# SOIL WATER ENERGETIC STATE AND SACCHARINE SORGHUM IRRIGATED WITH SALT SOLUTIONS[1]

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**SUMMARY:** The potencial energy of the water, despite being a relevant tool for the detection of abiotic stresses, may present discrepancies related to its quantification, according to parameters such as time of day, soil type, content of salts in solution, need of water absorption by the plant species, among others. Therefore the water potential was related during predawn, in soil and saccharine sorghum irrigated with saline solutions of different ionic compositions. Therefore, between December 2015 and February 2016, 48 saccharine sorghum plants (IPA 2502) were harvested in a greenhouse and arranged in a randomized block. The plants were sown in a *Neossolo Flúvico* (Fluvent) and irrigated with two saline solutions with increasing levels of electrical conductivity (0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 dS $m^{-1}$), with each treatment being composed by 4 replicates. At 60 days after sowing, the leaf water potential in sorghum plants and soil water potential were determined during predawn. Discrepancies between water potentials were observed in the order of -0.032 MPa, disagreeing the classical theory of water relations. This fact is probably correlated with a severity of the disturbances caused by the abiotic stress, which can intervene in the homeostasis of the physiological mechanisms of the plant.

**KEYWORDS:** Water Relationships, Salinity, *Poaceae*.

## ESTADO ENERGÉTICO DA ÁGUA EM SOLO E EM SORGO SACARINO IRRIGAÇÃO COM SOLUÇÕES SALINAS[1]

O potencial energético da água apesar de ser uma relevante ferramenta para detecção de estresses abióticos, pode apresentar discrepâncias relacionadas à sua quantificação, de acordo

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com parâmetros como o horário do dia, o tipo de solo, teor de sais em solução, necessidade de absorção de água por parte da espécie vegetal, entre outros. Assim, relacionou-se o potencial hídrico durante a madrugada, em solo e em sorgo sacarino irrigados com soluções salinas de diferentes composições iônicas. Para tanto, entre os meses de dezembro de 2015 e fevereiro de 2016, totalizando 60 dias, 48 plantas de sorgo sacarino (IPA 2502), em ambiente protegido e dispostas em blocos ao acaso, foram semeadas em Neossolo Flúvico e irrigadas com duas soluções salinas com níveis crescentes de condutividade elétrica – CE (0,0; 2,5; 5,0; 7,5; 10,0 e 12,5 dS m-1), sendo que cada tratamento foi composto por 4 repetições. Aos 60 dias após a semeadura, durante a madrugada, foi determinado o potencial hídrico foliar das plantas de sorgo sacarino e o potencial hídrico no solo. Observaram-se discrepâncias entre os potenciais hídricos, na ordem de -0,032 MPa, discordando em tese com a teoria clássica das relações hídricas. Esse fato está, provavelmente, correlacionado com a severidade dos distúrbios provocados pelo estresse abiótico, que poderá intervir na homeostase dos mecanismos fisiológicos da planta.

**PALAVRAS – CHAVE:** Relações hídricas, Salinidade, *Poaceae*.

## INTRODUCTION

It is estimated that by 2050 the world population will reach 9 billion inhabitants, and an increase in agricultural production is necessary due to the demand for food (FAO, 2013). However, this potential increase in production may be affected by environmental constraints. Climate change, soil degradation and water quality decline directly affect agricultural production (IPCC, 2014). It occurs because the water and nutrientes supplies to a crop result from interactions that are established throughout the soil-plant-atmosphere system.

Among the most severe abiotic stresses is the soil salinity, which may be of natural or anthropogenic origin and results in the accumulation of soluble and Na + exchangeable salts in the soil, causing unfavorable changes in soil physical and chemical attributes (Ribeiro, 2010). For Shrivastava & Kumar (2015) salinized areas are increasing at a rate of 10% each year.

