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SALT STRESS AND LEACHING FRACTION IN COWPEA CULTURE

ESTRESSE SALINO E FRAÇÃO DE LIXIVIAÇÃO NA CULTURA DO FEIJÃO

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ABSTRACT: Salt stress negatively affects the agronomic performance of agricultural crops. In this sense, the objective of this work was to evaluate growth and soil saturation extract parameters (EC and pH) in cowpea crop irrigated with saline water under different leaching fractions. The experiment was conducted in the experimental area of the Auroras Seedling Production Unit, which belongs to the Universidade da Integração Internacional da Lusofonia Afro-Brasileira. The design used was entirely randomized, in a 5x2 factorial scheme, referring to five leaching fractions (0; 5; 10; 15 and 20%) and two electrical conductivities of the irrigation water (0.3 and 4.0 dS m^{-1}), with five repetitions. The leaf area, aboveground and root dry mass were negatively affected with the increase of the leaching fraction, however, with less intensity with water of lower salinity. Increasing the leaching fraction increased the number of leaves, stem diameter, and pH, but more efficiently with the lower salinity water. The increase of the leaching fraction associated with water of higher salinity increased the electrical conductivity of the saturation extract of the soil.

Keywords: *Vigna unguiculata (L.)*, irrigation management, salinity.

RESUMO: O estresse salino afeta negativamente o desempenho agronômico das culturas agrícolas. Neste sentido, o objetivo deste trabalho foi avaliar o crescimento e os parâmetros do extrato de saturação do solo (CE e pH) na cultura do feijão-caupi irrigado com água salina sob diferentes frações de lixiviação. O experimento foi conduzido na área experimental da Unidade de Produção de Mudas Auroras, pertencente à Universidade da Integração Internacional da Lusofonia Afro-Brasileira. O delineamento utilizado foi inteiramente casualizado, em esquema fatorial 5x2, referentes a cinco frações de lixiviação (0; 05; 10; 15 e 20%) e duas condutividades elétricas da água de irrigação (0,3 e 4,0 dS m^{-1}), com cinco repetições. A área foliar, a massa seca da parte aérea e da raiz foram afetadas negativamente com o aumento da fração de lixiviação, no entanto, com menor intensidade com água de menor salinidade. O aumento da fração de lixiviação aumenta o número de folhas, o diâmetro do caule e o pH, porém com maior eficiência na água de menor salinidade. O aumento da fração de lixiviação associada à água de maior salinidade aumentou a condutividade elétrica do extrato de saturação do solo.

Palavras-chave: *Vigna unguiculata* (L.), manejo da irrigação, salinidade.

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INTRODUCTION

The cowpea bean (*Vigna unguiculata* (L.) Walp.) is a crop originally from Africa and presents great importance for human nutrition, being one of the main sources of protein, besides its high level in energy, vitamins and minerals, being among the main subsistence crops in the Brazilian semiarid region (OLIVEIRA et al., 2017; FREIRE FILHO et al., 2011). In the Northeast region, the higher demand for irrigation water has led to the use of most of the available water sources, thus, the use of lower quality water such as brackish water at some point in the crop cycle is necessary (SOUSA et al., 2021).

Irrigated agriculture depends on water quantity and quality. In arid and semi-arid regions, known for water scarcity and poorly distributed rainfall, irrigation is chosen as an alternative, however, the water used generally presents high concentrations of salts.

The excess of salts reduces the availability of water for plants that modifies both metabolic and morphological structures, causing a reduction in germination and emergence of seeds and can compromise physiological functions, resulting in disturbances in water relations, changes in the absorption and utilization of nutrients (CEITA et al., 2020; MAGALHÃES et al., 2021; SOUSA et al., 2021).

Some strategies have been adopted to mitigate salt stress, among them the use of different leaching fractions. For Rhoades et al. (2000), the practice of leaching is an efficient alternative to reduce excess soluble salts in soils, at a rate that allows maintaining the average salinity in the root zone at values that do not economically harm crop productivity.

