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Soil chemical attributes under combinations of organic fertilizing and water salinity[1]

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ABSTRACT

The use of brackish water causes chemical changes in cultivated soils. It is therefore necessary to apply strategies that can minimize its negative impacts, such as the use of organic fertilizers. This study aimed to evaluate in the field the chemical attributes of a Red Yellow Argisol under irrigation with saline water and organic fertilizing in an area cultivated with corn. The design was randomized blocks, in a split-plot scheme, with the plots comprising salinity levels for the irrigation water (0.8 and 3.0 dS m^{-1}) and the subplots combinations of organic fertilizers (cattle manure + poultry biofertilizer + goat biofertilizer; cattle manure + goat biofertilizer; cattle manure + poultry biofertilizer; control), with four replications. The 3.0 dS m^{-1} irrigation has a negative effect on the soil chemical attributes, particularly reducing the pH and increasing the sodium, exchangeable sodium percentage and electrical conductivity of the soil saturation extract. The combination of cattle manure + poultry biofertilizer + goat biofertilizer mitigates the salt stress by favouring the accumulation of nitrogen and organic matter, while the cattle manure + poultry biofertilizer favours the potassium accumulation in the soil. The combination of cattle manure + poultry biofertilizer + goat biofertilizer increases the contents of phosphorus and potassium when using the 0.8 dS m^{-1} irrigation.

KEYWORDS: *Zea mays* L., organic fertilizers, salt stress.

RESUMO

Atributos químicos do solo sob combinações de adubação orgânica e salinidade da água

O uso de água salobra provoca alterações químicas em solos cultivados. Nesse sentido, é necessário aplicar estratégias que possam minimizar os seus impactos negativos, como, por exemplo, o uso de fertilizantes orgânicos. Objetivou-se avaliar em campo os atributos químicos de um Argissolo Vermelho Amarelo sob irrigação com água salina e adubação orgânica, em área cultivada com milho. O delineamento foi o de blocos ao acaso, em esquema de parcelas subdivididas, sendo as parcelas níveis de salinidade da água de irrigação (0,8 e 3,0 dS m^{-1}) e as subparcelas combinações de aplicação de fontes de adubos orgânicos (esterco bovino + biofertilizante de aves + biofertilizante caprino; esterco bovino + biofertilizante caprino; esterco bovino + biofertilizante de aves; controle), com quatro repetições. A irrigação de 3,0 dS m^{-1} altera negativamente os atributos químicos do solo, especialmente com redução do pH e elevação de sódio, percentagem de sódio trocável e condutividade elétrica do extrato de saturação do solo. A combinação de esterco bovino + biofertilizante de aves + biofertilizante caprino mitiga o estresse salino, favorecendo o acúmulo de nitrogênio e matéria orgânica, enquanto o esterco bovino + biofertilizante de aves favorece o acúmulo de potássio no solo. A combinação de esterco bovino + biofertilizante de aves + biofertilizante caprino aumenta o conteúdo de fósforo e de potássio quando utilizada a irrigação de 0,8 dS m^{-1}.

PALAVRAS-CHAVE: *Zea mays* L., fertilizantes orgânicos, estresse salino.

INTRODUCTION

Salinity is a problem all over the world, and when present in both water and soil ends up affecting the crop development and production. The correct use of brackish water in agriculture should therefore be preceded by an assessment of its quality and applicability with the aim of reducing any impact on the development and quality of agricultural products, as well as on the soil (Pereira et al. 2018, Rodrigues et al. 2018).

When in high concentrations, salts can change the soil chemical attributes, particularly due to the presence of Na^+ and Cl^-, which can reduce the osmotic potential of the soil solution (Rodrigues et al. 2018) and trigger nutritional, physiological

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and metabolic changes in the crops (Lima et al. 2019), with a negative impact on the formation of photoassimilates and, consequently, on yield (Lima et al. 2020).

Fertilization is a practice that aims to maximize the crop yield for different soil classes. In order to reduce the use of synthetic fertilizers, organic fertilizers have been used for base and cover fertilization in various crops. Furthermore, the use of fertilizers of animal origin, such as manure and biofertilizers, has been gaining prominence in the agricultural stage in areas cultivated under saline conditions (Gomes et al. 2018, Souza et al. 2019).

Employing such materials results in using animal waste for cultivating plants, thus reducing the cost of synthetic inputs and improving the soil physical and chemical conditions, affecting crop yield and partially or completely replacing chemical fertilization (Sousa et al. 2014).

Therefore, the present study aimed to evaluate how the use of organic fertilizer improves the soil quality and mitigates the effects of salinity in an area cultivated with corn.

MATERIAL AND METHODS

The experiment was conducted in the field from August to November 2020, under full sun, at the experimental farm of the Universidade da Integração Internacional da Lusofonia Afro-Brasileira, in Redenção, Ceará state, Brazil, in the micro-region of the Maciço de Baturité (04º14'53"S, 38º45'10"W and mean altitude of 340 m). The climate in the region is type BSh', with very high temperatures and rainfall predominantly during the summer and autumn (Alvares et al. 2013). During the experiment, the total rainfall was 30.2 mm, with mean temperature and humidity of 27.7 ºC and 66.0 %, respectively (FEP 2020).