Just as the soil suffers from the deleterious effects of salts, plants are also struck by their reflections. Under normal conditions, in the absence of salinity, the potential of water in the soil is greater than the potential of water in the plant, which favors the absorption of water by potential difference. This situation does not occur in salinized soils, since the total potential of the water is strongly influenced by the osmotic potential, which, often depending on the saline level, reduces or stops the absorption of water (Dias & Blanco, 2010; Pedrotti, 2015; Duarte & Souza, 2016).

Sorghum is considered a moderately tolerant to salinity plant. Efficiency in the use of water and soil nutrients allows this grass to be grown in places where the production of other cereals would be uneconomical. This fact places it in a prominent position, seeing the reduction of costs with raw material for the manufactured products industry.

In addition to the morphophysiological changes in plants, salinity causes changes in the water relations of the soil-plant continuum, what makes it necessary the quantification of these changes. As some postulates point to the fact that the equilibrium between water potentials in the plant and in soils (DONOVAN, 1999), other studies point to the effect of abiotic stresses on the imbalance of these parameters in the soil-plant relationship.

Therefore, the present study aimed to verify the occurrence of equilibrium between water potentials in soil and Sorghum Saccharine plants, during a dawn when irrigated with saline solutions.

## MATERIAL AND METHODS

### Location and assembly of the experimental

The experiment was conducted in a protected environment belonging to the Federal Rural University of Pernambuco, campus Recife, Brazil, from December 20, 2015 to February 20, 2016, totaling 63 days. The climate of the region, according to the climatic classification of Köppen adapted to Brazil (ALVARES, 2013), is type 'AM'. The annual average temperature is 25.5 ° C, and may vary according to the rainy season, with annual relative humidity of 79.8% and annual rainfall of 2,417.6 mm (INMET, 2014). The soil used came from the rural area of Pesqueira, located in the semi-arid region of the Northeast of the country, in Bacia do Alto Ipanema, state of Pernambuco. The collection was carried out to a layer of 0-30 cm in a soil classified with *Neosolo Flúvico* (Fluvent), according to Embrapa (2013). The soil was air-dried, de-rooted, homogenized and passed through a 4mm sieve, as a way of preserving micro-aggregates.

### Initial Soil Characterization

Initially, the physical and chemical characterization of the soil was carried out. For the chemical properties (Table 1), the pH in the soil:water ratio was determined, the saturation extract was obtained from the saturation paste (Richards, 1954) and from that the electrical conductivity and pH were evaluated. The exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$)

extracted with 1 mol $L^{-1}$ ammonium acetate (Thomas, 1982). The cation exchange capacity (CEC) was determined by the index cation method (RICHARDS, 1954). The sum of bases (SB) and the percentage of exchangeable sodium (PES) were calculated from the values obtained in the sortative complex.

In the physical characterization, the granulometry and dispersed clay in water in the air-dried fine earth (ADFE) were determined from the densimeter method; Soil density and particle density (Embrapa, 1997). In addition to the field capacity (FC) (ψm: - 0.1 atm) and the permanent wilting point (PWP) (ψm: - 15 atm). The physical properties of the soil were: Fine sand 314.99 g $kg^{-1}$, Thick sand 163.01 kg $kg^{-1}$, Silt 378.23 g $kg^{-1}$, Clay 144 g $kg^{-1}$, ADA 100 g $kg^{-1}$, Bulk Density 1.28 g $cm^{-3}$, Particle Density 2.52 g $cm^{-3}$, Total Porosity 49.15%, Flocculation Degree 30.56%, Dispersion Degree 69.44%, FC 0.26 g $g^{-1}$, PWP 0.05 g $g^{-1}$.

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

The sorghum cultivar chosen was IPA 2502. The seeds were planted in pots (8L) and filled with *Neosolo Flúvico* (Fluvent). Irrigation occurred daily, maintaining humidity at 80% of the soil field capacity. Two solutions were used (Table 2) with 4 increasing levels of electrical conductivity (0.0, 2.5, 5.0, 7.5 dS $m^{-1}$). Solution 1 was composed of NaCl and solution 2 by a mixture of NaCl, $CaCl_2$, Ca $(NO_3)_2$, $MgCl_2$, $MgSO_4$ and KCl salts.