Assis Júnior et al. (2007) evaluating the effects of irrigation with saline water on the culture of cowpea bean, found that water salinity of 5.0 dS m^{-1} increased soil salinity and sodicity, however, these effects were partially reversed by increasing the leached fraction. Carvalho et al. (2016) evaluating the use of irrigation with brackish water under different leaching fractions in the crop of cowpea, concluded that the best leaching fractions estimated for the best agronomic performance were 9.1 and 9.6%, that is, they were able to inhibit the damage caused by salinity.

The objective of this work was to evaluate growth and soil saturation extract parameters (EC and pH) of cowpea irrigated with saline water under different leaching fractions.

MATERIAL AND METHODS

The experiment was conducted in the experimental area of the Auroras Seedling Production Unit, belonging to the Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), in the city of Redenção, state of Ceará, with geographical coordinates 4° 13' 35" S latitude and 38° 43' 53" W longitude, average altitude of 92 meters.

The climate of the region, according to the Köppen classification, is of the Aw' type, rainy tropical, with high temperatures and a predominant rainy season in the fall.

The design used was entirely randomized, in a 5x2 factorial scheme, referring to the leaching fractions (0; 5; 10; 15 and 20%) and two electrical conductivities of the irrigation water - CEa (0.3 and 4.0 dS m^{-1}), with five repetitions.

The sowing was performed manually in plastic pots with a volume of 11 liters, placing five cowpea seeds in each pot filled with substrate from the mixture of area, arisco and bovine manure, at a ratio of 4:3:1, as shown in table 1.

Table 1. Chemical characteristics of the substrate sample before application of treatments.

N	O.M	P	Ca	Mg	Na	Al	H + Al	K^+	CEes	pH
---------- g kg^{-1} -------		mg kg^{-1}	---------------------------- $cmol_c$ dm^{-3} ------------- --------------						dS m^{-1}	H_2O
0.93	14.59	27	4.5	0,7	0.67	0.15	1.49	0.78	0.08	8

OM- Organic matter; ECse- Electrical conductivity of the soil saturation extract

At 10 days after sowing (DAS), when the plants were already established, the plants were thinned, leaving only two plants per pot, and the differentiation of treatments began at the same period.

Saline water was prepared using salts of NaCl, $CaCl.2H_2O$, and $MgCl_2.6H_2O$, in the proportion of 7:2:1, according to the ratio of the electrical conductivity of water and its contraction ($mmolc^{-1}$ = EC × 10) (RHOADES et al., 2000). Irrigation was performed manually, through the drainage lysimeter principle (BERNARDO et al., 2019), in order to maintain the soil at field capacity. The volume of water to be applied to the plants was determined by (Eq. 1):

$$VI = \frac{(Vp - Vd)}{(1 - LF)}$$

Where: VI = volume of water to be applied in irrigation (mL); Vp = volume of water applied in the previous irrigation (mL); Vd = volume of drained water (mL) and LF = leaching fraction used according to the treatments.

At 45 DAS the following growth variables were analyzed: stem diameter (SD) estimated with a digital pachymeter at the base of the stem, number of leaves (NL), by directly counting the complete leaves. For leaf area (LA) determined by the ratio between leaf length (LL), leaf width (LW) and the correction factor of 0.68.

For biomass evaluation, samples were identified according to the treatments and packed in paper bags. Afterwards, they were placed to dry in a forced air circulation oven at 60 °C for 72 hours. Afterwards the shoot dry matter (SDM) and the root dry matter (RDM) were evaluated with the help of an analytical balance of 0.0001 g. To evaluate the electrical conductivity of the soil saturation extract (ECes) and pH, single samples of the substrate of each pot were collected and followed the methodology contained in Richards (1954).

The data obtained were submitted to analysis of variance (ANOVA) by the computer program ASSISTAT 7.7 (SILVA & AZEVEDO, 2016). The data were submitted to the F test and, when significant, the data of the leaching fractions were submitted to regression analysis and the electrical conductivity of the water to Tukey's Test at 1% (**) and 5% (*) of significance.

In the regression analysis, the equations that best fitted the data were chosen based on the significance of the regression coefficients of probability by the F test and the highest coefficient of determination (R^2).

