ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.11, p.848-854, 2022
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n11p848-854

Organic fertilization and salt stress on the agronomic performance of maize crop[1]

Adubação orgânica e estresse salino no desempenho agronômico da cultura do milho

Márcio H. da C. Freire[2*], Thales V. de A. Viana[2], Geocleber G. de Sousa[3], Benito M. de Azevedo[2], Henderson C. Sousa[2], Geovana F. Goes[2], Carla I. N. Lessa[2] & Fred D. B. da Silva[3]

[1] Research developed at Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Redenção, CE, Brazil
[2] Universidade Federal do Ceará/Departamento de Engenharia Agrícola, Fortaleza, CE, Brazil
[3] Universidade da Integração Internacional da Lusofonia Afro-Brasileira/Instituto de Desenvolvimento Rural, Redenção, CE, Brazil

HIGHLIGHTS:
The maize crop was negatively affected by the combination of organic fertilizer and salinity water of 3.0 dS m^{-1}.
Saline stress was more obvious in the maize crop in the combination of goat biofertilizer and a salinity of 3.0 dS m^{-1}.
Under a salinity of 3.0 dS m^{-1}, cattle manure and poultry biofertilizer was the combination that increased maize yield.

ABSTRACT: Irrigation water salinity can cause serious problems in crop production, while organic fertilizer sources potentially mitigate saline stress. Thus, this study aimed to evaluate the productivity of maize crops under irrigation with saline water and organic fertilization. The study was conducted in the field from August to November 2020 at the experimental farm of the Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), Redenção-CE. A randomized block design was used, in subdivided plots, in which the plots consisted of two levels of irrigation water salinity (0.8 and 3.0 dS m^{-1}). Four combinations of organic fertilizer sources were applied in the subplots, composed of 10 plants each, with four replications: C1, cattle manure + poultry biofertilizer + goat biofertilizer; C2, cattle manure + goat biofertilizer; C3, cattle manure + poultry biofertilizer; and C4, control treatment. The combination of organic fertilizer sources did not influence the accumulation of assimilates and productivity of maize crops under the irrigation water salinity of 3.0 dS m^{-1}, except for C3, which attenuated the saline effect.

Key words: *Zea mays* L., organic material, nutrition, salinity

RESUMO: A salinidade da água de irrigação pode causar sérios problemas na produção agrícola, enquanto as fontes de fertilizantes orgânicos potencialmente mitigam o estresse salino. Assim, este trabalho teve como objetivo avaliar a produtividade da cultura do milho sob irrigação com água salina e adubação orgânica. O estudo foi conduzido em campo de agosto a novembro de 2020 na fazenda experimental da Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), Redenção-CE. Utilizou-se o delineamento em blocos casualizados, em parcelas subdivididas, em que as parcelas consistiram em dois níveis de salinidade da água de irrigação (0,8 e 3,0 dS m^{-1}). Nas subparcelas foram aplicadas quatro combinações de fontes de adubo orgânico, compostas por 10 plantas cada, com quatro repetições: C1, esterco bovino + biofertilizante de aves + biofertilizante de cabra; C2, esterco bovino + biofertilizante caprino; C3, esterco bovino + biofertilizante de aves; e C4, tratamento controle. A combinação de fontes de fertilizantes orgânicos não influenciou o acúmulo de assimilados e a produtividade das lavouras de milho sob a salinidade da água de irrigação de 3,0 dS m^{-1}, exceto C3, que atenuou o efeito salino.

Palavras-chave: *Zea mays* L., material orgânico, nutrição, salinidade

• Ref. 260637 – Received 18 Feb, 2022
* Corresponding author - E-mail: marciohcfreire@gmail.com
• Accepted 02 Jun, 2022 • Published 13 July, 2022
Editors: Geovani Soares de Lima & Hans Raj Gheyi

Introduction

Maize is an important crop cultivated worldwide (Kandil et al., 2020). Irrigation allows crops to achieve maximum production, but good quality water is not always sufficient to maintain this productive potential, that is, it is necessary to use water of poor quality (saline water).

However, irrigation of maize with saline water promotes stress as it decreases the osmotic potential of the soil solution, reducing the availability of water and thus causing water stress and leading to plant metabolic injuries in the photosynthetic apparatus (Lima et al., 2019). Saline irrigation water has also been shown to lead to the accumulation of dry matter and reduction in the productive yield of maize cultivated in pots and fields (Sousa et al., 2016; Costa et al., 2021; Goes et al., 2021; Sousa et al., 2022).

An alternative that has been gaining prominence in the agricultural scenario is organic fertilization in the form of manure and biofertilizer of animal origin in saline conditions. The use of these organic inputs reduces the costs associated with synthetic inputs and improves the physical and chemical properties of the soil and productivity of crops (Gomes et al., 2018; Silva et al., 2018; Sales et al., 2019).

Some studies have shown the positive effect of the use of organic sources in saline environments. Santos et al. (2020) investigated the effect of the use of organic matter on maize crop growth under salinity and showed positive effects, including mitigation of saline stress. Similarly, Nascimento et al. (2017) and Sousa et al. (2017) demonstrated the benefit of the use of organic inputs in mitigating salt stress in sesame and yellow passion fruit crops irrigated with saline water and Santos et al. (2019) demonstrated the same for bell pepper crops irrigated with saline water.