The design was randomized blocks, in a split-plot scheme, with four replications, in which the plots comprised two levels of electrical conductivity for the irrigation water [water supply (0.8 dS m^{-1}) and saline solution (3.0 dS m^{-1})] and the subplots four combinations of organic fertilizer (C1: cattle manure + poultry biofertilizer + goat biofertilizer; C2: cattle manure + goat biofertilizer; C3: cattle manure + poultry biofertilizer; C4: control).

Before setting up the experiment, soil samples were collected from the surface layer (0-20 cm) and sent to the laboratory (Table 1), where they were analyzed according to the methodology described by Teixeira et al. (2017).

The soil in the area was classified as a Red Yellow Argisol with a sandy loam texture (Santos et al. 2018), or Ultisoil (USDA 2010), with an overall bulk density of 1.32 kg dm^{-3}.

The area was planted with corn (*Zea mays* L.), BRS Caatingueiro cultivar, the same used by producers in the region. Sowing was by hand, placing 4 seeds per hole at a spacing of 1.0 m between rows and 0.2 m between plants. Thinning was carried out at eight days after sowing (DAS), with the plant stand already established, leaving one plant per hole. In all, the experiment consisted of eight rows of 8 m $plot^{-1}$ for each treatment, totaling 40 plants $plot^{-1}$.

A drip irrigation system was used, with emitters applying a flow rate of 8.0 L h^{-1}, spaced 0.20 m apart, with one dripper per plant. The irrigation management was estimated daily using the crop evapotranspiration (ETc) and reference evapotranspiration (ETo), collecting the data from a Class A evaporation tank and using crop coefficients (Kc) of 0.86 (up to 40 DAS), 1.23 (from 41 to 53 DAS), 0.97 (from 54 to 73 DAS) and 0.52 (from 74 DAS to the end of the cycle) (Souza et al. 2015) to estimate the irrigation depth, at an irrigation frequency of two days.

The water supply of 0.8 dS m^{-1} (Table 2) was stored in 500-L water tanks and used to prepare the 3.0 dS m^{-1} saline solution, made with sodium chloride (NaCl), calcium chloride ($CaCl_2.2H_2O$) and magnesium chloride ($MgCl_2.6H_2O$) in the proportion of 7:2:1 (Medeiros 1992), and maintaining the ratio between the water electrical conductivity and the molar concentration ($mmol_c$ L^{-1} = EC × 10).

Table 1. Soil chemical attributes of the experimental area before the experiment.

OM	N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	$H^+ + Al^{3+}$	SB	ESP	pH	ECse
g kg^{-1}		mg kg^{-1}	cmol$_c$ kg^{-1}						%	H_2O	dS m^{-1}
15.62	0.98	15.00	1.60	6.00	1.90	0.23	2.31	8.30	2.00	6.60	0.31

OM: organic matter; SB: sum of bases; ESP: exchangeable sodium percentage; ECse: electrical conductivity of the soil saturation extract.

Table 2. Chemical characterization of the experimental area water supply.

Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	HCO_3^-	pH	ECw	SAR	Classification
mmol$_c$ L^{-1}				mmol L^{-1}		-	dS m^{-1}	-	-
0.6	1.4	0.2	0.4	2.5	0.1	6.9	0.8	0.3	C_3S_1

ECw: water electrical conductivity; SAR: sodium adsorption ratio.

A distribution uniformity coefficient of approximately 92 % was used when irrigating, with a leaching fraction of 0.15 added for each applied irrigation depth (Ayers & Westcot 1999). The experiment was irrigated daily with non-saline water of 0.8 dS m^{-1} until the plant stand was established, when the treatments with brackish water were included.

The corn fertilization was based on the soil chemical analysis and the organic fertilizer sources (goat and poultry biofertilizers and cattle manure; Tables 1 and 3, respectively) applied as cover, based on the maximum recommendation for chemical fertilization by Fernandes (1993), which, for irrigated corn, equals 90 kg ha^{-1} of N, 40 kg ha^{-1} of P_2O_5 and 30 kg ha^{-1} of K_2O.

The cattle manure was stored in a dry covered area and taken to the experimental area only at the time of application. The biofertilizers (poultry and goat) were prepared using chicken and goat manure, adding water at a ratio of 1:1 (v/v) for each biofertilizer, which was then placed in plastic containers and left to ferment aerobically for 30 days.

Table 3. Chemical characterization of the organic fertilizers used.

Source	N	P	K^+	Ca^{2+}	Mg^{2+}
	g L^{-1}				
Cattle manure	0.96	0.47	0.59	1.10	0.25
Goat biofertilizer	0.26	0.26	4.20	4.00	0.90
Poultry biofertilizer	3.90	0.33	2.50	1.50	0.60

To carry out the chemical analysis of the organic fertilizer sources, samples were collected, stored and taken to the laboratory (Teixeira et al. 2017). The results are shown in Table 3.

The NPK values in the soil and in the organic fertilizers were determined to check the need for nutrient supplementation of the crop. In addition, the crop recommendations were followed, which, for a stand of 50,000 plants ha^{-1}, resulted in a maximum nutrient dose plant^{-1} cycle^{-1} of 1.8 g of N, 0.8 g of P_2O_5 and 0.6 g of K_2O.