RESULTS AND DISCUSSION

Table 2 shows from the analysis of variance that there was a significant interaction effect of salinity versus leaching fraction at 0.05 significance for LA, SD, SDM, RDM, TDM, ECes and pH.

Table 2. Summary of analysis of variance (ANOVA) for leaf area (LA), leaf number (LN), stem diameter (SD), shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM), soil saturation extracts electrical conductivity (ECes) and hydrogen potencial (pH) of cowpea plants at different leaching fractions.

S.V.	D.F.	Medium Square							
		LN	LA	SD	SDM	RDM	TDM	ECes	pH
Fraction (A)	4	53054.89**	11.01^{ns}	1.28**	1.28500 *	0.05635**	2.88840 **	0.28070**	0.09004**
Water (B)	1	87982.33**	296.95**	0.02^{ns}	100.25280**	0.19344**	110.12764**	0.63642**	0.00336^{ns}
Inter. A x B	4	17774.04 *	24.43 *	0.63 *	2.22980 **	0.07060**	2.14595 **	0.60174**	0.05252**
Treatment	9	41255.34**	48.75 **	0.85**	12.70133 **	0.07729**	14.47389 **	0.46291**	0.06373**
Residues	40	5014.75	7.71	0.22	0.4792	0.00919	0.21305	0.03036	0.0137
Total	49								
CV (%)	-	26.82	18.88	10.58	11.39	25.73	7.28	15.14	2.2

SV: Source of variation, DF: Degree of freedom, CV (%): Coefficient of variation; *Significant by F test at 5%; ** Significant by F test at 1%; ns = not significant.

The increase of the leaching fraction linearly increased the number of leaves in the bean crop, showing 17 leaves when irrigated with water of lower and 13 of higher salinity (Figure 1). This effect is related to the washing of salts near the root system, that is, favoring the uptake of essential nutrients such as nitrogen essential for this variable.

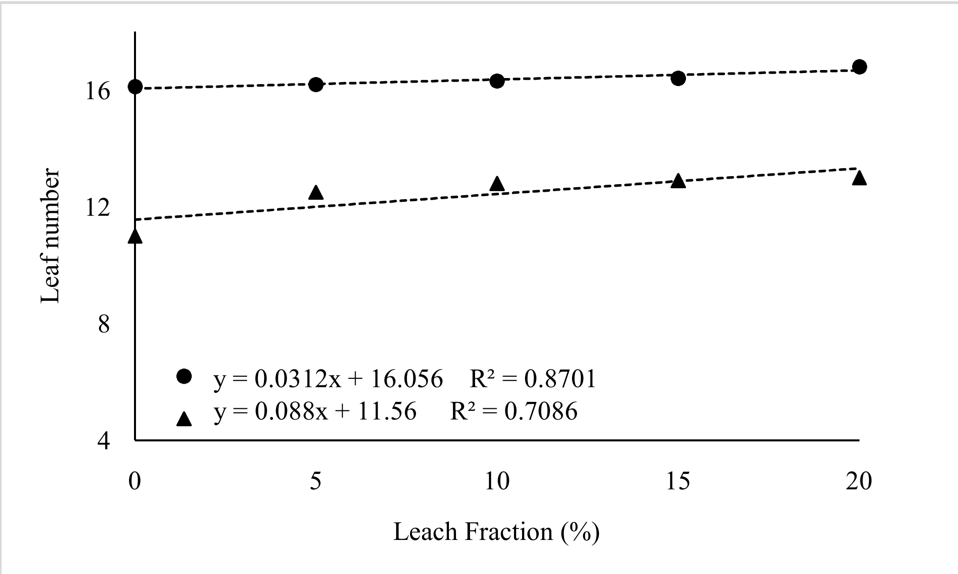

Figure 1: Leaf number of cowpea crop irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity at different leaching fractions.

One of the main effects of salinity on plant growth is related to the reduction in development, caused by the decrease in the water potential of the soil solution at a level below the limit of water assimilation by the root zone, limiting cellular enlargement, taking into account that the cell pressure potential tends to equalize with that of the soil (TAIZ et al., 2017). Similar trend to this study for irrigation with higher salinity water was verified by Sousa et al. (2021) in bean culture.