Thus, this study aimed to evaluate the productivity of maize crop under irrigation with saline water and organic fertilization.

Materials and Methods

The experiment was conducted in the field between August and November 2020 at the Fazenda Experimental Piroás, Universidade da Integração Internacional da Lusofonia Afro-Brasileira-UNILAB, Redenção, Ceará, Brazil. The climate of the region is of the BSh' type with high temperatures and predominant rainfall in the summer and autumn seasons (Alvares et al., 2013); the average temperature and relative humidity are 27.7 °C and 66.0%, respectively (FEP, 2020) (Figure 1).

The experimental design adopted was a randomized block design, in a subdivided plot scheme, with four repetitions. The plots consisted of two electrical conductivities of the irrigation water (ECw): A1, municipal supply water of 0.8 dS m^{-1} and A2, saline solution of 3.0 dS $m^{-1.}$ The subplots referred to four combinations of application of organic fertilizer sources (AD): C1, cattle manure + poultry biofertilizer + goat biofertilizer; C2, cattle manure + goat biofertilizer; C3, cattle manure + poultry biofertilizer; and C4, control treatment. Each subplot contained 10 plants, with a total of 40 plants per plot.

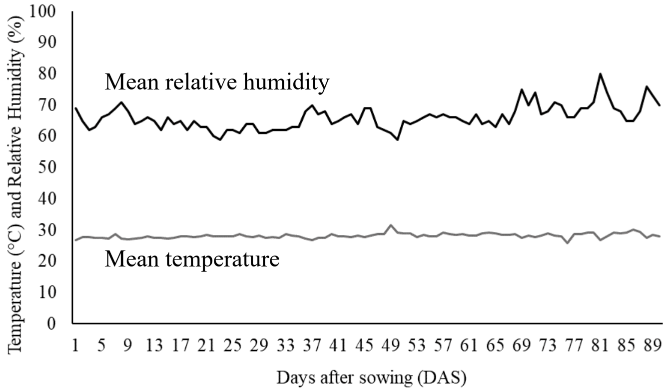


Figure 1. Mean values of temperature and relative air humidity during the experimental period

Soil samples were collected from the surface layer (0-20 cm) in the area and taken to the Soil and Water Laboratory of the Department of Soil Sciences/Federal University of Ceara for the determination of chemical attributes and soil fertility (Table 1), according to the methodology described by Teixeira et al. (2017).

The soil of the area is classified as Ultisol, of sandy loam texture (65% sand, 17% silt, and 18% clay), and presents an overall density of 1.32 kg dm^{-3}.

Maize (*Zea mays* L.), cultivar BRS Caatingueiro, the same used by producers in the region, was sown in the area. The seeds were placed manually in pits, with four seeds per pit, at a spacing of 1.0 × 0.2 m between planting lines and between plants. Eight days after sowing (DAS), thinning was performed with the plant stand already established, leaving one plant per pit and 40 plants per plot.

A drip irrigation system was adopted, with emitters adjusted for a flow rate of 8.0 L h^{-1} and spaced at 0.20 m, that is, one dripper per plant. Irrigation management was estimated daily by reference evapotranspiration, using data from a Class A evaporimetric tank. The crop coefficient used were: 0.86 (up to 40 days after sowing, 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), with a two-day irrigation shift.

The 0.25 dS m^{-1} supply water (Table 2) was stored in 500-liter (L) capacity water tanks and used in the preparation of the 0.8 and 3.0 dS m^{-1} salines solutions, which was prepared with sodium chloride (NaCl), calcium chloride ($CaCl_2.2H_2O$), and magnesium chloride ($MgCl_2.6H_2O$) maintaining equivalent proportion of 7:2:1 (Medeiros, 1992), following the relationship between ECw and its molar concentration ($mmol_c$ L^{-1} = EC × 10).

For irrigation, a distribution uniformity coefficient of approximately 92% was used. Irrigation time was estimated using Eq. 1:

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

OM	N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	$H^+ + Al^{3+}$	SB	T	V	ESP	pH	ECse
(g kg^{-1})		(mg kg^{-1})	($cmol_c$ kg^{-1})							(%)		(in water)	(dS m^{-1})
15.62	0.98	15.00	1.60	6.00	1.90	0.23	2.31	9.73	12.04	80.81	1.91	6.60	0.31

OM - Organic matter; SB - Sum of bases; T - Cation exchange capacity; V - Base saturation; ESP - Exchangeable sodium percentage; ECse - Electrical conductivity of soil saturation extract

Table 2. Chemical characterization of irrigation water

Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	HCO_3^-	pH	ECw	RAS	Classification
(mmol$_c$ L^{-1})							(dS m^{-1})	(mmol L^{-1})$^{0.5}$	Richards (1954)
0.6	1.4	0.2	0.4	2.5	0.1	6.9	0.25	0.4	C_2S_1

ECw - Electrical conductivity of water; RAS - Sodium adsorption ratio

$$Ti = \frac{ETc \times Ep}{Ea \times q} \times 60 \quad (1)$$

where:

Ti - irrigation time (min);
ETc - crop evapotranspiration (mm);
Ep - spacing between drippers (m);
Ea - application efficiency (0.9); and,
q - flow rate (L h^{-1}).

