

## CHLOROPHYLL A FLUORESCENCE IN SACCHARINE SORGHUM IRRIGATED WITH SALINE WATER<sup>1</sup>

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**SUMMARY:** Salinity affects the thylakoid membrane, interfering with the emission of the fluorescence, besides acting on the activation of the enzyme chlorophyllase that contributes to the degradation of the photosynthetic pigments. Thus, estimating the damage in the photosynthetic apparatus caused by salt water is an interesting tool to detect abiotic stresses. For this purpose, for 65 days (December 2015 to February 2016), 48 plants of saccharine sorghum (IPA 2502), irrigated with two saline waters (NaCl and Salt Mix) both with six levels of electrical conductivity - CE (0, 2.5, 5, 7.5, 10 and 12.5 dS m<sup>-1</sup>) were cultivated in greenhouse and in randomized blocks, with four replicates. At 60 days after sowing, in the middle third of the plants, chlorophyll a fluorescence was evaluated using a FluorPen fluorometer, model F100 determining: the intensity of emission of the initial fluorescence (F<sub>0</sub>), Variable fluorescence (F<sub>v</sub>), Maximum fluorescence (F<sub>m</sub>), Quantum efficiency of photosystem II (F<sub>v</sub>/F<sub>m</sub>), Dissipated energy (ET<sub>0</sub>/CR) and Quantum energy dissipation (ϕD<sub>0</sub>). In the same leaf, fresh vegetable material was collected, refrigerated and it had its fresh mass quantified in laboratory besides the realization of the protocol for extraction of the photosynthetic pigments. The photosynthetic pigments showed a significant interaction between the sources of salts and the increasing levels of electrical conductivity. When comparing the levels of photosynthetic pigments between the different levels of EC, it was observed that the contents of chlorophyll a and b reduced with the increase of EC, and that in the same conditions the levels of carotenoids increased. When raising the EC level of the irrigation water, the fluorescence emission of chlorophyll a presented negative interference. With the increase in the salts contents of the irrigation water, irreversible damages are observed in the photosynthetic apparatus of sorghum plants.

**KEYWORDS:** Salinity, Photosynthetic Pigments, Photochemical Efficiency

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## **FLUORESCÊNCIA DA CLOROFILA A EM SORGO SACARINO IRRIGADO COM ÁGUA SALINA**

**RESUMO:** A salinidade afeta a membrana dos tilacoides, interferindo na emissão da fluorescência e promovendo degradação dos pigmentos fotossintéticos. Assim, estimar o dano no aparato fotossintético provocado por águas salinas é uma ferramenta interessante para detectar estresses abióticos. Para tanto, plantas de sorgo sacarino foram cultivadas em ambiente protegido e em blocos ao acaso, irrigadas com duas fontes de água (NaCl e Mistura de sais) com seis níveis de condutividade elétrica – CE (0; 2,5; 5; 7,5; 10 e 12,5 dS m<sup>-1</sup>). Aos 60 dias após a semeadura, foram avaliados os parâmetros da fluorescência da clorofila *a* : F<sub>0</sub>, F<sub>v</sub>, F<sub>m</sub>, F<sub>v</sub>/F<sub>m</sub>, ET<sub>0</sub>/CR, DI<sub>0</sub>/CR e  $\phi D_0$ ; juntamente com a coleta de material vegetal para quantificação dos pigmentos fotossintéticos. Os pigmentos fotossintéticos apresentaram interação significativa entre as fontes de sais e os níveis crescentes de condutividade elétrica. Foi observado que os teores de clorofila *a* e *b* reduziram com o aumento da CE, sendo que para as mesmas condições os teores de carotenoides apresentaram acréscimo. Ao se elevar o nível da CE da água de irrigação, a emissão fluorescência da clorofila *a* apresentou interferência negativa. Com o incremento nos teores de sais da água de irrigação, observam-se danos irreversíveis no aparato fotossintético das plantas de sorgo.

**PALAVRAS-CHAVE:** Salinidade, Pigmentos Fotossintéticos, Eficiência fotoquímica.

### **INTRODUCTION**

In the semi-arid region, besides the low water availability and high temperatures, another important factor is salinity, and sorghum is characterized by its moderate resistance to this stressing agent (NABATI et al., 2013). This is probably associated with mechanisms such as control of sodium accumulation in leaves, increased water use efficiency, osmotic adjustment associated with the accumulation of soluble sugars, mainly non-reducing, maintenance in the synthesis and protection of pigments such as chlorophylls (COELHO, 2013) .

