CONCENTRATION OF N, K AND P IN DRAINED WATER AS A FUNCTION OF LEACHING FRACTION ADOPTED IN MAIZE CULTIVATED IN SOIL COLUMNS UNDER SALT STRESS[1]

Emanuel Dias Freitas[2], Claudivan Feitosa de Lacerda[3], Bruno Gabriel Monteiro da Costa Bezerra[4], Adriana Cruz de Oliveira[4], Wíliana Júlia Ferreira de Medeiros[5]

ABSTRACT: The aim of this study was to evaluate the losses of nitrogen, potassium and phosphorus caused by the leaching fraction, determined by two methods, in maize cultivated in soil columns and irrigated 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 dS m^{-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 & Merrill (1976); B. Application of the LF of 15% calculated from the soil water balance of the experimental plots. The results showed higher nitrogen losses in the nitrate form in the treatments that received water with EC = 6 dS m^{-1}, regardless of the LF adopted, and at 75 days after sowing, there is practically no more nitrate in the leachete. As the nitrate, the larger potassium concentrations in leachate were observed in higher salinity treatments. However, the concentrations of this element in the leachate were linearly increased throughout the experiment. The levels of phosphorus in the leachate were low and did not differ between the treatments, nor did they differ during the periodic evaluations of the leachate.

KEYWORDS: salinity. loss of nutrients. fertilization.

---

[1] Parte da tese de doutorado do primeiro autor.

[2] Estudante de doutorado, Departamento de Engenharia Agrícola, Universidade Federal do Ceará – UFC, CEP: 60451-970, Fortaleza, CE. Fone (85) 33669127. e-mail:emanueldiasfreitas@gmail.com.

[3] Professor Doutor, Departamento de Engenharia Agrícola, Universidade Federal do Ceará – UFC, Fortaleza, CE.

[4] Estudantes de graduação, Departamento de Engenharia Agrícola, Universidade Federal do Ceará – UFC, Fortaleza, CE.

[5] Estudante de doutorado, Departamento de Ciência do Solo, Universidade Federal do Ceará – UFC

CONCENTRAÇÃO DE N, K E P NA ÁGUA DRENADA EM FUNÇÃO DA FRAÇÃO DE LIXIVIAÇÃO ADOTADA NA CULTURA DO MILHO CULTIVADO EM COLUNAS DE SOLO SOB ESTRESSE SALINO

RESUMO: O objetivo do presente estudo foi avaliar as perdas de nitrogênio, potássio e fósforo provocado pela fração de lixiviação, determinado por dois métodos, na cultura do milho cultivado em colunas de solo e irrigado 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 (LF). 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 LF de acordo com a fórmula de Rhoades (1974), Rhoades & Merrill (1976); B. Aplicação de LF de 15 % calculada a partir do balanço hídrico do solo. Conforme os resultados, as maiores perdas de nitrogênio na forma de nitrato nos tratamentos que receberam água com CE = 6 dS m^{-1}, independente da LF adotada, sendo que, aos 75 dias do início do experimento, praticamente não se observa mais nitrato no lixiviado. Assim como o nitrato, as maiores concentrações de potássio no lixiviado, foram verificadas nos tratamentos de maior salinidade. Entretanto, as concentrações desse elemento no lixiviado foram aumentando linearmente ao longo no experimento. Os teores de fósforo no lixiviado foram baixos e não diferiram entre os tratamentos.
PALAVRAS-CHAVE: salinidade. perda de nutrientes. adubação.

INTRODUCTION

Salinity is one of the main problems responsible for the decline in agricultural productivity. 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.

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). However, 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., 2018). In addition, the increase in LF could not guarantee an increase in crop yield (Freitas et al., 2018).

The aim of this study was to evaluate the losses of nitrogen, potassium and phosphorus caused by the leaching fraction, determined by two methods, in maize cultivated in soil columns and irrigated with water of different salinities.

MATERIAL AND METHODS

The experiment was installed in a greenhouse in the weather station area of the Federal University of Ceará, Fortaleza - Ceará. According to the Köppen classification, the area of the experiment is located in an Aw' climate region with an average precipitation of 1600 mm and an average temperature between 26 ºC and 27 ºC.