A leaching fraction of 0.15 (Ayers & Westcot, 1999) was added to the applied volume, and until the establishment of the plant stand, the experiment was irrigated daily with water of 0.8 dS m^{-1}, with subsequent differentiation of treatments with saline water.

To monitor soil water potential, puncture tensiometers were installed in each plot at a depth of 20 cm. Fertilization of maize plants was performed based on chemical analyses of the soil and organic fertilizer sources (goat and poultry biofertilizers and bovine manure) (Tables 1 and 3, respectively) and was applied as a basal dose and as topdressing, following the recommendation of Fernandes (1993) for irrigated maize, corresponding to 90 kg ha^{-1} of N, 40 kg ha^{-1} of P_2O_5, and 30 kg ha^{-1} of K_2O.

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

To perform chemical analyses of the organic fertilizer sources, samples were collected, stored, and transported to the laboratory. Methodologies cited by Teixeira et al. (2017) were used for the analysis. The results are shown in Table 3.

To verify the need for supplementation of nutrients for the maize crop, the values of NPK present in the soil and the organic fertilizers were observed (Tables 1 and 3). With a stand of 50,000 plants ha^{-1}, the maximum dosage of nutrients recommended per plant per cycle is 1.8 g N, 0.8 g P_2O_5, and

Table 3. Chemical characterization of organic fertilizers used

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

0.6 g K_2O. In addition to this, 20% and 80% N was applied in the foundation and topdressing, respectively, and 50% P and K was applied in both the foundation and topdressing.

According to the need for nutrient complementation and the amount of NPK presented in Table 3, the amount of fertilizer applied per phenological phase is presented in Table 4. The application of biofertilizers and manure was performed in an open furrow 15 cm from the planting line at a depth of 15 cm.

At 90 DAS, four ears were collected from the plot of each treatment and dried until they reached a constant mass, and the following variables were determined: dry mass of the cob with straw (DMCWS) and without straw (DMCWoS), in grams per cob (g cob^{-1}), using a scale with a precision of 0.001 g; and the diameter (DCWoS) and length (LCWoS) of the cob without straw using a digital pachymeter in millimeters (mm).

The average mass of grains was determined from the grains removed from the four ears, which were subsequently counted, separated, and weighed to determine the mass of 1000 grains (TGM) (g per plant), according to the seed analysis norms; furthermore, seed moisture was determined as being 18% at the time of evaluation, using a balance with 0.1-g precision, and yield (Y) in kg ha^{-1} was calculated.

Shapiro-Wilk test revealed that the observed data followed a normal distribution. Analysis of variance (Anova) was applied and when significant under the F test, the data were subjected to the Tukey test at a probability level of 0.05, using the ASSISTAT 7.7 Beta software (Silva & Azevedo, 2016).

Results and Discussion

Within their combination, a significant interaction was observed between saline water (ECw) and organic fertilizer (AD) for the cob dry mass with and without straw (DMCWS

Table 4. Quantities of organic fertilizers applied in the different phenological stages of the maize crop

Combinations	Fertilizer	Quantity	Phenological stage	Nutritional requirement by stage* N	P	K
				g per plant		
C1	Cattle manure	3.0 kg per plant	Growth	0.36	0.4	0.3
	Poultry biofertilizer	1.5 g L^{-1} per plant	Flowering	0.72	0.4	0.0
	Goat biofertilizer	3.0 g L^{-1} per plant	Grain filling	0.0	0.0	0.3
C2	Cattle manure	3.0 kg per plant	Growth	0.36	0.4	0.3
	Goat biofertilizer	3.0 g L^{-1} per plant	Flowering	0.72	0.4	0.0
			Grain filling	0.0	0.0	0.3
C3	Cattle manure	3.0 kg per plant	Growth	0.36	0.4	0.3
	Poultry biofertilizer	1.5 g L^{-1} per plant	Flowering	0.72	0.4	0.0
			Grain filling	0.0	0.0	0.3
C4	Without fertilization	-	-	0.0	0.0	0.0

* The recommendation already includes data regarding the requirement of the crop and the plant stand

Table 5. Summary of analysis of variance for cob dry mass with and without straw (DMCWS and DMCWoS), diameter and length of the cob without straw (DCWoS and LCWoS), thousand grain mass (TGM) and yield (Y) of maize under saline water irrigation and combinations of organic fertilization