According to Tavakkoli et al. (2011) the main ionic constituents of the soluble salts of the soil are sodium, calcium, magnesium, chlorides, as well as carbonates and bicarbonates. The action of these salts is directly linked to the injuries in the functioning of photosystem II (PSII) (AMBEDE et al., 2012). In stressful environmental conditions, especially in plants under the

influence of saline stress, the enzyme chlorophyllase correlates with the degradation of photosynthetic pigments (SHARMA & HALL, 1991; NEVES & SPAT, 2013).

Generally, the estimation of chlorophyll *a* fluorescence is used as a way to monitor the electron transfer (integrity of the photosynthetic apparatus) in the face of environmental adversities, considering that these are fast, precise and non-destructive techniques (MAXWELL & JOHNSON, 2000 (1990)). Thus, the study of physiological parameters such as stomatal resistance, pigment contents and chlorophyll *a* fluorescence are important in the clarification of the effects of osmotic and water conditions on photosynthetic efficiency in plants (MELO et al., 2010).

Thus, the objective of this work was to evaluate the foliar photosynthetic pigment contents and chlorophyll *a* fluorescence in sorghum plants submitted to irrigation with saline solutions of different ionic compositions and increasing levels of electrical conductivity.

## MATERIAL AND METHODS

### Location and assembly of the experiment

The experiment was conducted in a protected environment located at the Federal Rural University of Pernambuco, campus Recife, Brazil, from December 2015 to February 2016, totaling 60 days of experimental period. During the conduction of the experiment, the mean values of relative humidity and temperature were 64.5% and 31 ° C, respectively, monitored by datalogger.

The soil used came from the rural area of the city of Pesqueira (08 ° 21 '28 "S and 36 ° 41' 47" W), located in the semi-arid region of the Northeast, in the Upper Ipanema Basin, state of Pernambuco, Brazil. It is important to point out that the collection area is characterized by intense agricultural use, mainly olericultura, with a tendency to undergo salinization. The collection was carried out in the 0-30 cm layer in a soil classified as *Neossolo Flúvico* (Fluvent), according to Embrapa (2013). The soil was air dried, decanted, homogenized and passed through a 4 mm sieve as a way of preserving the micro-aggregates.

### Initial soil characterization

To the characterization of the chemical properties of the soil (Table 1), the pH in water was determined in the proportion of 1:2.5 (soil; solution); Ca<sup>2+</sup>, Mg<sup>2+</sup> were extracted in 1 mol L<sup>-1</sup> KCl solution and titrated in EDTA and Na<sup>+</sup> and K<sup>+</sup> extracted by Mehlich -1 and quantified in a flame emission photometer, both according to the methodology proposed by Embrapa (1997). The cation exchange capacity (CEC), the sum of bases (SB) and the percentage of

exchangeable sodium (PES) were calculated from the values obtained in the sortative complex. The saturation extract was obtained from the saturation paste (RICHARDS, 1954) and from this the electrical conductivity and pH were measured.

For the physical characterization, the granulometry and water dispersed clay (WDC) were determined in the fine dry earth in the air (FDEA) from the densimeter method; Soil density and particle density (EMBRAPA, 1997). In addition to the field capacity (FC) ( $\psi_m$ : - 0.1 atm) and the permanent wilting point (PWP) ( $\psi_m$ : - 15 atm). The physical properties of the soil were: Fine sand: 315 g kg<sup>-1</sup>, Thick sand: 163 g kg<sup>-1</sup>, Silt: 378 g kg<sup>-1</sup>, Clay: 144 g kg<sup>-1</sup>, ADA: 100 g kg<sup>-1</sup>, Bulk density: 1.28 g cm<sup>-3</sup>, Particle density: 2.52 g cm<sup>-3</sup>, Total porosity: 49.15%, flocculation degree: 30.56%, Degree of dispersion: 69.44%, Moisture in field capacity: 0.26 g g<sup>-1</sup>; Humidity at the Permanent Wilt Point of 0.05 g g<sup>-1</sup>.

### **Installation of the experiment and definition of treatments**

Four sacarine sorghum seeds of the cultivar IPA 2502 were seeded in pots (8L) filled with *Neossolo Flúvico* (Fluvent). After the emergence of the seedlings and according to their sanity, thinning was done leaving one sorghum plant per pot. Irrigation occurred daily, maintaining humidity at 80% of the soil field capacity. Two solutions were used (Table 2) with six levels of electrical conductivity (0; 2,5; 5; 7,5; 10 and 12,5 dS m<sup>-1</sup>). Two sources of salts were used to elaborate the electrical conductivities: only sodium chloride and a mixture of salts with water-like proportions of the wells used in the soil collection region for irrigation with NaCl, CaCl<sub>2</sub>, Ca (NO<sub>3</sub>)<sub>2</sub>, MgCl<sub>2</sub>, MgSO<sub>4</sub> and KCl.