Figure 2 shows that the model that best fitted the data was the quadratic polynomial model for leaf area in water with lower salinity, obtaining a maximum leaf area of 335 cm^2 for a leaching fraction of 14.2%.

For the water with higher salinity, the best model was a decreasing linear model, where the increase of the leaching fraction reduced the leaf area by 9.92% from higher to lower salinity.

This result may be associated with the period of salt stress and adaptation of the crop to osmotic adjustment, that is, the effect was more nutritional caused by the washing of nutrients with the increase of the leaching fraction than by the effect of salts in the irrigation water.

However, the smaller leaf area when irrigated with water of higher salinity corroborates with Pereira Filho et al. (2020), when affirming that the negative influence of salinity on leaf area may be related to the action of the osmotic part that hinders the absorption of water by the plant, as well as the toxicity caused by the excess of certain ions.

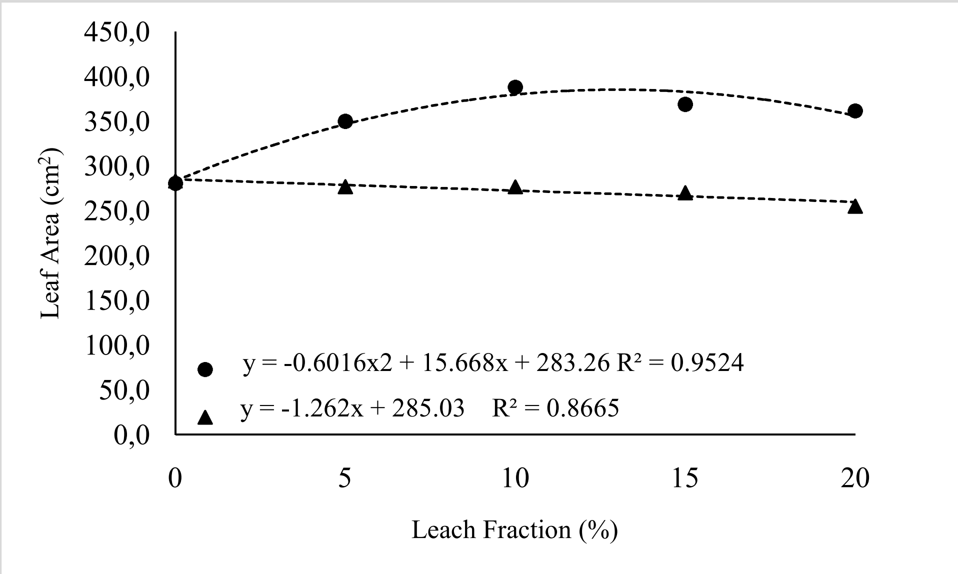

Figure 2: Leaf area of cowpea crop irrigated with water with lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity in different leaching fractions.

Similarly, Sousa et al (2021) observed a reduction in the leaf area of the bean crop when irrigated with increasing saline water at a leaching fraction of 15%. For water with a higher salinity, there was a greater reduction in leaf area. This effect corroborates the study of Magalhães et al. (2021) in the bean crop grown with 15% leaching fraction. For stem diameter, the increasing linear model was the best fit to the data, where increasing the leaching fraction for higher and lower salinity water promoted better performance in stem diameter of 110.08 and 104.44 mm respectively (Figure 3).