SV	DF	Mean squares					
		DMCWS	DMCWoS	DCWoS	LCWoS	TGM	Y
Blocks	3	299.80^{ns}	141.08*	5.88^{ns}	0.18^{ns}	3.93^{ns}	38743.23*
Saline Water (ECw)	1	2553.14*	3275.43**	147.34**	26.47*	6384.49^{ns}	6189529.17**
Residue (ECw)	3	141.79	8.72	1.9	0.82	1063.08	2676.77
Fertilization (AD)	3	99.18^{ns}	95.96^{ns}	2.58^{ns}	1.58^{ns}	2537.98**	92299.34^{ns}
ECw × AD	3	1524.46**	1171.90**	44.85**	10.66**	1768.20*	1827326.55**
Residue (AD)	18	164.08	73.58	1.18	0.63	452.12	58715.46
CV (%) – ECw	-	21.71	6.74	4.12	9.55	19.90	3.35
CV (%) – AD	-	23.36	19.56	3.24	8.40	12.98	15.69

SV - Source of variation; DF - Degree of freedom; CV - Coefficient of variation; **Significant at 0.01 probability level ($p \leq 0.01$); *Significant at 0.05 probability level ($p \leq 0.05$); ns – Not significant

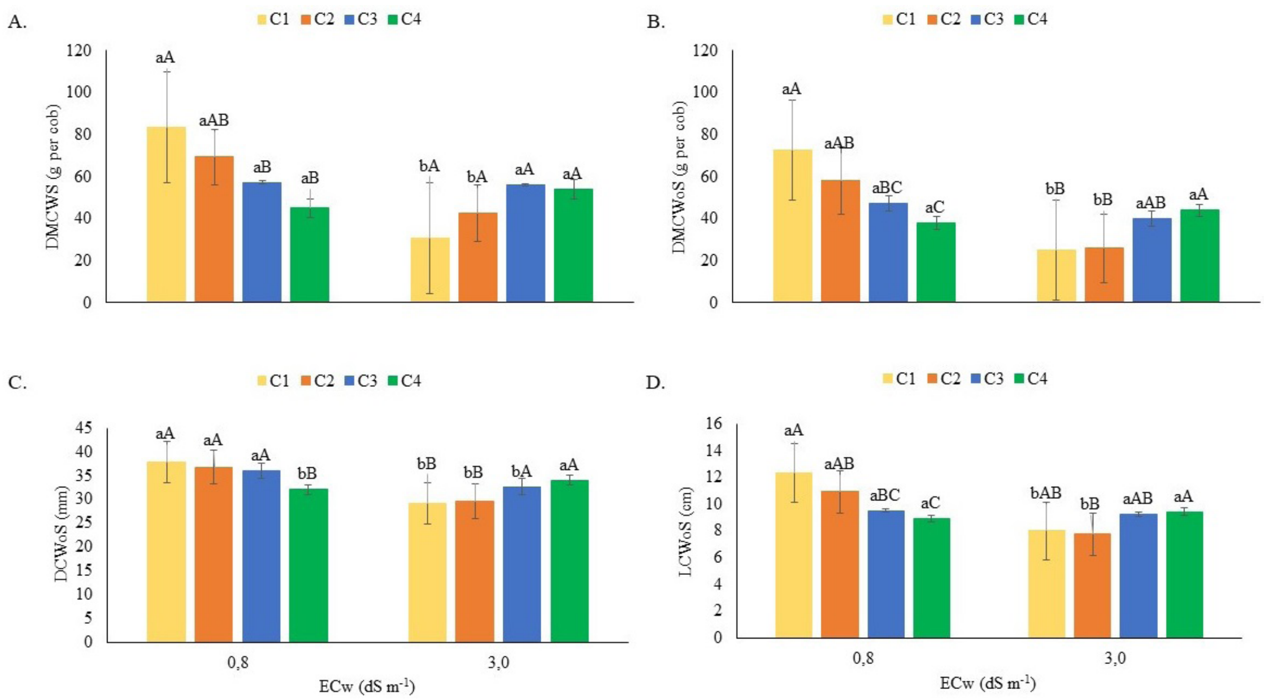
and DMCWoS), diameter and length of the cob without straw (DCWoS and LCWoS), 1000-grain mass (TGM), and yield (Y) (Table 5).

The dry mass of ears with straw was influenced by both organic fertilizer combinations and irrigation water (Figure 2A). For the water of 0.8 dS m^{-1}, an increase of 85.19% was observed in the mass of ears with straw in treatment C1 compared to that in treatment C4 (control, 45.04 g per cob), which significantly differed from each other. Increasing the ECw of water from 0.8 to 3.0 dS m^{-1} reduced the dry mass of the cobs with straw according to the increase of ECw in treatments C1 and C2 (63.03% and 38.52%, respectively); these did not differ significantly from the other treatments (C3, 56.00 g per cob and C4, 54.16 g per cob).

The accumulation of mass in maize straw generally occurs as a function of the amount of N that is applied to the crops (Lins et al., 2017) and since the nutritional composition of the biofertilizers used was quite variable, the higher content in the C1 and C2 combinations favored these results. Moreover, the high sodium content in the soil may have affected the absorption of nutrients, especially K, which is responsible for the adequate transport of assimilates to the different parts of a plant (Meurer et al., 2018).