The experimental design was completely randomized. The composition of the treatments resulted from the combination of the application of 2 methods to determine the leaching fraction and the use of irrigation water with 4 salinity levels (0.5, 2, 4 and 6 dS m^{-1}). the experiment had 8 treatments and 7 replications, totaling 56 plots.

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 & Merrill (1976); B. Application of 15% LF calculated from soil water balance of experimental plots. The composition of the treatments 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.

The experimental plots were composed of a soil column cultivated with maize. For the preparation of the soil columns, PVC pipes with a diameter of 20 cm and a length of 100 cm were used. The lower ends were closed and sealed with PVC caps (Figure 1). To allow the drainage and collection of the leachate, the lids were drilled and coupled to hoses. The hoses were connected to plastic bottles positioned at the base of the columns at ground level.

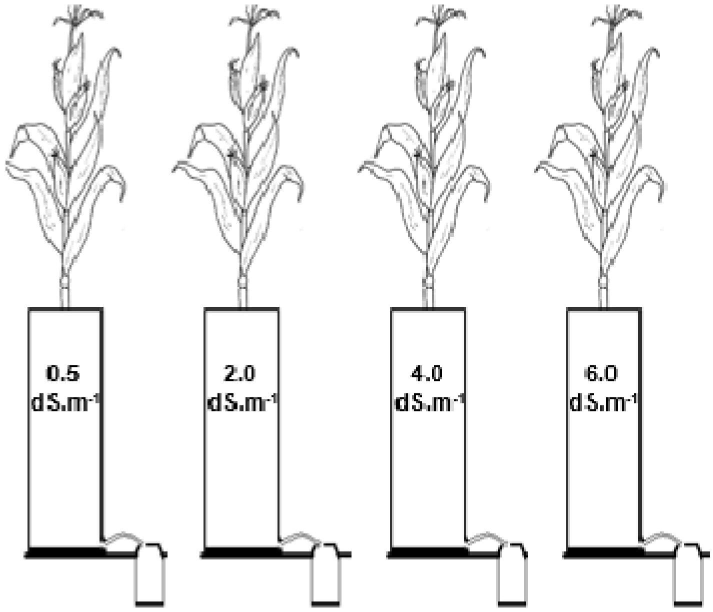

Figure 1. Schematic drawing of experimental plots (columns of soil cultivated with maize)

The soil used to fill the columns was collected by trenching in the experimental area belonging to the Department of Agricultural Engineering of the Federal University of Ceará. The soil of the area was classified as Argissolo Vermelho-amarelo eutrófico típico (Embrapa, 2018). The boundaries of the horizons were made according to the morphological description of the profile according to Santos et al. (2013). From the markings established based on the thickness of the horizons, the soil samples were collected in order to simulate, in the columns, the same sequence of horizons found "*in situ*".

The maize fertilization was carried out according to the recommendation of Embrapa (2006) for the crop. The addition of nitrogen (as urea) and potassium (as KCl) was split, 15% during sowing, 25% provided 20 days after sowing (DAS), 30% at 35º DAS and 30%. remaining at 50 DAS. The phosphorus was applied in single fertilization, in foundation, in the form of simple superphosphate.

The water drained from each column was quantified and collected 24h after each irrigation. The aliquots were transferred to 250 mL plastic bottles and stored under refrigeration. When the 250 mL aliquot was reached, the analyzes were performed. The aliquots were reached and, consequently, the analyzes were performed in five different periods during the experiment: 25, 35, 50, 65 and 75 days. The NO_3^- and P readings were performed by spectrophotometry. The K concentrations were obtained directly from leachate samples submitted to the flame photometer.

The results obtained for the evaluated parameters were submitted to analysis of variance by the F test and for the comparison test of means, Scott-knott was applied to the qualitative variables. For the quantitative variables, a regression test was used. Statistical analysis was performed using the SISVAR software version 5.6, considering the 95% confidence level.

RESULTS AND DISCUSSION

The results of the nitrate (NO_3^-) concentration are shown in figure 2A and 2B. At 25 DAS the highest mean values of the element were verified in the treatments AS3 (0.66 ppm) and AS4 (0.59 ppm). These treatments had the highest LF, respectively, 47 and 92%. In the second collection, the highest concentrations of NO_3^- were observed in the treatments irrigated with water of 4 and 6 dS m^{-1}.

