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EFFECT OF LEACHING FRACTION DETERMINED BY TWO METHODS ON GROWTH AND YIELD OF MAIZE SUBMITTED TO SALT STRESS[1]

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1 ABSTRACT

The aim of this study was to evaluate the effects of the leaching fraction determined by two methods in maize cultivated in a soil column and submitted to irrigation with water of different salinities. The experiment was conducted in the meteorological station of the Federal University of Ceará, Fortaleza - CE, in a completely randomized design, composed by four levels of irrigation salinity water (0.5, 2.0, 4.0 and 6.0 dSm^{-1}) and two methods of determination of the leaching fraction. Each treatment had seven replicates. The plots were constituted by maize cultivated in soil columns, measuring 20 cm in diameter and 100 cm in length. The leaching fractions (LF) were defined as follows: A. Application of the LF calculated according to the formula proposed by Rhoades (1974), Rhoades and Merrill (1976); B. Application of the LF of 15% calculated from the soil water balance of the experimental plots. The results showed that plants that were irrigated with EC_w of 0.5 and 4 dS m^{-1}, the LF of 5 and15%, respectively, were able to minimize the effects of salinity. For EC_w of 6 dS m^{-1}, the LF of 15 and 92% showed no improvement in maize growth and yield.

Keywords: *Zea mays* L. soil columns, saline water.

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2 RESUMO

Objetivou-se com o trabalho avaliar os efeitos da fração de lixiviação determinado por dois métodos na cultura do milho cultivado em coluna de solo e submetido a irrigação com água de diferentes salinidades. O experimento foi instalado na estação meteorológica da Universidade Federal do Ceará, Fortaleza – CE, em delineamento inteiramente casualizado, composto por quatro salinidade de água de irrigação (0,5, 2,0, 4,0 e 6,0 dS m^{-1}) e duas formas de determinação da fração de lixiviação (FL). Utilizou-se sete repetições para cada tratamentos. As parcelas foram constituídas por milho cultivado em colunas de solo, medindo 20 cm de diâmetro e 100 cm de comprimento. As frações de lixiviação foram determinadas pelos seguintes métodos: A. Aplicação das FL de acordo com a fórmula de Rhoades (1974), Rhoades e Merrill (1976); B. Aplicação de FL de 15 % calculada a partir do balanço hídrico do solo. Os resultados mostraram que as plantas que foram irrigadas com CE_a de 0,5, 4 dSm^{-1} as LF de 5 e 15%, respectivamente, foram capazes de dirimir os efeitos da salinidade. Para a CE_a de 6 dSm^{-1} as LF de 15 e 92% não apresentaram melhoria no crescimento e produção do milho.

Palavras-chave: *Zea mays* L., colunas de solo, água salina.

3 INTRODUCTION

Salinity is one of the main problems responsible for the decline in agricultural productivity (NAZÁRIO et al., 2013). This reduction in crop yields is as greater as higher the salt concentration in the irrigation water and the sensitivity of the plant species to salinity.

According to Ayers e Westcot (1999), maize (*Zea mays* L.) is a plant considered moderately sensitive to salinity. The authors report that the threshold salinity of the culture for irrigation water is 1.7 dS m^{-1}, and irrigation with salinity water above 3.9 dS m^{-1} could cause a loss of more than 50% of the crop yield. However, due to the scarcity of good quality water, saline water is often used in the agricultural sector, mainly in the Brazilian northeast.

An alternative used to deal with saline water is the use of leaching fraction (LF). The LF is the water layer applied in order to remove the salts from the root zone (RHOADES, 1974; RHOADES; MERRILL, 1976; COSTA et al., 2015). Although, the water that crosses the soil does not solubilize and carries only toxic ions, such as Na^+ and Cl^-. Large amounts of essential elements can be leached, mainly under stress conditions for the plant (LACERDA et al., 2016; LACERDA et al., 2018). In addition, the increase in LF could not guarantee an increase in crop yield (COSTA et al., 2015).

The aim of this study was to evaluate the effects of the leaching fraction determined by two methods in maize cultivated in a soil column submitted to irrigation with water of different salinities.

4 MATERIAL AND METHODS

The experiment was installed in a greenhouse in the meteorological station area of the Federal University of Ceará - UFC, Fortaleza - Ceará. According to the classification of Köppen, is inserted in a region of climate Aw'. The experimental design was completely randomized. The composition of the treatments resulted from the combination of the application of two methods to determine the leaching fraction and the use of irrigation water with four levels of salinity (EC_w = 0.5, 2, 4 and 6 dS m^{-1}). Thus, the experiment had eight treatments and seven replications.

The leaching fractions (LF) were defined as follows: A. Application of the LF calculated for each salinity level, according to the formula proposed by Rhoades (1974), Rhoades e Merrill (1976); B. Application of the LF of 15% calculated from the soil water balance of the experimental plots. The treatments composition can be observed in table 1.

Table 1. Composition of the treatments of the experiment.