Corroborating these data, Fernandes et al. (2019) irrigated maize crop with water of lower salinity and obtained higher dry mass accumulations in the cobs with straw at higher amounts of nitrogen applied, reaching 121.03 g per cob for 340 kg ha^{-1} of N used. Under saline conditions, reductions in the dry mass of cobs with straw were verified in studies conducted by Rodrigues et al. (2020) who detected reductions starting at a irrigation water salinity of 2.34 dS m^{-1}.

According to Figure 2B, there was an increase in the dry mass of cobs without straw for the treatments that received the combination of the three organic inputs compared to that of the control treatment with irrigation water of 0.8 dS m^{-1}; on the other hand, a decrease in the dry mass of cobs without straw



Means followed by the same lowercase letter between ECw for the same fertilizer treatment and uppercase between combinations in the same ECw, do not differ statistically from each other by Tukey's test at the 0.05 probability level. C1 - Cattle manure + poultry biofertilizer + goat biofertilizer, C2 - Cattle manure + goat biofertilizer, C3 - Cattle manure + poultry biofertilizer and C4 - Control treatment

Figure 2. Dry mass of the cob with straw - DMCWS (A), without straw - DMCWoS (B), diameter of the cob without straw - DCWoS (C) and the length of the cob without straw - LCWoS (D) of maize under irrigation with saline water and organic fertilizer combinations

was observed in that same treatment with irrigation water of 3.0 dS m^{-1}. The increase in mass for the ECw of 0.8 dS m^{-1} for C1 and C2 reached 90.90% and 52.47%, respectively, in relation to the control treatment (C4, 38.04 g per cob), while for the ECw of 3.0 dS m^{-1}, the combinations C1 and C2 did not differ from each other but both treatments differed from treatment C4. Between the two ECw, a reduction of 65.69% and 55.46% was obtained in ears subjected to high-salinity water compared to that of the low-salinity water in treatments C1 and C2 (72.62 and 58.00 g per cob, respectively).

This behavior was similar to that obtained in the dry mass of the cobs with straw, which again demonstrates the beneficial nutritional effect of the fertilizer combinations in low-salinity water, compared to the detrimental effects of salts on the acquisition of nutrients in the saline treatment for the fertilizer combinations that had higher levels of N and K (C1 and C2). This demonstrates that the combination of organic fertilizers and salinity negatively affects the production and allocation of assimilates, as described by Meurer et al. (2018). In contrast, the C4 treatment, which did not receive fertilizers, demonstrated that the allocation of assimilates in the straw was insignificant, with the greatest accumulation directed to the main sink, that is, the ears.

Similarly, Fernandes et al. (2019) obtained higher dry mass accumulation in maize ears without straw when higher amounts of nitrogen were offered (87.04 g per cob for 340 kg ha^{-1} of N). Under saline conditions, there were reductions in the mass of the cobs without straw from a salinity of 2.52 dS m^{-1}, reaching 60.83 g, according to results obtained by Rodrigues et al. (2020).

Figure 2C shows that the highest values were obtained with water salinity of 0.8 dS m^{-1} in all combinations of organic fertilizers, except in C4, which showed the largest diameter only in water salinity of 3.0 dS m^{-1}. With water salinity of 0.8 dS m^{-1}, the smallest ear diameter was obtained in the control treatment (C4, 32.03 mm), which was significantly different from the other combinations, with ear diameter increasing by 18.14%, 14.67%, and 12.20% for C1, C2, and C3, respectively, in relation to the control treatment. Under the water salinity of 3.0 dS m^{-1}, the highest ear diameter values were obtained in treatments C3 (32.63 mm) and C4 (33.99 mm), differing from the other treatments (C1 and C2) at the same ECw, which were reduced by 14.21% and 12.91%, respectively, compared to that of the control treatment (C4).

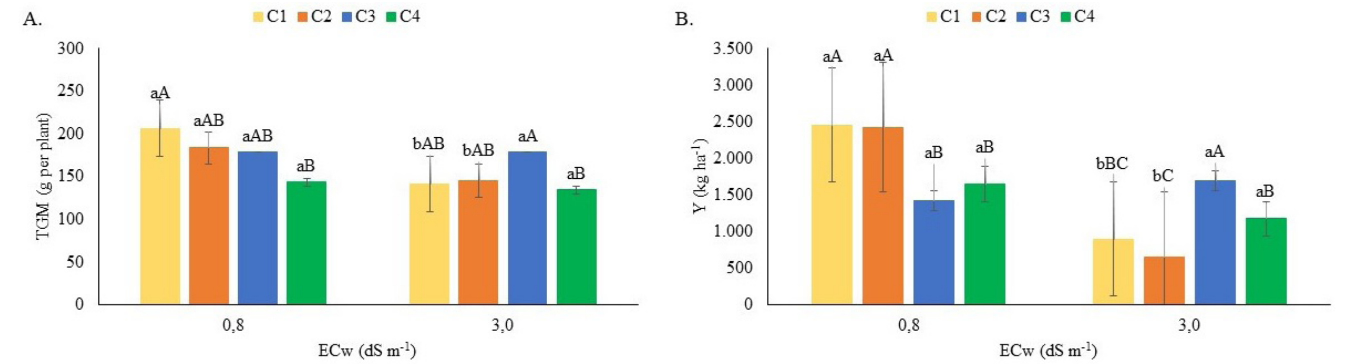
Except for treatments C1 and C2 at the 3.0 dS m^{-1} water salinity (29.16 and 29.6 mm, respectively), all other treatments showed values within the commercial diameter for maize crop, that is, greater than 3.0 cm (Rodrigues et al., 2018).