Based on the need for NPK nutrient supplementation, as described in Table 3, the amount of fertilizer applied per phenological phase is shown in Table 4. The biofertilizer and manure were applied at a depth of 15 cm in an open furrow, at 15 cm from the plants row.

At 90 DAS, the soil surface in each plot was cleaned, so that single soil samples could be collected from each experimental unit at a depth of 0-20 cm. The material was packed in plastic bags, labelled according to the treatment and taken to the laboratory to determine the chemical attributes: nitrogen (N) and organic matter (g kg^{-1}); phosphorus (P) (mg kg^{-1}); potassium (K) and sodium (Na) (cmol$_c$ kg^{-1}); exchangeable sodium percentage; electrical conductivity of the soil saturation extract (dS m^{-1}); and hydrogen-ion potential of the soil solution (pH) (Teixeira et al. 2017).

The data were submitted to tests of normality and, when a normal data distribution was found by the

Table 4. Amounts of organic fertilizers applied in the phenological stages of the corn crop.

Combinations	Fertilizers	Amount	Phenological phase
C1	Cattle manure	3.0 kg plant^{-1}	Growth
	Poultry biofertilizer	1.5 g L^{-1} plant^{-1}	Flowering
	Goat biofertilizer	3.0 g L^{-1} plant^{-1}	Grain filling
C2	Cattle manure	3.0 kg plant^{-1}	Growth
	Goat biofertilizer	3.0 g L^{-1} plant^{-1}	Flowering Grain filling
C3	Cattle manure	3.0 kg plant^{-1}	Growth
	Poultry biofertilizer	1.5 g L^{-1} plant^{-1}	Flowering Grain filling
C4	Without fertilization	-	-

Shapiro-Wilk test, an analysis of variance (Anova) was carried out. If significant by the F-test, the mean values were submitted to the Tukey test at a level of 0.05, using the Assistat 7.7 Beta software (Silva & Azevedo 2016).

RESULTS AND DISCUSSION

There was a significant effect from the interaction between the saline water and the combinations of organic fertilizer on the levels of nitrogen (N), phosphorus (P) and potassium (K); hydrogen-ion potential (pH); electrical conductivity of the soil saturation extract; and organic matter content (Table 5). An isolated significance was also found from saline water for the sodium content (Na) and exchangeable sodium percentage.

Figure 1A shows the N values in the soil under irrigation with saline water and combinations of organic fertilizer. In comparison to the N levels in the soil before the experiment, an increase greater than the initial value of 0.98 g kg^{-1} was seen under each treatment. For the water of 0.8 dS m^{-1}, treatments that included combinations did not differ statistically, while, for the water of 3.0 dS m^{-1}, there was an increase of around 45.95 % in the nitrogen content of the soil under the treatment C1, in relation to the control (C4: 1.11 g kg^{-1}), which differed statistically from the other treatments. For the irrigation water, there was an increase of 25.58 % in the nitrogen content of the soil that received the treatment C1 and water of 3.0 dS m^{-1}, when compared to the water of 0.8 dS m^{-1}, for which the nitrogen content was 1.29 g kg^{-1}.

The main N source for plants is organic matter, whose supply depends on the mineralization rate, a process developed by microorganisms in the soil. For this reason, N shows a similar behaviour to the levels of organic matter obtained in this study, given the increase in the soil organic content from the fertilizers used in the experiment, particularly for C1 under salinity.

The greater N levels in the soil for C1 after irrigation with saline water may be related to an increase of this nutrient throughout the study, or the presence of microorganisms tolerant to the saline effect of the treatment. In contrast to the results of this study, Santos et al. (2016) found that an excess of salts in soil with exchangeable sodium percentage greater than 7.0 causes a reduction in the nitrification process, which ends up reducing the soil N content.

Contrary to the present study, Mavi et al. (2012), in studies related to the dynamics of organic matter in saline soils, found that raising the salinity had a negative effect on microbial activity, reducing the mineralization of the organic matter.

Figure 1B shows the values for assimilable P in the soil under irrigation with brackish water and combinations of organic fertilizer, where it was found that, for water of 0.8 dS m^{-1}, the treatments that included combinations differed statistically from each other, with an increase in the P levels of the order of 376.11, 232.05 and 92.08 %, respectively for C1, C2 and C3, in relation to the control treatment (C4: 8.33 mg kg^{-1}). C3 and C4 were statistically equal, while, for the water of 3.0 dS m^{-1}, there was no statistical difference among the treatments that included combinations of organic fertilizer. For the irrigation water, there was a reduction of 67.22 % in the P content of the soil that received the treatment C1 with water of 3.0 dS m^{-1}, when compared to the water of 0.8 dS m^{-1}, where the content was 39.66 mg kg^{-1}.

Table 5. Summary of the analysis of variance for chemical attributes variables of soil cultivated with corn under saline irrigation and organic fertilization combinations.