The treatment of 12.5 dS m<sup>-1</sup> was disregarded, since the experimental units related to it did not resist until the end of the experiment due to the high salts contents of the solutions.

### **Fluorescence of Chlorophyll a**

The fluorescence parameters of chlorophyll *a* - initial fluorescence ( $F_0$ ), variable fluorescence ( $F_v$ ), maximum fluorescence ( $F_m$ ), quantum efficiency of PSII ( $F_v / F_m$ ), electron flow per reaction center ( $ET_0 / CR$ ), energy ( $D_0 / CR$ ) and quantum energy dissipation ( $\phi D_0$ ) were measured at 60 days after sowing (DAS) with the aid of the FluorPen, F100 (Photon Systems Instruments) fluorometer. The measurements were performed on the second fully expanded and healthy upper leaf after the period of adaptation to the dark for 30 minutes, with the aid of tweezers, for total oxidation of the PSII reaction center.

### **Extraction of Photosynthetic Pigments**

The chemical extraction and determination of the chlorophyll *a*, *b*, and carotenoid contents followed the methodology described by Lichtenthaler & Buschmann (2001). The

obtained data were applied in equations (01), (02) and (03) to quantify the levels of photosynthetic pigments in the sorghum leaf, from the wavelength for each pigment.

$$Ca (\mu g ml^{-1}) = 13,36 A_{664,1} - 0,97 A_{648,6} \quad (01)$$

$$Cb (\mu g ml^{-1}) = 16,36 A_{648,6} - 2,43 A_{664,1} \quad (02)$$

$$C_{(x+b)} = \frac{100 A_{470} - 1,43 Ca - 35,87 Cb}{209} \quad (03)$$

On what:

*Ca* - Leaf content of Chlorophyll *a*; *Cb* - Leaf content of Chlorophyll *b*; *C (x + b)* - Leaf content of carotenoids; *A664.1* - Values obtained in the spectrophotometer at a wavelength of 664.1 nm; *A648.6* - Value obtained in the spectrophotometer at the wavelength of 648.6nm; *A470* - Value obtained in the spectrophotometer at the wavelength of 470nm.

### Statistical analysis

The data were submitted to analysis of variance and the means were compared by Tukey Test at 5% probability ( $p < 0.05$ ).

## RESULTS AND DISCUSSION

### Foliar contents of photosynthetic pigments

There was significant interaction at 1% ( $p < 0.01$ ) between the sources of salts and the increasing levels of electrical conductivity. With the increase of the electrical conductivity of the irrigation water, the chlorophyll *a*, *b* and carotenoid contents were verified in relation to the control (Table 3). Chlorophyll *a* (*Cl<sub>a</sub>*) leaf contents decreased, except for the treatment of 2.5 dS m<sup>-1</sup>, which presented an increase of 28.25%, for the solution mixture of salts, in relation to the control (0 dS m<sup>-1</sup>). The highest decreases were observed for the electrical conductivity of 10 dS m<sup>-1</sup>, 70.66%, in the NaCl solution and for the electrical conductivity of 7.5 dS m<sup>-1</sup>, 68.14%, for the mixing solution of salts.

There was a decrease in these chlorophyll *b* (*Cl<sub>b</sub>*) leaf contents with the increase in the electrical conductivity (EC) of the solutions. For the test of means, there was no difference between treatments, except for the last salinity level (10 dS m<sup>-1</sup>) of the NaCl solution and for the electrical conductivity 7.5 dS m<sup>-1</sup> of the salt mixture solution, which showed a decrease of 41.10% and 54.45%.

The carotenoids presented a 35.27% reduction in their electrical conductivity content of 7.5 dS m<sup>-1</sup> in the salt mixing solution. However, for the other electrical conductivities an

increase of 30.98% ( $2.5 \text{ dS m}^{-1}$ ), 0.05% ( $5 \text{ dS m}^{-1}$ ) and 0.69% ( $10 \text{ dS m}^{-1}$ ) was observed, when compared with the control ( $0 \text{ dS m}^{-1}$ ). For the NaCl solution the carotenoid content decreased with the increase of the electrical conductivities, reaching a decrease of 40.43% for the electrical conductivity of  $10 \text{ dS m}^{-1}$ , when compared with the control ( $0 \text{ dS m}^{-1}$ ).