Favarato et al. (2016) obtained commercial cob diameters in maize crops with the application of organic material in topdressing, similar to crops with NPK in mineral form. Regarding the observed reductions, the salt content of the organic fertilizers may have potentiated the saline effect of irrigation water (Souza et al., 2019), causing lower water uptake owing to osmotic stress, which may have compromised the processes of nutrient uptake, cell division, and expansion, thus causing reduction in cob diameter (Costa et al., 2021; Sousa et al., 2021). Contrary to these results, Rodrigues et al. (2020) found no influence of salt on the cob diameter of maize under the same edaphic and climatic conditions as used in this study.

A significant difference was observed between fertilizer combinations for water salinity of 0.8 dS m^{-1}, with an increase of 38.38% and 22.56% in the length of the cobs in treatments C1 and C2 in relation to the control treatment C4 (8.91 cm). For water salinity of 3.0 dS m^{-1}, the greatest length was observed in the control C4 (9.44 cm), with a reduction of 17.90% in C2, which was significantly different from the control. There was also a significant difference between the treatments of combinations C1 and C2, with a reduction of 35.11% and 29.03%, respectively, when using water of 3.0 dS m^{-1} (Figure 2D). The length of the cobs obtained in this experiment did not meet the minimum commercial standard for maize crops, that is, values greater than 15 cm (Rodrigues et al., 2018).

Kandil et al. (2020) verified an increase in the length of maize cobs when irrigated with water of lower salinity and fertilized with organic compost in the form of humic acid, with an average of 17.8 cm, a value higher than that obtained in the present study. A study by Costa et al. (2021), under field conditions, showed lower performance in terms of ear length in areas irrigated with increased saline water.

For the 1000-grains mass (Figure 3A), for water salinity of 0.8 dS m^{-1}, there was an increase of 43.95% of grain mass for C1 in relation to the control (C4, 143.33 g), significantly differing from each other, but not from the other combinations



Means followed by the same lowercase letter between ECw for the same fertilizer treatment and uppercase between combinations in the same ECw, do not differ statistically from each other by Tukey's test at the 0.05 probability level. C1 - Cattle manure + poultry biofertilizer + goat biofertilizer, C2 - Cattle manure + goat biofertilizer, C3 - Cattle manure + poultry biofertilizer and C4 - Control treatment

Figure 3. Thousand grains mass – TGM (A) and Yield - Y (B) of maize under irrigation with saline water and organic fertilizer combinations

of organic fertilization. For the water salinity of 3.0 dS m^{-1}, the gains in grain masses were 33.25% for C3 in relation to the control (C4, 134.33 g); hence, the biggest mass gain occurred in C3, significantly differing from each other, but not from the other combinations. For treatments C1 and C2, there were reductions of 31.66% and 21.09% in grain mass (206.33 and 183.33 g per plant, respectively) in plants treated with water salinity of 3.0 dS m^{-1} and 0.8 dS m^{-1}, respectively.

The mass gain in saline-water-treated crops in C1 (0.8 dS m^{-1}) and C3 (3.0 dS m^{-1}), in relation to the control, is a result of the use of biofertilizers that are rich in N and K (Table 2) and the dynamics of ions in saline environments. N stands out as a nutrient responsible for directly acting in the synthesis of osmoregulatory compounds in the plants treated with saline water (Dias et al., 2017) and K is responsible for the translocation of assimilates from the source to the sink (grains), in addition to regulating stomatal opening (Meurer et al., 2018).

However, organic fertilizers, especially biofertilizers, tend to have salt ions in their composition (Souza et al., 2019) that can affect the availability of nutrients in the soil and subsequent uptake by plants, especially owing to the antagonistic effects between Na^+ and K^+ and Cl^- and NO_3^-, which influences the accumulation of assimilates (Costa et al., 2021).

It is noteworthy that the negative effect of salinity on grain mass in maize plants irrigated with saline water has been reported by Rodrigues et al. (2020), in which a reduction in grain mass was observed starting at an ECw of 1.98 dS m^{-1} in the same variety and under the same environmental conditions as in the present study.

The maize yield (Figure 3B) was altered among the combinations of organic fertilization in the ECw of 0.8 dS m^{-1}, with the highest values obtained in treatments C1 and C2, with 2,450.6 and 2,421.1 kg ha^{-1}, respectively, which did not differ significantly and which represented increases of 48.8% and 47.0%, respectively, in relation to that of the control treatment (1,646.1 kg ha^{-1}). In the ECw of 3.0 dS m^{-1}, the values varied according to the combination used, with the highest yield obtained in treatment C3 (1,693.3 kg ha^{-1}), representing an increase of 43.9% when compared to the control treatment (1,176.3 kg ha^{-1}). A reduction of the order of 63.4% and 73.0% was obtained in treatments C1 and C2, respectively, when treated with water salinity of 3.0 dS m^{-1} compared to water salinity of 0.8 dS m^{-1}.