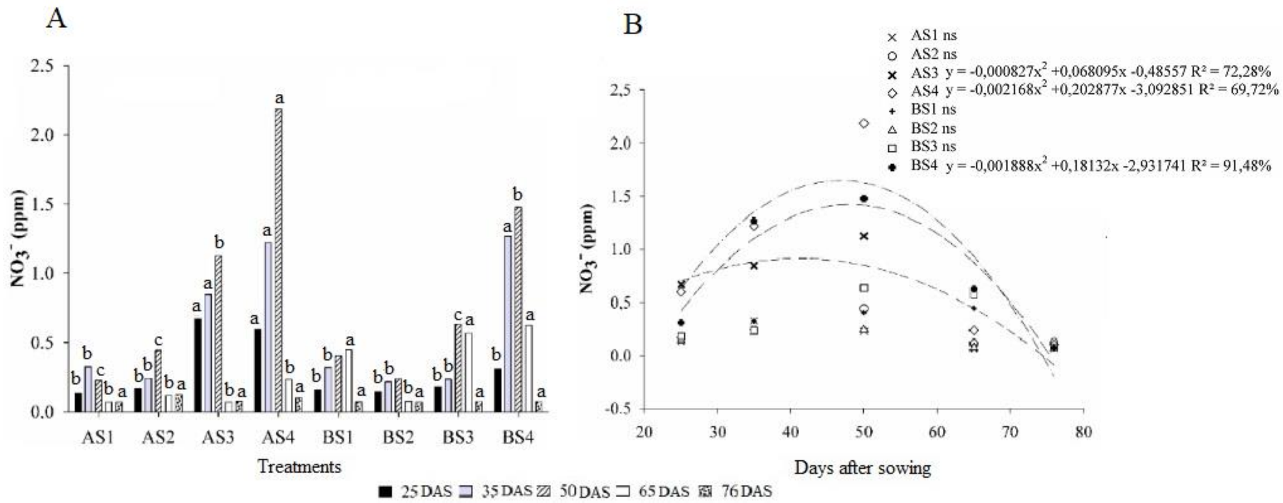

Figure 2. (A) Mean nitrate values, (B) regression curve of nitrate concentration in the leachate of the experiment submitted to different salinities and leaching fractions (LF) as a function of collection periods (25, 35, 50, 65 and 75 days).

The maximum concentration of NO_3^- in leachate in all treatments occurred at 50 DAS (third collection). In the last collection (76 DAS), there was no statistical difference between treatments. It should be noted that the nitrogen and potassium fertilization of the experiment was parceled out and the last dose was applied in 50 DAS. Thus, in the last collection period, all the nitrogen previously present in the soil had already been consumed by the plants or lost by leaching.

In Figures 3A and 3B, the increase of the potassium values in the leachate as a function of time was verified. The highest concentrations of K were observed in treatments that received water with 6 dS m^{-1} (AS4 and BS4), and the peak nutrient concentration for most treatments was observed in the last leachate collection (75 DAS). As the N, the availability of K to the plant is affected by excess sodium chloride. In addition, the physiological disorders that causes in plants, this element is able to replace the potassium in loads of clay. This phenomenon contributes to the loss of K by leaching (Brady & Weil, 2013). The same occurs in the dispute between the Cl^- and NO_3^- anions, where the excess of chloride in the soil promoted by the irrigation with saline water, interferes in the nitrogen utilization by the plant.