Photosynthetic pigments are responsible for capturing the photon of light and transmitting energy to the reaction centers. In stress conditions such pigments are directly affected and as stress progresses, biochemical changes may limit photosynthetic activity more directly, resulting in oxidative damage in cells (VIANA et al., 2002). With the increase of NaCl in the irrigation water, the activation of the chlorophyllase enzyme occurs in stressed plants, being indicated as the main factor related to the reduction of the contents of photosynthetic pigments (SHARMA & HALL, 1991; NEVES & SPAT., 2013).

In the study of sorghum genotypes and their response to solutions with 100 mM NaCl concentration, Lacerda et al. (2003) observed a reduction in chlorophyll content in the range of 32 to 52% for the sensitive genotype and 19 to 27% for the Salinity tolerant genotype.

In sugarcane plants submitted to irrigation with solutions with 200 mM saline concentration ( $\sim 20 \text{ dS m}^{-1}$ ) of NaCl, there was a decrease in the levels of chlorophyll *a*, *b* and carotenoids in the order of 68.9%, 70%, 49.8%, respectively at 0 mM concentration (BARRETO et al., 2013). Viana et al. (2002) found reductions of more than 50% in rice cultivars irrigated with saline solutions with concentrations ranging from 0 mM to 150 mg / L MM ( $\sim 15 \text{ dS m}^{-1}$ ) NaCl.

When the chlorophyll *a* leaf content was related to chlorophyll *b* leaf content, a significant difference was observed between the factors at the 1% probability level ( $p < 0.01$ ). With the increase of the electrical conductivity of the saline solutions the chlorophyll *a* and chlorophyll *b* decreased (Figure 1). The highest decreases, when compared to the control ( $0 \text{ dS m}^{-1}$ ) were observed for the CEs of  $10 \text{ dS m}^{-1}$  (NaCl) and  $7.5 \text{ dS m}^{-1}$  (Mixture of salts), comprising values in the order of 51, 15% and 29.37%.

Mutava et al. (2011) in identifying physiological characteristics of more than 300 sorghum genotypes tolerant to abiotic stresses concluded that the chlorophyll content varies according to the variety. In a study of 6 rice cultivars under stress conditions, Cancellier et al. (2011) found a reduction in the chlorophyll *a/b* ratio. These authors consider that cultivars that present lower chlorophyll *a* and chlorophyll *b* relations are more efficient in the capitation of light, since this decrease is not due to the reduction of chlorophyll *a*. This fact was differently observed by this study, where chlorophyll *a* reductions are perceived to be higher than reductions in chlorophyll *b*. For Silva et al. (2014), when studying sugarcane cultivars under

water deficit, it was observed the reduction of the chlorophyll *a* / *b* ratio in 22.2% in relation to the control.

### **Fluorescence of chlorophyll a in leaves of sorghum under salt stress**

No significant difference was observed for the salt sources, however it was verified for the increasing levels of electrical conductivity, a significant difference was observed at 1% of probability ( $p < 0.01$ ). It was observed that the  $F_0$  of sorghum plants showed increase with the increase of electrical conductivity of the irrigation (Figure 3). The electrical conductivity of  $10 \text{ dS m}^{-1}$  was the most significant corresponding to the others, with an increase of 60.43%.

The initial fluorescence explains the fluorescence emission when the primary electron acceptor quinone (QA) of photosystem II (PSII) is fully oxidized and the reaction center (P680) is open, indicating the activation of the photochemical reactions (BAKER & ROSENQVST, 2004). In a study with sorghum and salinity, the emission of the initial fluorescence ( $F_0$ ) increased with the increase of the electrical conductivity (NABATI et al., 2013). The increase in  $F_0$  in plants subjected to some type of stress may be related to the increase of leaf thickness (MUNNS & TESTER, 2008), this thickening due to lipid peroxidation by reactive oxygen species (YAMANE et al., 2008).

The  $F_v$  and  $F_m$  presented a significant difference at 1% ( $p < 0.01$ ) of probability for the electrical conductivity levels. With the increase of the electrical conductivity of the irrigation water, the emission of both  $F_v$  and  $F_m$  decreased by 53% and 25%, respectively, when the EC of  $10 \text{ dS m}^{-1}$  was compared to the control (Figures 2B and 2C).