One of the effects of salinity on crops is the nutritional imbalance caused by excess salts in the soil solution, which can antagonize the uptake of important nutrients for crops, such as nitrogen and potassium, and reduce their productivity, which can be enhanced by the composition of fertilizers (Souza et al., 2019; Sousa et al., 2021), as verified for combinations C1 and C2.

The highest productivity obtained with water of lower salinity (0.8 dS m^{-1}) was observed for C1 (2,450.6 kg ha^{-1}) and C2 (2,421.1 kg ha^{-1}) and with water of higher salinity (3.0 dS m^{-1}) for C3 (1,693.3 kg ha^{-1}). The productivity data of this study are below those observed by Rodrigues et al. (2020) who irrigated a corn crop with water at 1.0 dS m^{-1} (3,295 kg ha^{-1}) and 5.0 dS m^{-1} (1,523 kg ha^{-1}) salinity in soil fertilized with bovine biofertilizer.

Costa et al. (2021) irrigated a corn crop with water of lower salinity (ECw = 1.0 dS m^{-1}) and obtained a productivity of 2,100 compared to 1,253.33 kg ha^{-1} when irrigated with water of higher salinity (ECw = 4.0 dS m^{-1}) in soil fertilized with cattle manure. Goes et al. (2021) also revealed a decrease in productivity in soil irrigated with water of higher (2,600 kg ha^{-1}) and lower (3,100 kg ha^{-1}) salinity for corn, but with less deleterious effects of salts compared to the present study.

Conclusions

1. The combination of cattle manure + poultry biofertilizer + goat biofertilizer increased the dry mass of ear with and without straw, ear length, 1000-grains mass, and yield in maize under irrigation water salinity of 0.8 dS m^{-1} water.

2. Combinations of cattle manure + poultry biofertilizer + goat biofertilizer and cattle manure + goat biofertilizer had no positive influence on mitigating salt stress in maize crop yield.

3. Irrigation water with an electrical conductivity of 3.0 dS m^{-1}, associated with the conductivity of manure + poultry biofertilizer, attenuated the deleterious effect of salts with a better performance on corn productivity with water salinity of 3.0 dS m^{-1}.

Acknowledgment

To Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for funding the research and to Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB) for the partnership in the conducting the experiment.

Literature Cited

Alvares, C. A.; Stape, J. L.; Sentelhas, P. C.; Gonçalves, J. L. de M.; Sparovek, G. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, v.22, p.711-728, 2013. http://dx.doi.org/10.1127/0941-2948/2013/0507

Ayers, R. S.; Westcot, D. W. A qualidade da água na agricultura. 2.ed. Campina Grande: UFPB, 1999. 153p.

Costa, F. H. R.; Goes, G. F.; Almeida, M. de S.; Magalhães, C. L.; Sousa, J. T. M. de; Sousa, G. G. Maize crop yield in function of salinity and mulch. Brazilian Journal of Agricultural and Environmental Engineering, v.25, p.840-846, 2021. http://dx.doi.org/10.1590/1807-1929/agriambi.v25n12p840-846

Dias, A. S.; Lima, G. S. de; Gheyi, H. R.; Soares, L. A. dos A.; Souza, L. de P.; Bezerra, I. L. Crescimento do algodoeiro 'BRS Rubi' em função da irrigação com águas salinas e adubação nitrogenada. Revista Brasileira de Agricultura Irrigada, v.11, p.1945-1955, 2017. https://doi.org/10.7127/rbai.v11n700660

Favarato, L. F.; Souza, J. L.; Galvão, J. C. C.; Souza, C. M. de; Guarconi, R. C.; Balbino, J. M. de S. Crescimento e produtividade do milho-verde sobre diferentes coberturas de solo no sistema plantio direto orgânico. Bragantia, v.75, p497-506, 2016. https://doi.org/10.1590/1678-4499.549

FEP - Fazenda Experimental Piroás. Dados climáticos de 2020. Available on: <http://unilab.edu.br/dados-climaticos-do-datalogger/>. Accessed on: Mar. 2021.

Fernandes, C. N. D.; Fernandes, C. N. V.; Viana, T. V. de A.; Sobreira, A. E. A.; Alves, J. L. de S.; Azevedo, B. M. de. Fertirrigação nitrogenada e potássica na cultura do milho verde. Revista Brasileira de Agricultura Irrigada, v.13, p.3724-3730, 2019. https://doi.org/10.7127/rbai.v13n6001141

Fernandes, V. L. B. Recomendações de adubação e calagem para o estado do Ceará. Fortaleza: UFC, 1993. 248p.