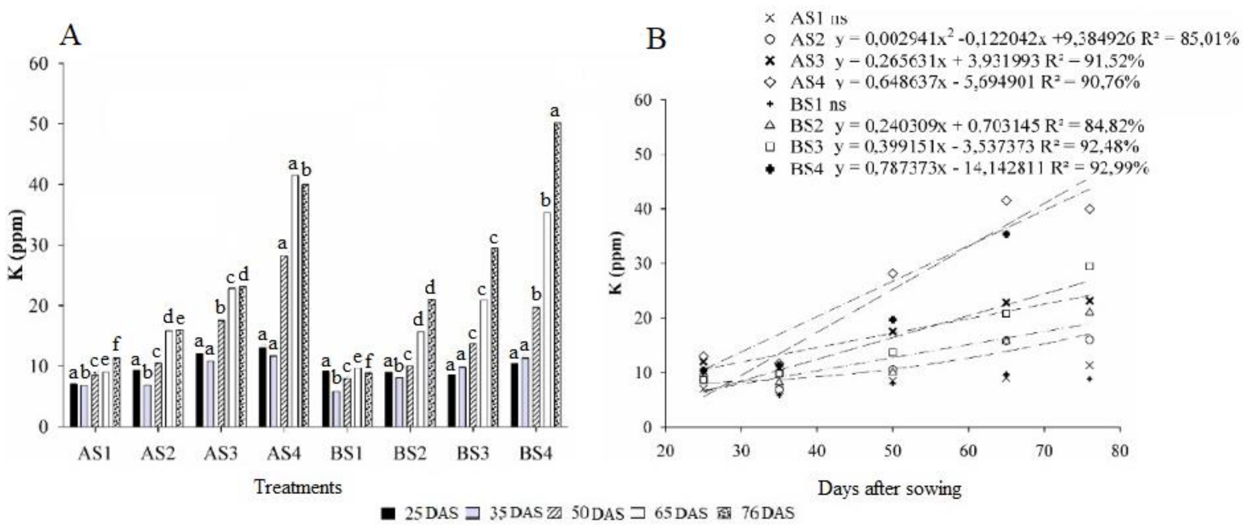

Figure 3. (A) Mean potassium values, (B) regression curve of the potassium concentration in the leachate of the experiment submitted to different salinities and leaching fractions (LF) as a function of collection periods (25, 35, 50, 65 and 75 days).

Research by Larceda et al. (2016) showed that maize under salt stress had a better efficiency of the use of inputs (water, nitrogen fertilizers and potassics) when the fertilization was reduced according to the reduction of crop evapotranspiration. The same authors in a complementary study, showed the accumulation of NO_3^- and K^+ in deeper layers of the soil cultivated with maize under salt stress. The study revealed that while water is used with higher salinity, increased to nitrogen and potassium concentration in the soil in depth (Lacerda et al., 2018). These losses are greater as a greater LF is adopted without necessarily signifying the reduction of the salts present in the soil and the effects that the salts cause in the plant.

Compared to N and K, phosphorus has lower losses by leaching. The concentration of P in the leachate treatment and during the experimental period were on average below 0.02

ppm. Thus, losses of this element by leaching were low and not influenced by the treatments over the entire study period, as seen in Figures 4A and 4B.

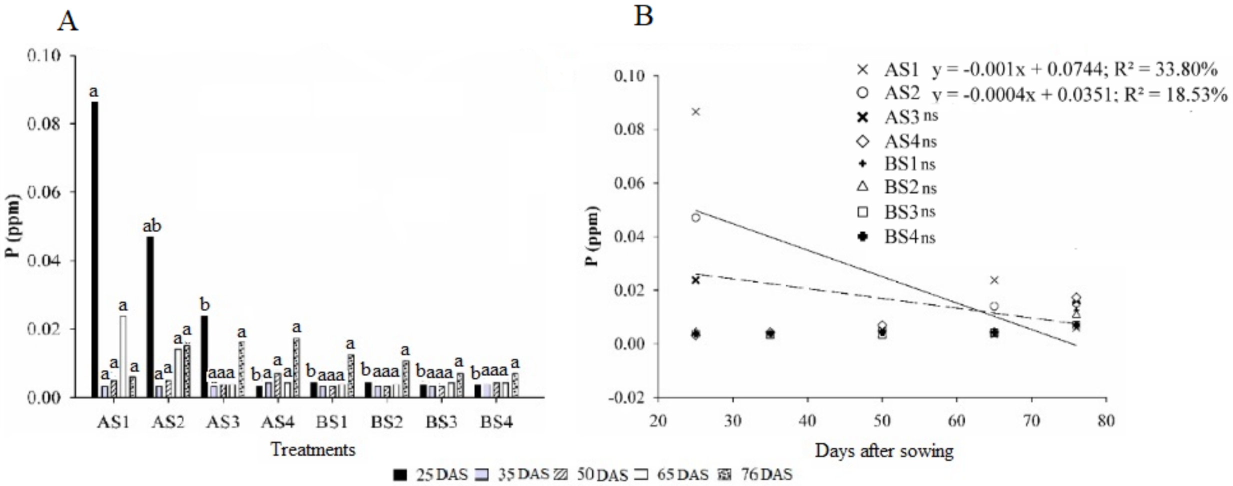

Figure 4. (A) mean phosphorus values (B) regression curve of the phosphorus concentration in the leachate of the experiment submitted to different salinities and leaching fractions (LF) as a function of collection periods (25, 35, 50, 65 e 75 days).