The experimental design was a randomized complete block design with a 4 x 2 factorial scheme with 4 replicates, totaling 32 experimental units.

**Balance between soil potentials and sorghum plants**

In order to verify if there was a balance between the potentials in the soil-plant system, the total potential of the soil (Ψmatric + Ψosmotic) and the total potential of the plant - Ψ plant (obtained using the Scholander chamber) were quantified. The potential gradient (ΔΨ), for each electrical conductivity, was obtained as follows:

$$\Delta = \boldsymbol{\Psi soil} - \boldsymbol{\Psi plant} \quad \textbf{(1)}$$

Where: Ψsoil – potential of soil (MPa); Ψplant – potential of the plant (obtainet using the Scholander Chamber) (MPa).

**Statistical analysis**

The data were analyzed by means of analysis of variance and the means of water potentials in soil and sorghum plants were compared by Tukey Test at 5% of probability ($p < 0.05$).

## RESULTS AND DISCUSSION

In soil cultivated with sorghum and irrigated with saline solutions with increasing levels of electrical conductivity, it was observed that there was no equilibrium between the water potential in the plant and in the soil during the predawn (Figure 1). The plants submitted to irrigation with the treatments of 0 dS $m^{-1}$ presented the smallest difference between the water potential in the soil and in the plant (-0.032 MPa). However, the salinity level of 5 dS $m^{-1}$ presented the greatest difference between soil and plant water potential (0.355 Mpa).

According to Bergonci et al., (2000) when considering the measurement of leaf water potential before stomatal opening, there is a balance between the water status of the leaf and the soil. However, some authors report differences in water potential of soil and plants before dawn (Ceulemans et al., 1988, Lelles et al., 1998, Donovan et al., 2001, James et al., 2006).

Katerji & Hallaire (1984) state that the water potential in the plant depends on the water status of the soil, the density and depth of the root system. For Donovan et al. (2001), some mechanisms may contribute to the imbalance between the water potential of the plant and the soil at dawn, such as soil heterogeneity, hydraulic redistribution, hydraulic conductivity or capacitance, nocturnal sweating and apoplastic solutes.

By correlating soil water potential and leaf water potential under conditions of water restriction. Bergonci et al. (2000) stated that although there is a high association between the variables, it is observed a dispersion of the values, which can be the result of the resistance during the absorption process and in the water flow, mainly in relation to the root-soil relationship, whose impediment decreases water availability.

Even with water availability, the stress caused by excess salts in the solution of the soil and plant tissues causes a series of physiological dysfunctions in the plant, interfering in the process of water absorption by the soil.

Sorghum has a greater amplitude in the variations of the stomatal conductance, when compared to corn, which promotes a greater mismatch of the leaf water potential (Vieira Júnior et al., 2007). For James et al. (2006) the imbalance between soil and plant potential could be greater than 0.5 MPa in halophytes. Donovan et al. (1999) found imbalance in soil-plant water potential up to 1.2 MPa for Chrysothamnus nauseosus (0 and 100 mM NaCl) and 1.8 MPa for sarcobatus vermiculatus (0, 100, 300 and 600 mM NaCl).

The imbalance between soil and plant water potentials may be related to the osmotic adjustment process, provoking in the plants the probable accumulation of solutes in the foliar cells and thus to try to increase the water absorption by the plant, especially during the dawn that is the moment where the stomatal conductance is minimized due to known environmental conditions.

## CONCLUSION

The relationship between water potential in *Neossolo Flúvico* and Saccharine Sorghum plants presented imbalance during dawn, when they were submitted to irrigation with saline solutions. This fact is derival the severity of the disturbances caused by the abiotic stress, interfering in plants metabolic homeostasis.