Sources of variation	DF	Mean square							
		N	P	K	Na	pH	ECse	ESP	OM
Blocks	3	0.02^{ns}	62.11^{ns}	0.004^{ns}	0.05^{ns}	0.07^{ns}	0.03^{ns}	4.86^{ns}	4.15^{ns}
Saline water (SW)	1	0.00^{ns}	578.00^{ns}	0.001**	21.14**	0.46*	14.27**	1,266.72**	0.07^{ns}
Residue (SW)	3	0.02	65.33	0.001	0.07	0.02	0.05	6.36	7.39
Fertilizer (COF)	3	0.17**	493.77**	0.007**	0.11^{ns}	0.008^{ns}	0.37**	14.57^{ns}	40.69**
Residue (COF)	18	0.01	91.72	0.001	0.06	0.01	0.03	5.12	3.55
SW X COF	3	0.11**	347.33*	0.007**	0.07^{ns}	0.05*	0.16*	8.50^{ns}	15.74*
CV(%) - SW	-	11.43	43.30	21.72	4.12	2.26	14.68	24.12	14.04
CV(%) - COF	-	10.13	51.31	19.92	3.24	1.95	12.02	21.66	9.74

DF: degrees of freedom; CV: coefficient of variation; OM: organic matter; ESP: exchangeable sodium percentage; ECse: electrical conductivity of the soil saturation extract; COF: combinations of organic fertilizer. ** Significant at 1 % of probability ($p < 0.01$); * significant at 5 % of probability ($0.01 \leq p < 0.05$); ^{ns} not significant ($p \geq 0.05$).

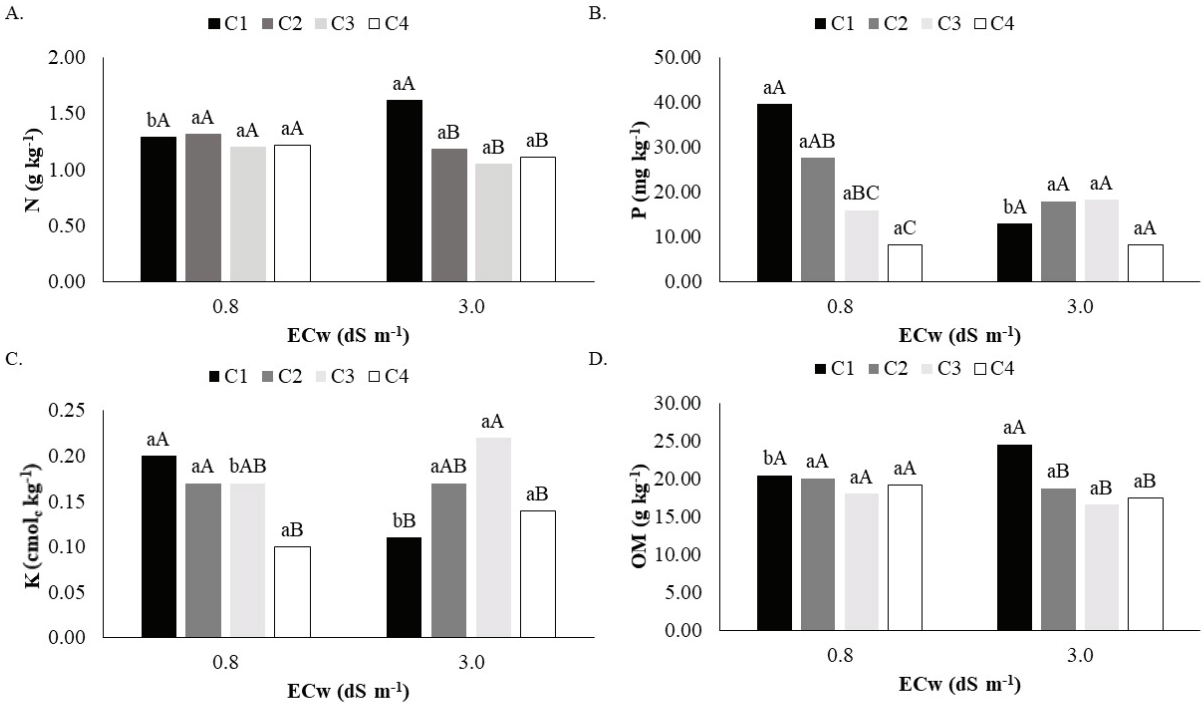

Figure 1. Nitrogen (N; A), phosphorus (P; B), potassium (K; C) and organic matter (OM; D) contents in soil irrigated with saline water and organic fertilizer combination. Means followed by the same letter, lowercase between water electrical conductivity (ECw) and uppercase between combinations in the same water electrical conductivity, do not differ statistically from each other by the Tukey test at 5 % of probability. C1: cattle manure + poultry biofertilizer + goat biofertilizer; C2: cattle manure + goat biofertilizer; C3: cattle manure + poultry biofertilizer; C4: control.

For both types of water, there was an increase in the soil P content, when compared to the initial value before the treatments were applied (15 mg kg^{-1}), except for the control treatment (C4), for which there was a reduction with both types of water. This can be attributed to the supply of nutrients afforded by organic fertilizers, which increases the soil P content (Table 3), particularly at lower salinity levels, and to the fact that the nutrient is also extracted from the soil solution by the plant during its cycle, what can also reduce its levels in the soil. Contrary to the present study, Mengmeng et al. (2021) found an increase in the levels of available phosphorus in soil affected by salts, when using organic fertilizer.