The maximum fluorescence emission is the indicator that represents the maximum intensity of the fluorescence, when practically all the quinone is reduced and the reaction centers reach their maximum capacity of photochemical reactions (BAKER & ROSENQVIST, 2004; SILVA et al., 2015). According to Nabati et al. (2013) sorghum plants submitted to irrigation with increasing levels of electrical conductivity ( $5.2$ ;  $10.5$ ;  $23.1 \text{ dS m}^{-1}$ ) presented a reduction of  $F_m$  with the elevation of salinity. Still in this study, they affirm that the decrease in the maximum fluorescence is related to the photoinhibition provoked by the saline stress.

The quantum efficiency of PSII ( $F_v / F_m$ ) presented significant difference only for the electrical conductivity levels. Saccharin sorghum plants reduced the quantum efficiency of PSII with elevated salinity levels (Figure 2D), showing reductions from EC of  $5 \text{ dS m}^{-1}$ , reaching values of 63.3% lower in EC of  $10 \text{ dS m}^{-1}$  when compared to the control.

Coelho et al. (2011) studied sorghum plants submitted to irrigation with saline solution with  $15 \text{ g L}^{-1}$  NaCl concentration ( $\sim 250 \text{ mM} \Rightarrow 25 \text{ dS m}^{-1}$ ) and observed reductions of 35% in quantum efficiency of PSII ( $F_v / F_m$ ). According to Tezara et al. (2005) plants that present  $F_v /$

$F_m$  below 0.8 are subjected to stressful conditions and reduction of maximum quantum efficiency of PSII, a situation similar to the plants of the present study that presented their  $F_v / F_m$  below 0.728 (2.5 dS m<sup>-1</sup>) to 0.266 (10 dS m<sup>-1</sup>). In stress-prone situations, plants do not show changes in the primary photochemistry of PSII, but the reduction in quantum efficiency in electron transport is observed (SHARMA & HALL, 1991; LU & ZHANG 1998).

As EC levels increased, the electron transport flux decreased progressively (Figure 3A) and presented a statistical difference between the EC levels imposed in the experiment. The greatest reduction occurred for the EC of 10 dS m<sup>-1</sup> in the order of 45.70%, as compared to the control (0 dS m<sup>-1</sup>). The electrical conductivity of 2.5 dS m<sup>-1</sup>, 5 dS m<sup>-1</sup> and 7.5 dS m<sup>-1</sup> decreased by 2.28%, 10.66% and 25.13%, respectively.

With increasing levels of saline concentration (0, 50, 100, 250 mM), the reduction of the electron transport rate, in the order of 20% and 29%, was observed for two sorghum varieties irrigated with increasing levels of saline concentration (0, 50, 100, 250 mM) (NETONDO et al., 2004). This reduction in electron transfer rates can be attributed to the ions that cause deleterious effects on the thylakoid membranes, disrupting the electron transport in the lipid-protein bilayer, damaging the activity of the complex (AMBEDE et al., 2012). In a study with sorghum plants submitted to water stress, the electron transport flux decreased with increasing stress severity (ZEGADA-LIZARAZU et al., 2015).

The energy dissipated by the reaction center showed a significant effect at 1% ( $p < 0.01$ ) of probability for the electrical conductivity levels of the irrigation water. At 60 DAS, it was observed that the energy dissipated by the reaction center increased with increasing salinity levels (Figure 3B). The electrical conductivity of 10 dS m<sup>-1</sup> presented an increase referring to 179.29% in relation to the electrical conductivity of 0 dS m<sup>-1</sup>. According to Zegada-Lizarazu et al. (2015), the dissipation of excess energy is a mechanism of release and regulation of photosystem II (PSII), allowing the closure of the reaction centers preserving the cycles of xanthophyll and lutein. Also in this study, it was noted that young sorghum plants suffering from severe stress increase energy dissipation more strongly than maturing plants.

The quantum yield for heat dissipation ( $\phi D0$ ) showed significant interaction between salt sources and levels of electrical conductivity at 5% probability ( $p < 0.05$ ). With the increase of salinity, it was observed that for both salt sources there was an increase in  $\phi D0$  (Figure 4), except for the EC of 2.5 dS m<sup>-1</sup>, which presented reduction of 17.29% (NaCl) and 10, 82% (Mixture of salts). The highest increments were observed for EC 10 dSm<sup>-1</sup> (NaCl) in the EC of 7.5 dS m<sup>-1</sup> (Mixture of salts), corresponding to 153.07% and 125.65%, respectively.