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

| Variable | Value |
|---|---|
| **Saturation Extract** | |
| Eletric Condutivity - EC (dS $m^{-1}$) | 3,2 |
| pH in saturate extract ($pH_{se}$) | 7,9 |
| **Exchange Comples** | |
| $pH_{H2O}$ (1:2,5) | 6,5 |
| $Ca^{2+}$ ($cmol_c$ $kg^{-1}$) | 4,35 |
| $Mg^{2+}$ ($cmol_c$ $kg^{-1}$) | 2,73 |
| $Na^{+}$ ($cmol_c$ $kg^{-1}$) | 1,48 |
| $K^{+}$ ($cmol_c$ $kg^{-1}$) | 0,77 |
| SB ($cmol_c$ $kg^{-1}$) | 9,33 |
| Hidrogênio ($cmol_c$ $kg^{-1}$) | 1,43 |
| Alumínium ($cmol_c$ $kg^{-1}$) | 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 – Exchageble Sodium Percentage (ESP = (100*Na+)/CTC).

**Table 2.** Quantity of salts (g $L^{-1}$) required for the formulation of saline solutions, in order to obtain the electrical conductivities of the treatments.

| CE | NaCl | Salt mixture | | | | | |
|---|---|---|---|---|---|---|---|
| | | NaCl | $CaCl_2$ | $Ca(NO_3)_2$ | $MgCl_2$ | $MgSO_4$ | KCl |
| dS $m^{-1}$ | g $L^{-1}$ | | | | | | |
| 0,0 | - | - | - | - | - | - | - |
| 2,5 | 1,203 | 0,751 | 0,229 | 0,079 | 0,258 | 0,402 | 0,069 |
| 5,0 | 2,773 | 1,728 | 0,528 | 0,181 | 0,593 | 0,925 | 0,159 |
| 7,5 | 4,461 | 2,950 | 0,901 | 0,309 | 1,012 | 1,580 | 0,272 |
| 10,0 | 6,397 | 4,256 | 1,300 | 0,445 | 1,460 | 2,279 | 0,392 |
| 12,5 | 8,372 | 5,842 | 1,785 | 0,612 | 2,005 | 3,129 | 0,538 |

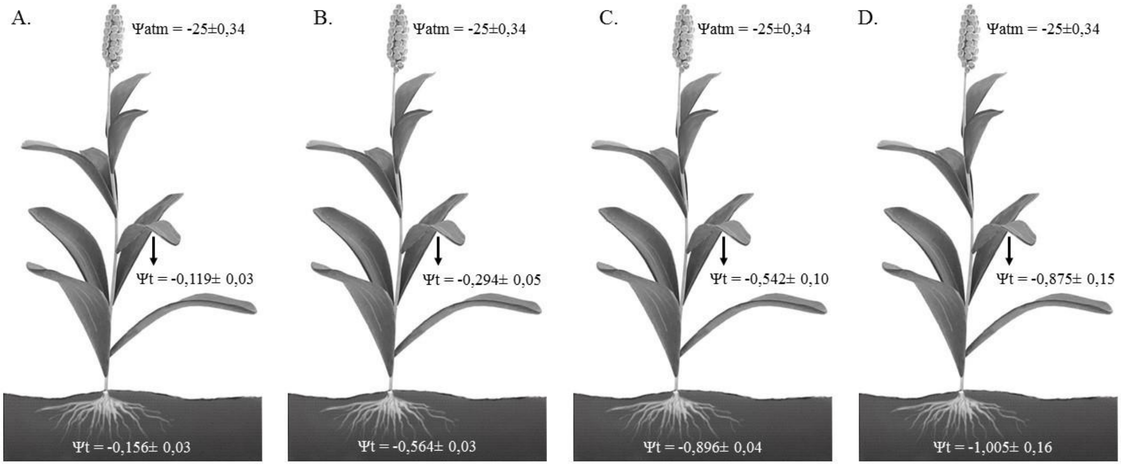


**Figure 1.** Soil and plant water potential and gradient (difference) in *Neossolo Flúvico* (Fluvent) and saccharine sorghum plants, and their respective standard deviation, at dawn, at 60 DAS.