Figure 1C shows the values for K in the soil under irrigation with saline water and combinations of organic fertilizer, where it was found that, for the water of 0.8 dS m^{-1}, the treatments that included combinations differed statistically from each other, with an increase in the levels of K of the order of 100, 70 and 70 %, respectively for C1, C2 and C3, in relation to the control treatment (C4: 0.10 $cmol_c$ kg^{-1}), with C3 and C4 being statistically equal. For the water of 3.0 dS m^{-1}, there was a statistical difference among the treatments, with increases of 21.42 and 57.14 % in the K content, respectively under C2 and C3, when compared to C4 (0.14 $cmol_c$ kg^{-1}), which did not differ statistically from C1. For the irrigation water, there was a 45 % reduction in the potassium content of the soil that received the treatment C1 when irrigated with water of 3.0 dS m^{-1}, when compared to the water of 0.8 dS m^{-1} (0.20 $cmol_c$ kg^{-1}).

It should be noted that the values obtained after the experiment for both types of water were lower than the initial K content of 1.6 $cmol_c$ kg^{-1}, showing that either the plants were able to absorb K from the soil solution as needed, what would reduce it from the exchange complex, or it underwent leaching. Similar results regarding the benefit of organic fertilizer were found by Mariano et al. (2020), with a 42 % increase in the soil K content, in relation to the soil of the control treatment.

However, under saline conditions, this increase is caused by the displacement of K from the exchange complex through the concentrating effect of Ca^{2+} and Na^{+} from the irrigation water, in addition to low K absorption due to the antagonistic effects triggered between Ca^{2+} and Na^+. Rodrigues et al. (2018), studying the chemical attributes of soil cultivated with corn and irrigated with saline water, showed that raising the water electrical conductivity to 5.0 dS m^{-1} reduced the soil K content.

The organic matter content of the soil under each of the treatments was higher than its initial content of 15.62 g kg^{-1} (Figure 1D), but was not affected by the combinations of organic fertilizer when using water of 0.8 dS m^{-1}, whereas, with water of 3.0 dS m^{-1}, only C1 differed statistically from the other combinations, with an increase of 40.76 %, in relation to the control treatment (C4: 17.44 g kg^{-1}). For both types of water, there was an increase in the organic matter content of the order of 20.10 % only for C1 when using water of 3.0 dS m^{-1}, if compared to the content obtained for a water electrical conductivity of 0.8 dS m^{-1} (20.44 g kg^{-1}), all of these values being considered average.

Various soil microorganisms can adapt to the saline conditions to which they are exposed, producing metabolites that regulate them osmotically in this medium, ensuring they maintain their activity in the soil and decompose organic materials, maintaining and/or increasing their concentration in the solution (Setia & Marschner 2013).

The soil pH (Figure 2A) was reduced in all the treatments under evaluation, when compared to its initial value of 6.6; however, there was no change among the treatments from the combinations of organic fertilizer for any water electrical conductivity under study. There was a reduction for the type of irrigation water, except for the control treatment, which proved not to be superior to the other treatments, so that, for the water of 3.0 dS m^{-1} in the treatments C1, C2 and C3, these reductions were of the order of 5, 75, 3.58 and 5.69 %, respectively, when compared to the same treatments with the water of 0.8 dS m^{-1} (6.43, 6.43 and 6.5 %, respectively for C1, C2 and C3).

When organic compounds are oxidized by microbial activity in the soil, carbon dioxide (CO_2) is produced, which, when in contact with water, can react and form carbonic acid (H_2CO_3), which dissociates and releases protons (H^+) to the solution, reducing the soil pH (Souza et al. 2007). This can be aggravated by the ionic composition of the irrigation water that contains calcium chloride, which can replace anions such as carbonates and bicarbonates and increase the H^+ ions in the solution.

Differing from the present study, Dias et al. (2015) found that the use of biofertilizers in soil irrigated with saline water increased the pH of the soil solution, attributing this fact to a reduction in the organic matter and increase in the potential acidity. Pereira Filho et al. (2017), evaluating soil conditions under irrigation with saline water, found a reduction in pH for the increasing salinity of the irrigation water.

The electrical conductivity of the soil saturation extract increased significantly both as a function of the salinity of the irrigation water and as a function of the combinations of organic fertilizer, and were higher than the initial value in the soil (0.31 dS m^{-1}) (Figure 2B). There were increases of 52.5, 30 and 8.75 % in the soil saturation extract under the treatments C1, C2 and C3, respectively,