## CONCLUSIONS

Salinity causes the degradation of photosynthetic pigments, such as chlorophyll a and b, but carotenoid contents increase in response to the severe abiotic stress to which the sorghum plants were submitted;

The increase in the electrical conductivity of the saline solutions used in plant irrigation negatively affects the quantum efficiency of photosystem II and the electron flow per reaction center, thus modifying the emission of chlorophyll a fluorescence showing that the salts contents of the irrigation water cause irreversible damages to the photosynthetic apparatus of sorghum plants.

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**Table 1:** Chemical characterization of the Neossolo Flúvico used to fill the pots in the greenhouse experiment

Variable	Value
<b>Saturation Extract</b>	
Electric Conductivity - EC (dS m <sup>-1</sup> )	3,2
pH in saturate extract (pH <sub>se</sub> )	7,9
<b>Exchange Complex</b>	
pH <sub>H2O</sub> (1:2,5)	6,5
Ca <sup>2+</sup> (cmol <sub>c</sub> kg <sup>-1</sup> )	4,35
Mg <sup>2+</sup> (cmol <sub>c</sub> kg <sup>-1</sup> )	2,73
Na <sup>+</sup> (cmol <sub>c</sub> kg <sup>-1</sup> )	1,48
K <sup>+</sup> (cmol <sub>c</sub> kg <sup>-1</sup> )	0,77
SB (cmol <sub>c</sub> kg <sup>-1</sup> )	9,33
Hidrogênio (cmol <sub>c</sub> kg <sup>-1</sup> )	1,43
Alumínio (cmol <sub>c</sub> kg <sup>-1</sup> )	0
T (pH 7,0)	10,76
ESP (%)	13,75

SB – Sum of bases (SB = Ca + Mg + Na + K); T – Cation Exchange Capacity (CTC = SB + (Al + H)); ESP – Exchangeable Sodium Percentage (ESP = (100\*Na+)/CTC).

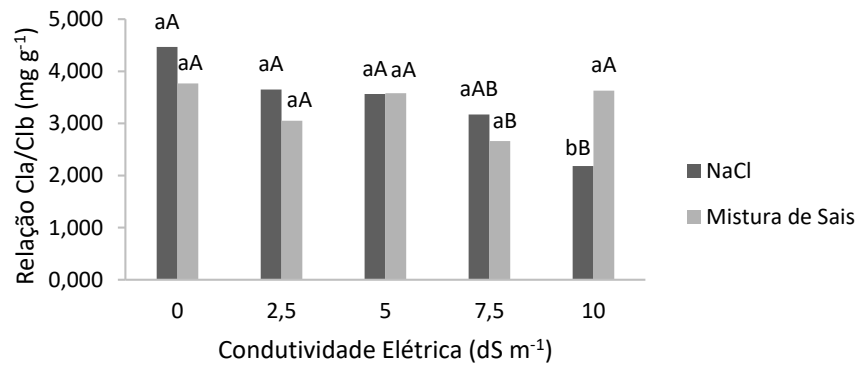
**Table 2:** Quantity of salts (g L<sup>-1</sup>) required for the formulation of saline solutions, in order to obtain the electrical conductivities of the treatments.

CE	Salt mixture						
	NaCl	NaCl	CaCl <sub>2</sub>	Ca(NO <sub>3</sub> ) <sub>2</sub>	MgCl <sub>2</sub>	MgSO <sub>4</sub>	KCl
dS m <sup>-1</sup>	g L <sup>-1</sup>						
<b>0,0</b>	-	-	-	-	-	-	-
<b>2,5</b>	1,203	0,751	0,229	0,079	0,258	0,402	0,069
<b>5,0</b>	2,773	1,728	0,528	0,181	0,593	0,925	0,159
<b>7,5</b>	4,461	2,950	0,901	0,309	1,012	1,580	0,272
<b>10,0</b>	6,397	4,256	1,300	0,445	1,460	2,279	0,392
<b>12,5</b>	8,372	5,842	1,785	0,612	2,005	3,129	0,538