It is characteristic of the phosphorus the high adsorption to the soil matrix, consequently, it has the low mobility and enormous possibility of precipitation of the phosphates (Embrapa, 2011). Garcia et al. (2008) conducted studies in two distinct classes of soil cultivated with common bean and observed that application of saline water decreased phosphorus availability only in the Latossolo. However, in Neossolo element availability was not affected. Phosphorus losses by leaching are often irrelevant, regardless of soil class. It is inferred that the low utilization of P in the saline environment is due to the lower efficiency of plants in the capture of this element caused by stress.

In general, large losses of nitrogen and potassium are observed in salt-affected environments promoted by the lower absorption of these elements by the plant, and by the interference of Na^+ and Cl^- ions in the adsorption sites of soil colloids. Finally, we emphasize that research on this subject is still scarce and necessary, especially in the Northeast region of Brazil.

CONCLUSION

Losses of $N\text{-}NO_3^-$ occurred most markedly in treatments with high salinity and greater LF. The peak concentration of N in the leachate occurred at 50 DAS, depleting at 75 DAS.

The K concentrations in the leachate were maximized with the highest salinity of the water and were increasing throughout the experiment in all treatments.

The amount of phosphorus present in the leachate did not differ as a function of the different salinities and leaching fractions adopted. The concentration of this element remained low throughout the study.

AKNOWLEDGMENTS

We are grateful to CNPq and INCTSal to financial support.

REFERENCES

Brady, N. C.; Weil, R. R. **Elementos da natureza e propriedades dos solos**. 3.ed. Porto Alegre: Bookman, 2013. 704p.

Embrapa. Centro Nacional de Pesquisa do Solo. **Sistema brasileiro de classificação de solos**. 5.ed. Brasília, 2018. 356p.

Embrapa. **Irrigação e fertirrigação em fruteiras e hortaliças**. Brasília, 2011. 771p.

Embrapa. **Manejo da cultura do milho**. Circular Técnica 87. Sete Lagoas, MG, dez, 2006.

Freitas, E. D; Lacerda, C. F. De; Vieira, J. M.; Bezerra, B. G. M. C.; Ribeiro, A. A. Effect of leaching fraction determined by two methods on growth and yield of maize submitted to salt stress. **Irriga**, v. 1, p. 34-39, 2018.

Garcia, G.O.; Martins Filho, S.; Reis, E.F.; Moraes, W.B.; Nazário, A.A. Alterações químicas de dois solos irrigados com água salina. **Ciência Agronômica**, Fortaleza, v.39, n.1, p.7-18, 2008.

Lacerda, C. F. De; Ferreira, J. F. S.; Liu, X.; Suarez, D. L. Evapotranspiration as a criterion to estimate nitrogen requirement of maize under salt stress. **Journal of Agronomy and Crop Science**, v.202, p.192-202, 2016.

Lacerda, C. F. De; Ferreira, J. F. S.; Suarez, D. L.; Freitas, E. D.; Liu, X. Evidence of nitrogen and potassium losses in soil columns cultivated with maize under salt stress. **Revista Brasileira Engenharia Agrícola e Ambiental**, v.22, n.8, p.553-557, 2018.

Embrapa. **Irrigação e fertirrigação em fruteiras e hortaliças**. Brasília, 2011. 771p.

Rhoades, J.D. Drainage for salinity control. In: VAN SCHILFGAARDE, J. (Ed.), Drainage for Agriculture. Agronomy Monograph No. 17. SSSA, Madison, 1974. p. 433–461.

Rhoades, J.D.; Merrill, S.D. **Assessing the suitability of water for irrigation: Theoritical and empirical approaches**. In: Prognosis of Salinity and Alkalinity. Rome: FAO, 1976. p.69 - 110.

SANTOS, R.D.; LEMOS, R.C.; SANTOS, H.G.; KER, J.C.; ANJOS, L.H. & SHIMIZU, S.H. **Manual de descrição e coleta de solos no campo**. 6.ed. Viçosa, MG, Sociedade Brasileira de Ciência do Solo, 2013. 100p.

Shabala S.; Cuin T. A. Potassium transport and plant salt tolerance. **Physiologia Plantarum**, v.133, p.651-669, 2008.