Method for applying LF[1]	Water salinity (dS m^{-1})	LF for saline water levels (%)	Treatments
A. $LF=\frac{ECw}{5ECe-ECw}$	S1 = 0.5	5	AS1
	S2 = 2.0	19	AS2
	S3 = 4.0	47	AS3
	S4 = 6.0	92	AS4
B. Soil water balance	S1 = 0.5	15	BS1
	S2 = 2.0	15	BS2
	S3 = 4.0	15	BS3
	S4 = 6.0	15	BS4

[1]Formula A: ECw – Irrigation water salinity (dS m^{-1}); ECe – salinity of soil saturation extract representing tolerable salinity for crop (for maize, ECe = 2.5 dS m^{-1}). Formula B: Soil water balance = applied water – drained water, in mm. **Source:** Freitas et al. (2018).

The plots were composed of a soil column cultivated with hybrid maize BRS 2020. For the preparation of the soil columns, PVC pipes with a diameter of 20 cm and a length of 100 cm were used. The columns were filled with soil collected from an ArgisoloVermelho-amarelo Eutrófico. Thus, column horizons sequences were similar to those of soil *in situ*.

To determine the water requirement of the crop, a plot of each treatment was used as a drainage lysimeter. The plots were submitted to saline water application seven days after sowing (DAS) of the maize.

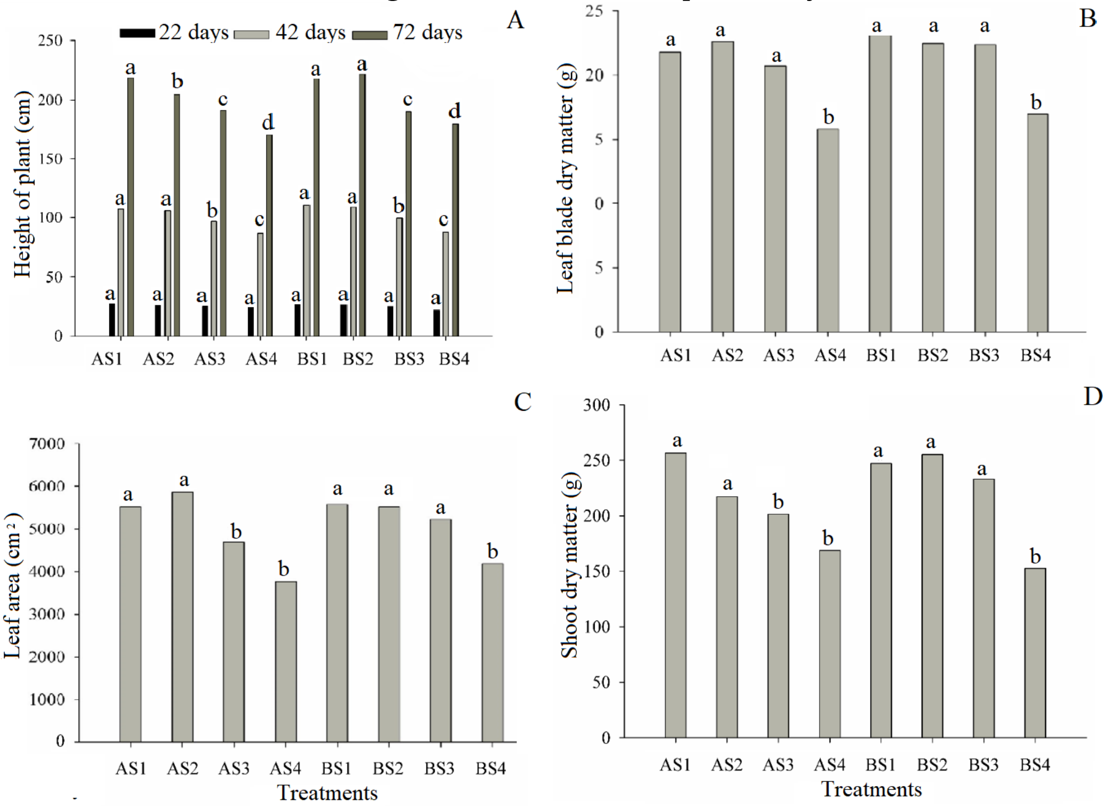
At 22, 42 and 72 DAS of the plant height were measured with a tape measure. At the end of the experiment (80 DAS) the plants were collected for the determination of the following variables: leaf area, leaf blade dry matter, shoot dry matter and yield.

The results were submitted to analysis of variance by the F test and the means comparison test performed by the Scott-Knott at 5% of probability.

5 RESULTS AND DISCUSSION

In the first measurement of plant height (22 DAS), there was no difference between treatments (Figure 1A). It is important to note that the application of saline water occurred on the seventh DAS. Thus, the plants were already established and able to support the amount of salts deposited in the soil until that period. Studies show that maize is more sensitive to salinity in the early stages of development (AYERS; WESTCOT, 1999).

Figure 1. Height of plant (A), Leaf blade dry matter (B), Leaf area (C) and Shoot dry matter (D). Means followed by the same letter do not differ among themselves by the Scott-Knott test at the significance level of 5% probability.