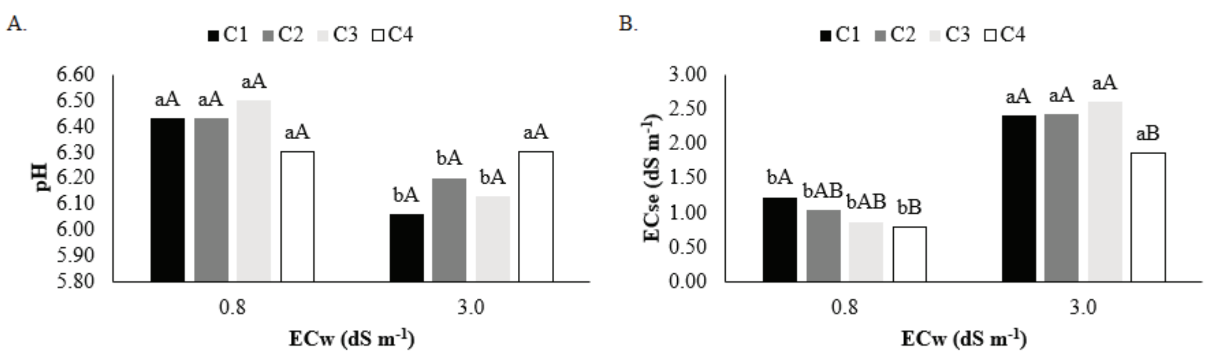

Figure 2. Hydrogenionic potential (pH; A) and electrical conductivity of the soil saturation extract (ECse; B) under irrigation with saline water and organic fertilizer combinations. Means followed by the same letter, lowercase between water electrical conductivity (ECw) and uppercase between combinations in the same water electrical conductivity, do not differ statistically from each other by the Tukey test at 5 % of probability. C1: cattle manure + poultry biofertilizer + goat biofertilizer; C2: cattle manure + goat biofertilizer; C3: cattle manure + poultry biofertilizer; C4: control.

in relation to the control (C4: 0.8 dS m^{-1}), at a water electrical conductivity of 0.8 dS m^{-1}, while, for the same treatments, at a water electrical conductivity of 3.0 dS m^{-1}, the increases were of 29.03, 30.11 and 39.78 %, when compared to the control (C4: 1.86 dS m^{-1}). The increase in the salinity of the irrigation water also caused increases in the soil saturation extract of the order of 96.72, 132.69, 198.85 and 132.5 %, respectively for C1, C2, C3 and C4, which, at a water electrical conductivity of 0.8 dS m^{-1}, achieved soil saturation extract values of 1.22, 1.04, 0.87 and 0.80 dS m^{-1}.

This increase due to the water electrical conductivity can be explained by the deposition of salts in the soil with the progressive irrigation, enhanced by the association with the combinations of organic fertilizer, further increasing deposition (Souza et al. 2019). These same authors obtained an isolated response for soil saturation extract, which increased under irrigation from 1.5 dS m^{-1} onwards, with cattle and goat biofertilizer affording an increase in relation to the control.

The soil sodium content increased for both types of water, and was more marked for that of 3.0 dS m^{-1} (Figure 3A). The initial sodium content in the soil was 0.23 $cmol_c$ kg^{-1}, so that, at the water electrical conductivity of 0.8 dS m^{-1}, the sodium content was 0.41 $cmol_c$ kg^{-1}, while, at that of 3.0 dS m^{-1}, the content increased to 2.03 $cmol_c$ kg^{-1}, an increase of around 395 % in relation to the water electrical conductivity of 0.8 dS m^{-1}.

A progressive irrigation with saline water (3.0 dS m^{-1}) caused a significant increase in the sodium (Na^+) accumulated in the soil solution due to the high concentration of this element in the water. It should be noted that the presence of sodium in irrigation water causes clay dispersion, pore obstruction and reduction in the soil permeability and hydraulic conductivity (Pedrotti et al. 2015).

Ashraf et al. (2017), irrigating a sunflower (*Helianthus annus* L.) crop with brackish water, obtained a higher sodium concentration in the soil using water of 5.56 dS m^{-1}. Rodrigues et al. (2018) found an increase of 127 % in the sodium content from irrigating with saline water (5.0 dS m^{-1}) in soil cultivated with corn.

Similarly to the sodium content, the exchangeable sodium percentage also increased when irrigation water of 3.0 dS m^{-1} was used, and was higher in both types of water, if compared to the initial exchangeable sodium percentage (Figure 3B). The soil exchangeable sodium percentage before the experiment was 2.0 %, rising to 4.16 % at the water electrical conductivity of 0.8 dS m^{-1}, while, at the water electrical conductivity of 3.0 dS m^{-1}, this percentage increased more significantly to 16.75 %, an increase of around 302.6 % in relation to the low-salinity water.

Soil Na^+ concentrations increase following irrigation with saline water of 3.0 dS m^{-1}, with a consequent increase in the soil Na^+ concentration exchange complex, explaining the present result and raising the exchangeable sodium percentage (Pedrotti et. al. 2015).

Similarly to the results found in this study, Silva & Nascimento (2019) found an increase in the exchangeable sodium percentage using irrigation water with a high salt content, where, at the highest saline level (2.0 dS m^{-1}), this percentage increased to 30 %.

