stress, which can be influenced by genetic, environmental and management factors.

The identification of the second day of the week as the period with the highest leaf transpiration values for all treatments is intriguing and suggests the existence of weekly patterns in the physiological response of plants. Additional studies would be needed to further investigate this observation and understand the mechanisms underlying this pattern.

The results in Figure 3 highlight the importance of irrigation water quality and duration of water stress in regulating plant leaf transpiration. These findings have significant implications for agricultural practice, highlighting the need for water management strategies that take into account the dynamic effects of water stress on plant physiology.

Figure 4 provides a detailed view of stomatal conductance across different treatments and time periods, providing important insights into how African mahogany plants respond to variation in the electrical conductivity of irrigation water and the imposition of water restriction.

When observing the weekly behavior of stomatal conductance, it is clear that the variation in values is related to the concentration of salts in the irrigation water. In the first days of the week (Figure 4.A), a consistent decrease in stomatal conductance is noted as the electrical conductivity of the water increases. This pattern persists in subsequent days (Figure 4.A) and reflects the physiological response of plants to the quality of water available for transpiration.

The average reduction in stomatal conductance throughout the week, particularly on day 4, is an additional indication of how plants are adjusting their stomatal activity in response to water restriction. This adaptation is a known strategy of plants to conserve water during periods of drought stress (Qiu et al., 2020; Jiang et al., 2022; Nie et al., 2021; Bai et al., 2021; Fan et al., 2020).

Figure 4.B shows a notable consistency in the pattern observed in the first time period (January 28-31, 2022). The increase in the electrical conductivity of irrigation water results in a pronounced reduction in stomatal conductance, highlighting the sensitivity of plants to the salt content in the water.

The period from February 19 to 23 (Figure 4.C) highlights the initial influence of water restriction on the first day of the week, where stomatal conductance is higher in the control treatment. This suggests an immediate response by plants to the onset of water stress, with the control treatment being more resilient initially.

The change in behavior observed in Figure 4.D, where the second day of the week presents the highest stomatal conductance values, is intriguing and may indicate seasonal variation or additional external influences that deserve further investigation.

In the period from March 14 th to 18 th (Figure 4.E), the third day of the week stands out as the one with the highest stomatal conductance values. The control treatment, once again, exhibits a higher stomatal conductance, indicating its superior capacity to respond to water stress during this period.

Figure 4.F reveals that, at the end of march, the control treatment maintains higher values of stomatal conductance compared to the other treatments, except on the first day of the week. This

persistent behavior highlights the importance of the electrical conductivity of irrigation water in regulating stomatal conductance, especially when plants are under prolonged water stress.

An interesting finding is the variation in the magnitude of stomatal conductance between the different treatments, especially on the first day of the week. This suggests that plants respond differently to water availability, with treatments with lower electrical conductivity presenting higher values of stomatal conductance. This observation highlights the importance of appropriate irrigation strategies to optimize water efficiency and maximize crop productivity.

Furthermore, the identification of the second day of the week as the period with the highest stomatal conductance values is intriguing and deserves further investigation. This observation may be related to specific environmental factors or intrinsic physiological patterns of plants, and their complete understanding can provide valuable insights for irrigation management.

These results are consistent with previous studies, such as (Xu et al., 2021; Li et al., 2020; L. Zhao et al., 2023), which demonstrated the critical influence of irrigation water quality on plant stomatal physiology. Understanding these patterns is crucial to optimizing water management strategies, ensuring the health and sustainable performance of African mahogany plantations.

Figure 5 provides a visual representation of the distribution of photosynthetic rate over the days of the week for the different electrical conductivity treatments of irrigation water. Surprisingly, the results indicate that photosynthesis did not demonstrate a clear trend of conformity towards increasing electrical conductivity of irrigation water.

Over the six periods of analysis, photosynthesis appears to be robust and resilient to water restriction and variation in electrical conductivity values. This suggests that for the African mahogany plants in this particular study, other factors may be playing a more significant role in regulating photosynthetic rate than irrigation water quality.

The lack of variation in photosynthesis values over the days of the week, even under different levels of water stress, indicates a possible adaptation of plants or an ability to maintain photosynthesis within optimal limits, regardless of environmental conditions. This phenomenon can be attributed to complex physiological mechanisms developed by plants to optimize photosynthetic efficiency and minimize the effects of stress.

The period from march 14 to 18, 2022 (Figure 5.E) is especially interesting, as it shows that photosynthesis values remain consistent for all treatments on all days of the week, with an average of around 6 mmol.m^{-2}.day^{-1}. This suggests that even under water stress conditions, plants maintained a relatively stable photosynthetic rate, which is essential to ensure biomass production and healthy plant growth (Foyo-Moreno et al., 2023 ; Henrique et al. , 2023 ; Zhao et al., 2023b) .

These results are intriguing and indicate the need for a more detailed analysis of the mechanisms underlying the regulation of photosynthesis in African mahogany plants. Future studies could explore gene expression, biochemical processes, and leaf anatomy to better understand how these plants respond to drought stress and varying environmental conditions. This information is essential for developing more effective and sustainable management strategies for African mahogany plantations.

5. Conclusions

- The results of environmental parameter measurements showed a consistent pattern of oscillation throughout the day, with highest values at midday and lowest at the beginning and end of the day. This behavior suggests a physiological response of plants to variation in sunlight intensity and temperature.
- Furthermore, detailed analysis of leaf transpiration and stomatal conductance revealed a reduction in these parameters with increasing electrical conductivity of irrigation water and over the days of the week under water restriction.
- Surprisingly, photosynthesis did not show a clear trend in relation to variation in water electrical conductivity or water restriction. Photosynthesis values remained consistent across days of the week, indicating a possible plant adaptation or an ability to maintain stable photosynthesis regardless of environmental conditions.

- These results suggest that African mahogany plants may possess robust physiological mechanisms to cope with drought stress and variation in irrigation water quality. However, additional research is still needed to fully understand the mechanisms underlying these responses and how they can be applied in practice to optimize the management of African mahogany plantations.
- This study provides valuable information for understanding the physiology of African mahogany plants and highlights the importance of considering a variety of environmental parameters when designing management strategies to optimize the growth and productivity of these plants under different growing conditions.

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