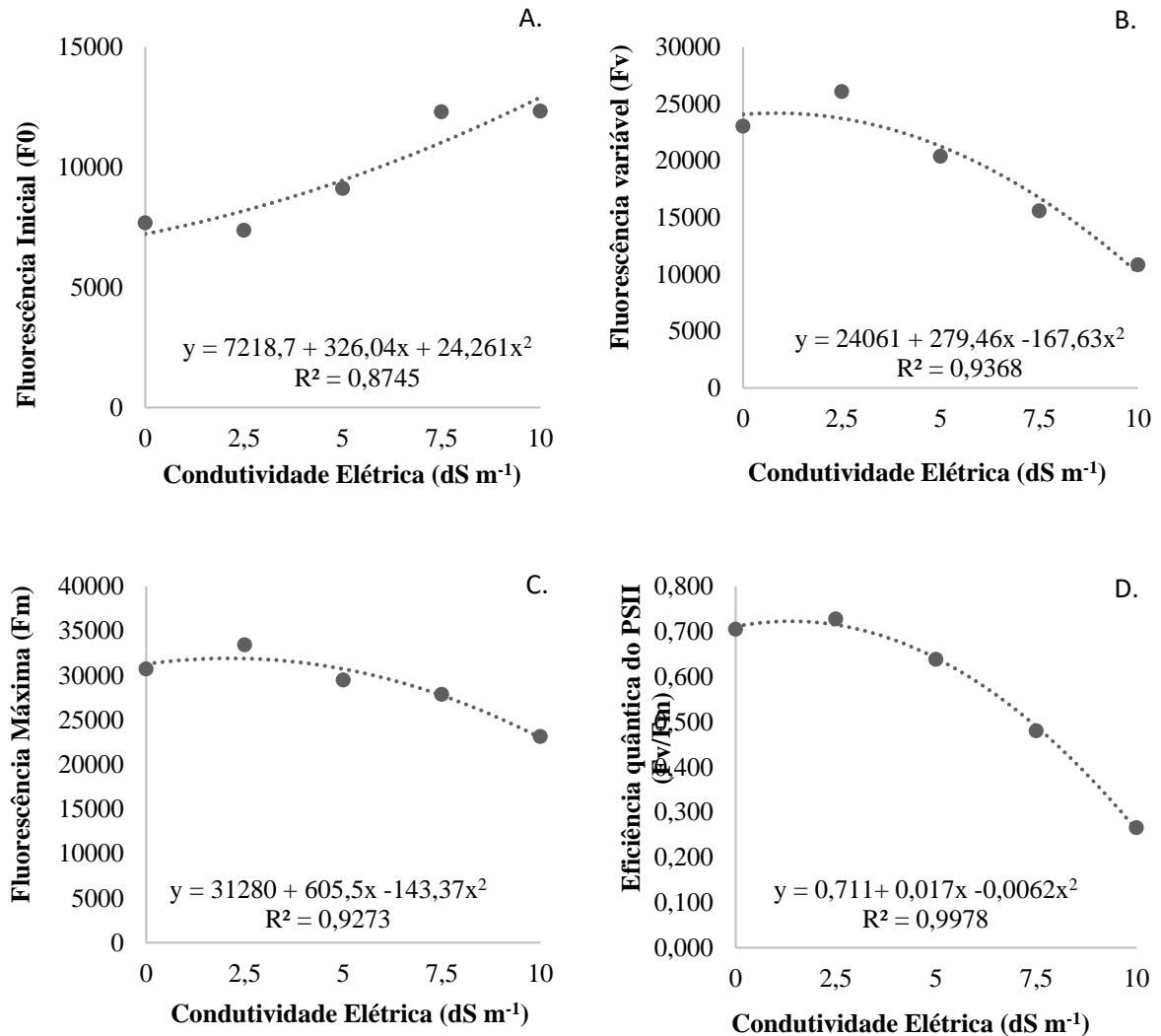
**Table 3:** Leaf content of chlorophyll a, b and carotenoids in sorghum sorghum irrigated with saline solutions with increasing levels of electrical conductivity (EC) at 60 days after sowing (DAS).

CE (dS m <sup>-1</sup> )	Clorofila a		Clorofila B		Carotenóides	
	(mg g <sup>-1</sup> )		(mg g <sup>-1</sup> )		(mg g <sup>-1</sup> )	
	NaCl	MS	NaCl	MS	NaCl	MS
<b>0</b>	1,64 aA	1,31aAB	0,37 aA	0,35 aBC	0,61 aA	0,50 bB
<b>2,5</b>	1,47 aA	1,69 aA	0,41 bA	0,65 aA	0,51 bAB	0,66 aA
<b>5</b>	1,22 aAB	1,29 aAB	0,34 aA	0,36 aB	0,51 aAB	0,50 aB
<b>7,5</b>	0,89 aB	0,42 bC	0,28 aA	0,16 aC	0,44 aBC	0,33 bC
<b>10</b>	0,48 bC	1,00 aB	0,22 aA	0,26 aBC	0,36 bC	0,51 aB
<b>CV (%)</b>	<b>17,22</b>		<b>23,02</b>		<b>10,01</b>	