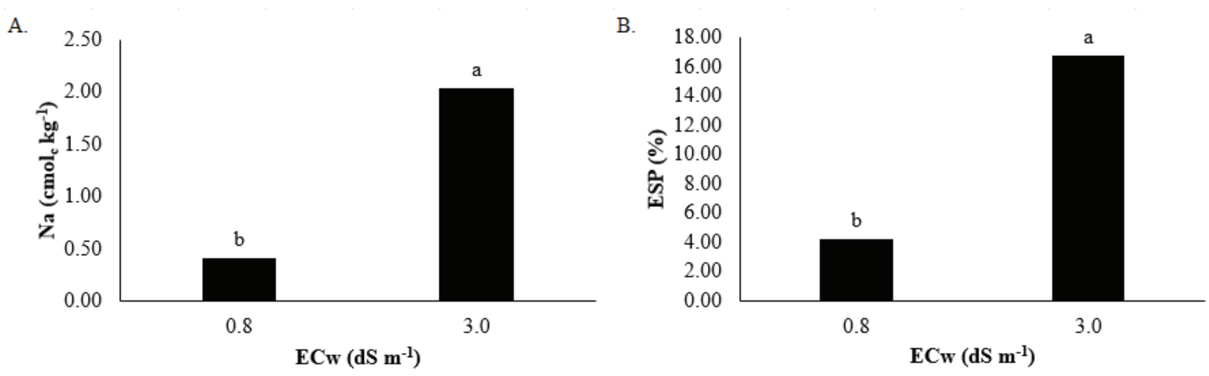

Figure 3. Sodium content (Na; A) and exchangeable sodium percentage (ESP; B) in soil irrigated with saline water. Means followed by the same letter do not differ statistically from each other by the Tukey test at 5 % of probability. ECw: water electrical conductivity.

CONCLUSIONS

1. Irrigation with water of 3.0 dS m^{-1} has a negative effect on the soil chemical attributes, particularly a reduction in the pH and an increase in the sodium, exchangeable sodium percentage and soil saturation extract;
2. The combination of cattle manure + poultry biofertilizer + goat biofertilizer mitigates the salt stress by favouring the accumulation of nitrogen and organic matter in the soil, while the combination of cattle manure + poultry biofertilizer favours the accumulation of potassium;
3. The combination of cattle manure + poultry biofertilizer + goat biofertilizer increases the soil phosphorus and potassium contents when using water of 0.8 dS m^{-1}.

REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, v. 22, n. 6, p. 711-728, 2013.

ASHRAF, M.; SHAHZAD, S. M.; AKHTAR, N.; IMTIAZ, M.; ALI, A. Salinization/sodification of soil and physiological dynamics of sunflower irrigated with saline-sodic water amending by potassium and farm yard manure. *Journal of Water Reuse and Desalination*, v. 7, n. 4, p. 476-487, 2017.

AYERS, R. S.; WESTCOT, D. W. *A qualidade da água na agricultura*. 2. ed. Campina Grande: Ed. UFPB, 1999.

DIAS, T. J.; FREIRE, J. L. O.; CAVALCANTE, L. F.; NASCIMENTO, E. S.; DANTAS, L. A.; DANTAS, M. M. M. Atributos químicos do solo irrigado com águas salinas e uso de mitigadores do estresse salino no maracujazeiro amarelo. *Revista Principia*, n. 17, p. 19-29, 2015.

FAZENDA EXPERIMENTAL PIROÁS (FEP). *Dados climáticos de 2020*. 2020. Available at: http://unilab.edu.br/dados-climaticos-do-datalogger/. Access on: Mar. 20, 2021.

FERNANDES, V. L. B. *Recomendações de adubação e calagem para o estado do Ceará.* Fortaleza: Ed. UFC, 1993.

GOMES, L. S. P.; BRAZ, T. G. S.; MOURTHÉ, M. H. F.; PARAÍSO, H. A.; PIRES NETO, O. S.; SILVA, F. E. G.; PEREIRA, L. R. F.; ALMEIDA, B. Q. Níveis de substituição de ureia por esterco bovino na adubação de capim-marandu. *Revista de Ciências Agrárias*, v. 41, n. 4, p. 914-923, 2018.

LIMA, G. S.; DIAS, A. S.; SOARES, L. A. A.; GHEYI, H. R.; NOBRE, R. G.; SILVA, A. A. R. Eficiência fotoquímica, partição de fotoassimilados e produção do algodoeiro sob estresse salino e adubação nitrogenada. *Revista de Ciências Agrárias*, v. 42, n. 1, p. 214-225, 2019.

LIMA, G. S.; SILVA, J. B.; PINHEIRO, F. W. A.; SOARES, L. A. A.; GHEYI, H. R. Potassium does not attenuate salt stress in yellow passion fruit under irrigation management strategies. *Revista Caatinga*, v. 33, n. 4, p. 1082-1091, 2020.

MARIANO, E. F.; ARAÚJO, R. C.; SANTOS, R. L.; DINIZ, B. L. M. T.; MAGALHÃES, W. B.; MELO, T. S. Atributos químicos de solo e crescimento de fava cultivada sob diferentes adubações orgânicas. *Scientific Journal of Environmental Sciences and Biotechnology*, v. 6, n. 3, p. 71-80, 2020.

MAVI, M. S.; MARSCHNER, P.; CHITTLEBOROUGH, D. J.; COX, J. W.; SANDERMAN, J. Salinity and sodicity affect soil respiration and dissolved organic matter dynamics differentially in soils varying in texture. *Soil Biology and Biochemistry*, v. 45, n. 1, p. 8-13, 2012.