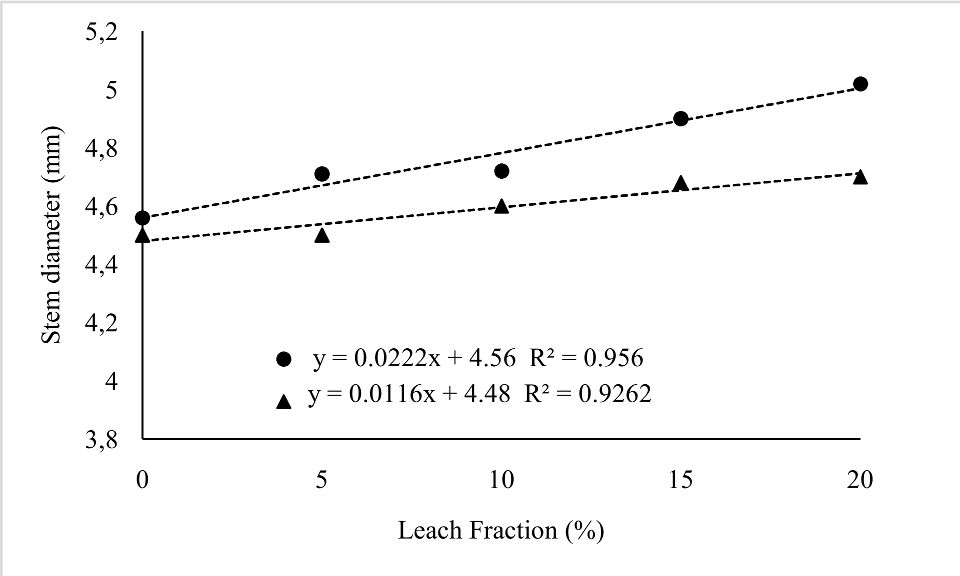

Figure 3: Stem diameter of cowpea crop irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity at different leaching fractions.

This result refutes the statement of Magalhaes et al. (2021) when studying salt stress in bean crop.

These same authors described that the use of the 15% leaching fraction did not reduce the effect of irrigation water salts on stem diameter. Similarly, Calvet et al. (2013) also found a reduction in stem diameter of cowpea plants irrigated with saline water with a leaching fraction of 15%.

The shoot dry matter fitted the quadratic model with increasing leaching fraction for the lower and higher salinity water, reaching a maximum of 5.35g and 8.04g for the fraction of 11.01% and 8.63%, respectively (Figure 4). The result of the present study reveals that salt leaching can favor higher performance of bean crop in biomass accumulation, but with less intensity when irrigated with higher salinity water.

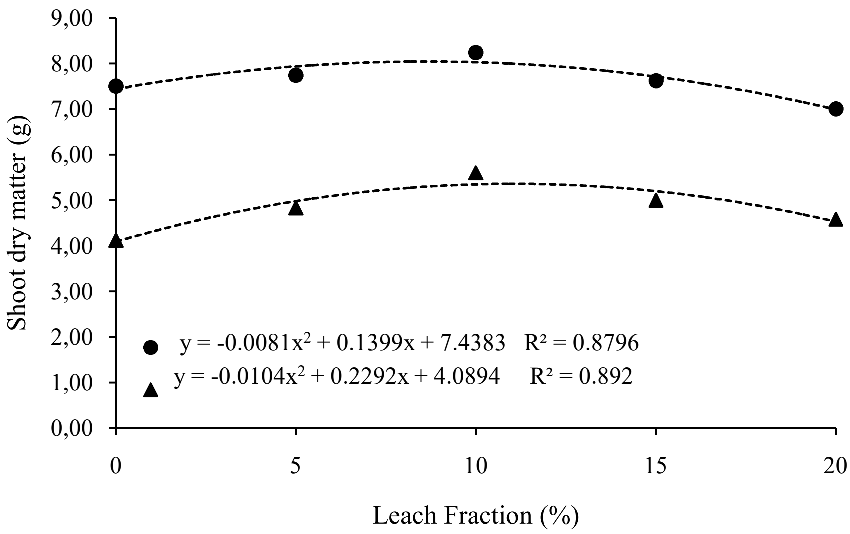

Figure 4: Shoot dry matter of the cowpea crop irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity in different leaching fractions.

Results opposite to this study, are reported by Lacerda et al. (2011), when describing that the reduction of aboveground dry matter in crops irrigated with saline water is related to the energy shift as a result of increasing soil salinity levels. Work performed by Pereira Filho et al. (2020) in bean culture also detected a reduction in the dry mass of the aerial part with the increase of salts in the irrigation water. For root dry matter (RDM) there was a quadratic effect for irrigation water of higher salinity, with a maximum value of 0.49 g occurring in the leaching fraction of 10% while, for water of lower salinity there was linear growth on the order of 23.81% with increasing leaching fraction (Figure 5). The osmotic effect of saline water hinders the capacity of roots to absorb water and, as a consequence, the reduction of leaf turgescence.