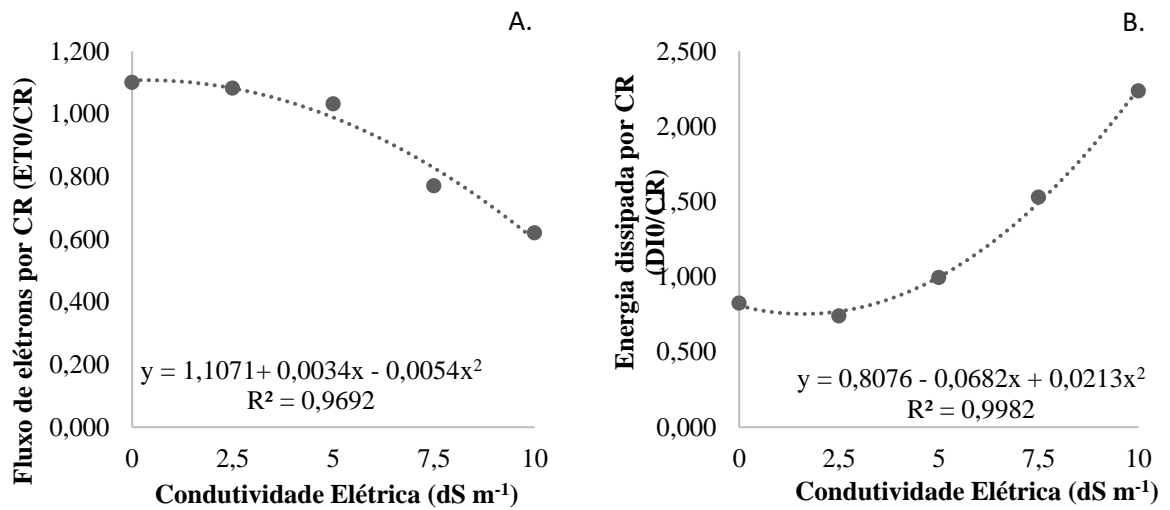
Equal, lowercase letters between water sources, upper case between treatments, do not differ from each other, by Tukey test, at 5% probability.



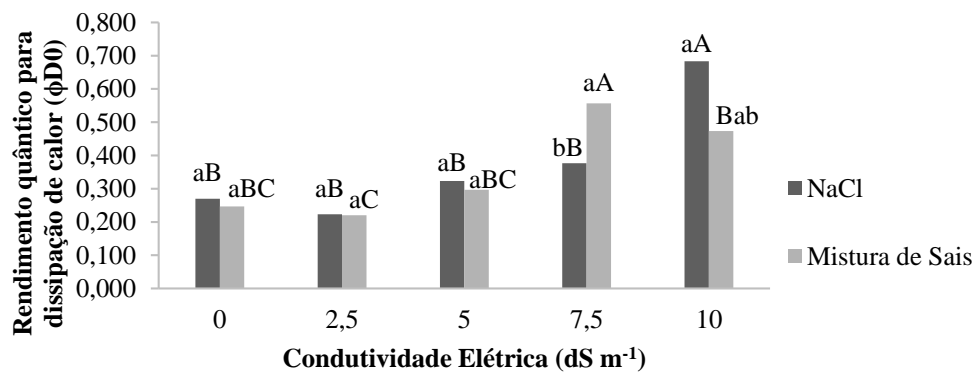
**Figure 1.** Relationship between chlorophyll *a* and *b* contents in leaves of sorghum irrigated with salt solutions with increasing levels of electrical conductivity (EC) at 60 DAS. Equal, lowercase letters between water sources, upper case between treatments, do not differ from each other, by Tukey test, at 5% probability.



**Figure 2.** Parameters of Chlorophyll a Fluorescence emission in Saccharine Sorghum plants under abiotic stress conditions at 60DAS. (A) Initial fluorescence (F<sub>0</sub>); (B) Variable fluorescence (F<sub>v</sub>); (C) Maximum fluorescence (F<sub>m</sub>); (D) Quantum efficiency of photosystem II (F<sub>v</sub> / F<sub>m</sub>).



**Figure 3:** (A) Electron flux per reaction center in sorghum plants submitted to irrigation with saline solutions at 60 DAS. (B) Energy dissipated by reaction center in sorghum plants under abiotic stress conditions at 60 DAS.



**Figure 4:** Quantum yield for heat dissipation in sorghum plants at 60 DAS irrigated with saline solutions with increasing electrical conductivity levels. Equal, lowercase letters between water sources, upper case between treatments, do not differ from each other, by Tukey test, at 5% probability.