MEDEIROS, J. F. *Qualidade da água de irrigação utilizada nas propriedades assistidas pelo "GAT" nos estados do RN, PB, CE e avaliação da salinidade dos solos*. 1992. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal da Paraíba, Campina Grande, 1992.

MENGMENG, C.; SHIRONG, Z.; LIPENG, W.; CHAO, F.; XIAODONG, D. Organic fertilization improves the availability and adsorptive capacity of phosphorus in saline-alkaline soils. *Journal of Soil Science and Plant Nutrition*, v. 21, n. 1-2, p. 487-496, 2021.

PEDROTTI, A.; CHAGAS, R. M.; RAMOS, V. C.; PRATA, A. P.; LUCAS, A. A. T.; SANTOS, P. B. Causas e consequências do processo de salinização dos solos. *Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental*, v. 19, n. 2, p. 1308-1324, 2015.

PEREIRA FILHO, J. V.; BEZERRA, F. M. L.; SILVA, T. C.; PEREIRA, C. C. M. S.; CHAGAS, K. L. Alteração química do solo cultivado com feijão-caupi sob salinidade e dois regimes hídricos. *Revista Brasileira de Agricultura Irrigada*, v. 11, n. 8, p. 2206-2216, 2017.

PEREIRA, E. D.; QUEIROGA, R. C. F. de; SILVA, Z. L.; ASSIS, L. E.; SOUSA, F. F. Produção e qualidade do meloeiro sob osmocondicionamento da semente e níveis de salinidade da água. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, v. 13, n. 1, p. 8-15, 2018.

RODRIGUES, V. S.; SOUSA, G. G.; SARAIVA, S. E. L.; CARDOSO, E. R. C.; PEREIRA FILHO, J. V.; VIANA, T. V. A. Atributos químicos do solo em área cultivada com milho sob irrigação com água salina. *Revista Brasileira de Agricultura Irrigada*, v. 12, n. 7, p. 3129-3138, 2018.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAUJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F. *Sistema brasileiro de classificação de solos*. 5. ed. Brasília, DF: Embrapa Informação Tecnológica, 2018.

SANTOS, R. V.; CAVALCANTE, L. F.; VITAL, A. F. M.; LACERDA, C. F.; SOUZA, E. R.; LIMA, G. S. Interação salinidade-fertilidade do solo. *In*: GHEYI, H. R.; DIAS, N. S.; LACERDA, C. F.; GOMES FILHO, E. (ed.). *Manejo da salinidade na agricultura*: estudos básicos e aplicados. 2. ed. Fortaleza: INCTSal, 2016. p. 277-293.

SETIA, R.; MARSCHNER, P. Carbon mineralization in saline soils is affected by residue composition and water potential. *Biology and Fertility of Soils*, v. 49, n. 1, p. 71-77, 2013.

SILVA, F. A. S.; AZEVEDO, C. A. V. The Assistat software version 7.7 and its use in the analysis of experimental data. *African Journal of Agriculture Research*, v. 11, n. 39, p. 3733-3740, 2016.

SILVA, P. V. S. R.; NASCIMENTO, P. S. Salinidade do solo e desenvolvimento do girassol submetido à irrigação com águas de diferentes qualidades. *Gesta*, v. 7, n. 2, p. 255-269, 2019.

SOUSA, G. G.; VIANA, T. V. A.; LACERDA, C. F.; AZEVEDO, B. M.; SILVA, G. L.; COSTA, F. R. B. Estresse salino em plantas de feijão-caupi em solo com fertilizantes orgânicos. *Revista Agro@mbiente On-Line*, v. 8, n. 3, p. 359-367, 2014.

SOUZA, D. M. G.; MIRANDA, L. N.; OLIVEIRA, S. A. Acidez do solo e sua correção. *In*: NOVAIS, R. F.; ALVAREZ, V. H.; BARROS, N. F.; FONTES, R. L. F.; CANTARUTTI, R. B.; NEVES, J. C. L. (ed.). *Fertilidade do solo*. Viçosa: SBCS, 2007. p. 205-274.

SOUZA, L. S. B.; MOURA, M. S. B.; SEDIYAMA, G. C.; SILVA, T. G. F. Requerimento hídrico e coeficiente de cultura do milho e feijão-caupi em sistemas exclusivo e consorciado. *Revista Caatinga*, v. 28, n. 4, p. 151-160, 2015.

SOUZA, M. V. P.; SOUSA, G. G.; SALES, J. R. S.; FREIRE, M. H. C.; SILVA, G. L.; VIANA, T. V. A. Saline water and biofertilizer from bovine and goat manure in the Lima bean crop. *Revista Brasileira de Ciências Agrárias*, v. 14, n. 3, e5672, 2019.

TEIXEIRA, P. C.; DONAGEMMA, G. K.; FONTANA, A.; TEIXEIRA, W. G. (ed.). *Manual de métodos de análise de solo*. 3 ed. Brasília, DF: Embrapa, 2017.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). Soil Survey Staff. *Keys to soil taxonomy*. 11. ed. Washington, DC: USDA, 2010.