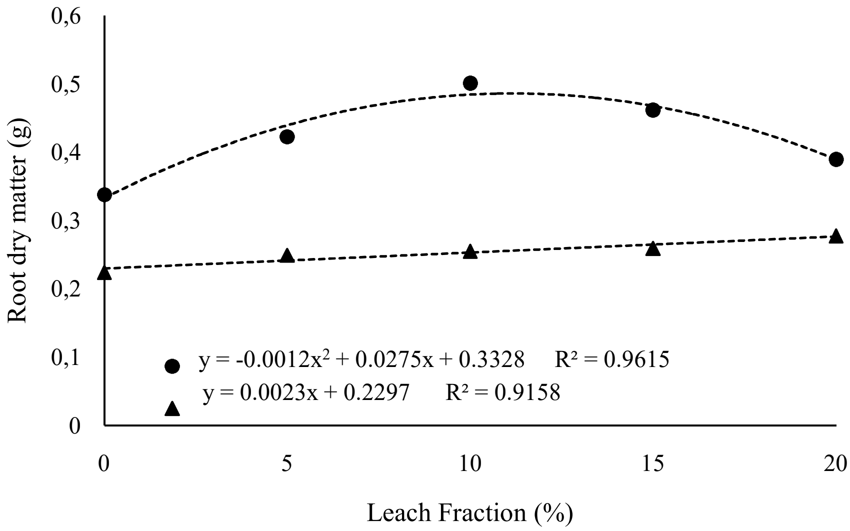

Figure 5: Root dry matter of cowpea crop irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity in different leaching fractions.

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Similarly, Sousa et al. (2021) evaluating the effect of irrigation with saline water using a leaching fraction of 15% on bean crop, also verified a reduction in root dry mass.

The total dry matter decreased linearly with increasing leaching fractions (Figure 6), with a decrease of 12.7% and 17.6% on average in higher and lower salinity waters, respectively.

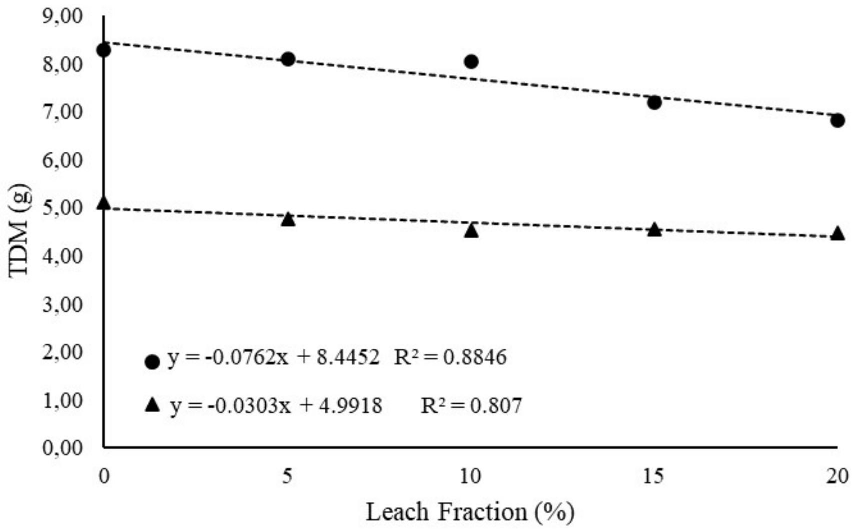

Figure 6: Total dry matter of cowpea crop irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity in different leaching fractions.

Sousa et al. (2017) point out that biomass allocation in certain plant organs may be a differentiated strategy as salt stress increases.

Similarly, Sousa et al. (2019) when evaluating the strawberry crop, irrigated with saline water, found a reduction in total dry matter. In Figure 7, it is observed for the hydrogenic potential (pH) that the increasing linear model was the best fit to the data, reaching maximum values of 5.35 and 5.30 for lower and higher salinity water, respectively.