Source: Freitas et al. (2018)

The effects of saline stress at plant height were verified at 42 DAS. The treatments with higher salinity (EC_w of 6 dS m^{-1}) presented the smallest plants. Regardless of the leaching fraction (LF) adopted, the treatments AS4 (LF = 92%) and BS4 (LF = 15%), which received EC_w of 6 dS m^{-1}, did not differ statistically and presented plants with heights lower than 89 cm. The highest plants were those that received EC_w of 0.5 dS m^{-1} (AS1 and BS1) and EC_w of 2.0 dS m^{-1} (AS2 and BS2).

At 72 DAS, the LF showed effects in the plant height that were irrigated EC_w of 2 dS m^{-1}. In the treatment that FL was 15% (BS2) the plants had an average height of 210 cm, similar performance to the plants of AS1 and BS1, irrigated with low salinity water (EC_w = 0.5 dS m^{-1}). Smaller plants were found in treatments with water more saline, AS4 and BS4. Even with FL of 92% the results of AS4 did not differ from BS4 with FL of 15% in the last measurement.

Similar pattern was verified in leaf blade dry matter (LBDM) and leaf area (LA) of the plants that received EC_w of 6 dS m^{-1}, according to figure1B and 1C. The lowest LBDM were verified in AS4 (15.76 g) and BS4 (16.94), as well as the lowest values of LA. The salt stress causes inhibition of leaf expansion and accelerate the senescence of mature leaves, thus reducing the area for the photosynthetic process and the total production of assimilates (LACERDA et al., 2016). In this way, the reduction in the production of photoassimilates reflects on the plant development and yield (Figure 1D and Table 2).

Table 2. Mean comparison test to Corn Cob with Husk Dry Matter (CHDM), Dehusked Corn Cob Dry Matter (DCDM), Corn Cob Length (CL) and Corn Cob Diameter (CD). Analysis performed at 80 DAS in maize plants irrigated with water of different salinities and applied different leaching fractions.

Treatments	CHDM	DCDM	CL	CD
	--------------- g ---------------		------------- cm ------------	
AS1	117,54 a	62,67 a	13,6 a	3,73 a
AS2	87,42 b	41,26 b	12,3 b	2,98 a
AS3	84,47 b	46,39 b	11,4 b	2,77 a
AS4	69,10 b	33,96 b	11,8 b	2,88 a
BS1	118,55 a	71,85 a	14,5 a	3,73 a
BS2	89,10 b	46,25 b	13,1 a	3,29 a
BS3	114,71 a	66,34 a	14,3 a	3,38 a
BS4	60,28 b	25,25 b	9,9 b	2,73 a
F calc	3,44**	3,40**	3,19*	1,65ns

ns, **, * No-significant and 0,01 and 0,05 probability by the F test, respectively; Means followed by same letter do not differ by the Scott-Knott test at a significance level of 5% probability. **Source:** Freitas et al. (2018).

The shoot dry matter (SDM) of plants irrigated with $EC_w \leq 4$ dS m^{-1} and LF of 15% (BS1, BS2 and BS3) presented values similar to those observed in treatments AS1 and AS2, which received $EC_w \leq 2$ dS m^{-1} and that FL were 5 and 19%.The treatmentAS3, submitted to CE_w of 4 dS m^{-1} and LF of 47%, had results of SDM, LA and yield equal to the plants that received CE_w of 6 dS m^{-1}. In contrast, BS3 that was irrigated with the salinity same water, however, with LF of 15% presented similar average values to the plants that received low salinity water (0.5 dS m^{-1}). Infer that LF 47% or higher, causes leaching of nutrients essential for plant growth, such as N, easily leached as NO_3^- (LACERDA et al., 2016; LACERDA et al., 2018).

Regarding yield, except corn cob diameter, all variables studied were influenced by water salinity and the leaching fraction adopted (Table 2). Plants irrigated with EC_w of 0.5 dS m^{-1} (AS1 and BS1) and EC_w of 4 dS m^{-1} and 15% LF (BS3) presented higher corn cob dry matter with husk and dehusked. These were respectively 50 and 70% higher than the other treatments. As observed in the LBDM, LA, SDM and yield, the treatment BS3even irrigated with EC_w of 4 dS m^{-1}, the FL of 15% proved to be adequate to resolve the deleterious effects caused by the presence of salts in the root zone.

Nazário et al. (2013) verified that the PL6880 maize had a reduction of shoot dry matter, leaf area and grain weight per plant submitted to irrigation with saline water. The disorders caused by salt stress in plants is due to the reduction in osmotic potential and / or excessive accumulation of Na^+, which may induce toxicity, nutritional imbalance or both (LACERDA et al., 2016), resulting in poor growth and yield of the crops.

6 CONCLUSIONS

In order to better development and yield of maize with lower water consumption, we conclude that for the EC_w of 0.5 and 4 dS m^{-1}, the most satisfactory LF were respectively 5 and 15%. The LF of 15 and 92% were not able to minimize the negative effects of water of 6 dS m^{-1}. For EC_w of 2 dS m^{-1}, the results were inconclusive.

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