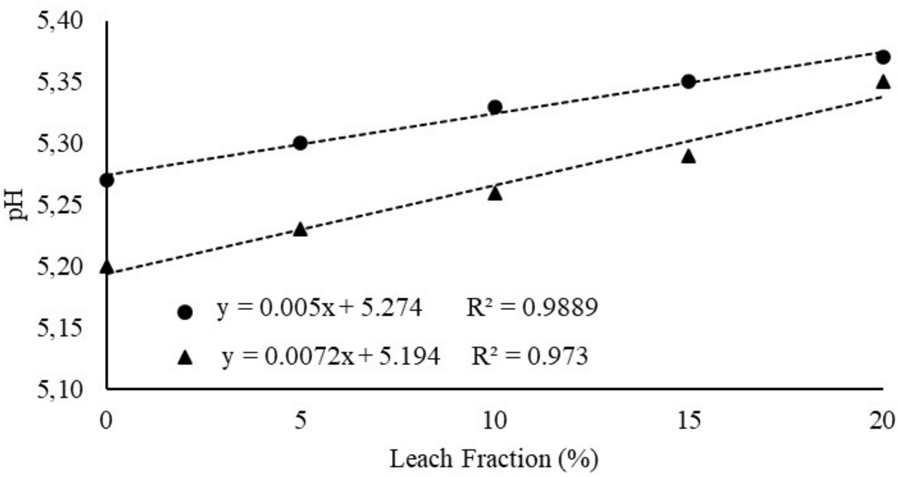

Figure 7. pH of the saturation extract of soil of cowpea crop irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity in different leaching fractions.

Different results were observed by Pereira Filho et al., (2017) when verifying linear decreasing response of soil pH when the concentration of salts in irrigation water increased.

Soil saturation extract electrical conductivity (ECse) linearly decreased by 16.3% with increasing leaching fractions for the higher salinity water and linearly increased by 31.8% with lower salinity water (Figure).

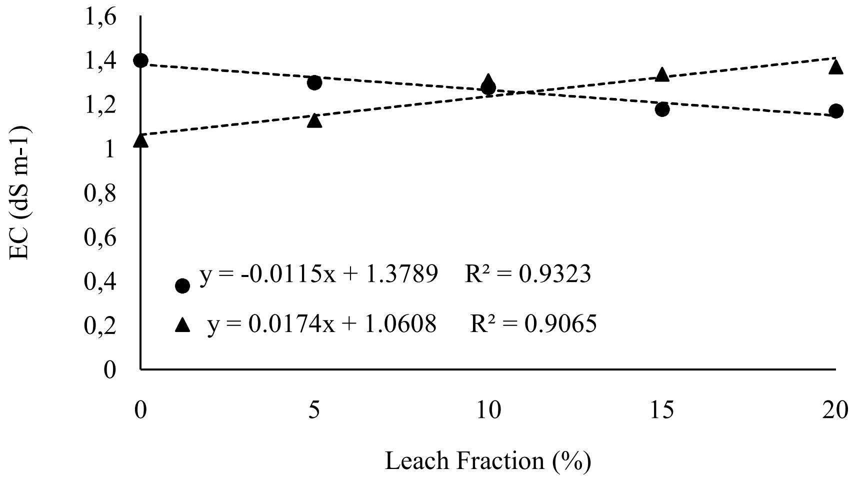

Figure 8. Electrical conductivity of the saturation extract irrigated with water of lower (●) 0.3 dS m^{-1} and higher (▲) 4.0 dS m^{-1} salinity at different leaching fractions.

This result shows that the washing of salts by increasing the leaching fraction provided lower concentration of salts in the soil profile, resulting in lower salinity in the root area, thus benefiting the growth and development of the crop. Similar results were found by Sousa et al. (2019) when irrigating strawberry crop under pot conditions with water of increasing salinity at a leaching fraction of 15%.

CONCLUSIONS

The leaf area, shoot and root dry mass were negatively affected with the increase of the leaching fraction, however, with less intensity with water of lower salinity.

Increasing the leaching fraction increased the number of leaves, stem diameter, and pH, but more efficiently with the lower salinity water.

The increase of the leaching fraction associated with water of higher salinity increased the electrical conductivity of the saturation extract of the soil.

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