Goes, G. F.; Sousa, G. G. de; Lessa, C. I. N.; Silva,F. D. B. da; Lacerda, C. F. de; Nogueira, R. S. da. Uso de cobertura morta e água salina na produtividade da cultura do milho. Irriga, v.1, p.730-738, 2021. https://doi.org/10.15809/irriga.2021v1n4p730-738

Gomes, L. S. de P; Braz, T. G. dos S.; Mourthé, M. H. F.; Paraíso, H. A.; Pires Neto, O. de 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, p.914-923, 2018. https://doi.org/10.19084/RCA17272

Kandil, E. E.; Abdelsalam, N. R.; Mansour, M. A.; Ali, H. M.; Siddiqui, M. H. Potentials of organic manure and potassium forms on maize (*Zea mays* L.) growth and production. Scientific Reports, v.10, p.1-11, 2020. https://doi.org/10.1038/s41598-020-65749-9

Lima, G. S. de; Dias, A. S.; Soares, L. A. dos A.; Gheyi, H. R.; Nobre, R. G.; Silva, A. A. R da. Eficiência fotoquímica, partição de fotoassimilados e produção do algodoeiro sob estresse salino e adubação nitrogenada. Revista de Ciências Agrárias, v.42, p.214-225, 2019. https://doi.org/10.19084/RCA18123

Lins, F. J. A.; Ferreira, P. V.; Assunção, M. C.; Santos, D. F. dos; Carvalho, A. P. V. de; Santos, N. E. A. dos. Crescimento de genótipos experimentais de milho em função de doses crescentes de nitrogênio. Ciência Agrícola, v.15, p.19-27, 2017.

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. Campina Grande: UFPB, 1992. 173p. Dissertação Mestrado

Meurer, E. J.; Tiecher, T.; Mattiello, L. Potássio. In: Fernandes, M. S.; Souza, S. R.; Santos, L. A. (eds). Nutrição mineral de plantas. 2.ed. Viçosa: SBCS, 2018. Cap.12. p.429-464.

Nascimento, E. S.; Cavalcante, L. F.; Gondim, S. C.; Souza, J. T. A.; Bezerra, F. T. C.; Bezerra, M. A. F. Formação de mudas de maracujazeiro amarelo irrigados com águas salinas e biofertilizante de esterco bovino. Revista Agropecuária Técnica, v.38, p.1-8, 2017. https://doi.org/10.25066/agrotec.v38i1.28090

Rodrigues, F.; Melo, P. G. S.; Resende, C. L. P.; Mrojinski, F.; Mendes, R. C.; Silva, M. A. Aptidão de híbridos de milho para o consumo in natura. Revista de Ciências Agrárias, v.41, p.484-492, 2018. https://doi.org/10.19084/RCA17216

Rodrigues, V. dos S.; Bezerra, F. M. L.; Sousa, G. G. de; Fiusa, J. N.; Leite, K. N.; Viana, T. V. de A. Yield of maize crop irrigated with saline waters. Revista Brasileira de Engenharia Agrícola e Ambiental, v.24, p.101-105, 2020. https://doi.org/10.1590/1807-1929/agriambi.v24n2p101-105

Sales, J. R. da S.; Sousa, G. G. de; Cavalcante, F.; Moraes, J. G. L.; Leite, K. N.; Viana, T. V. de A. Production and quality of okra fruits submitted to doses and types of biofertilizers. Journal of Agricultural Science, v.11, p.507-514, 2019. https://doi.org/10.5539/jas.v11n4p507

Santos, F. S. S. dos; Viana, T. V. de A.; Costa, S. C.; Sousa, G. G. de; Azevedo, B. M. de. Growth and yield of semi-hydroponic bell pepper under desalination waste-water and organic and mineral fertilization. Revista Caatinga, v.32, p.1005-1014, 2019. https://doi.org/10.1590/1983-21252019v32n417rc

Santos, R. H. S dos; Dias, M. dos S.; Silva, F. de A. da; Santos, J. P. de O.; Santos, S. C. dos; Reis, L. S.; Tavares, C. L. Matéria orgânica como atenuante da salinidade da água de irrigação na cultura do milho. Colloquium Agrariae, v.16, p.84-93, 2020. https://doi.org/10.5747/ca.2020.v16.n2.a374

Silva, F. de A. S.; Azevedo, C. A. V. de. The Assistat Software Version 7.7 and its use in the analysis of experimental data. African Journal of Agriculture Research, v.11, p.3733-3740, 2016.

Silva, W. C.; Moura, J. G. de; Viana, I. E. T.; Nogueira, A. L. da S. P.; Silva, T. M. da; Oliveira, A. B. de. Produtividade de feijão-caupi submetido a diferentes lâminas de irrigação com uso de biofertilizante. Revista Brasileira de Agricultura Irrigada, v.12, p.3028-3039, 2018. https://doi.org/10.7127/rbai.v12n600914

Sousa, G. G. de; Fiusa, J. N.; Leite, K. N.; Soares, S. C.; Silva, G. L. da. Água salina e biofertilizante de esterco bovino na cultura do gergelim. Agropecuária Técnica, v.38, p.117-124, 2017. https://doi.org/10.25066/agrotec.v38i3.33694

Sousa, G. G. de; Sousa, H. C.; Santos, M. F. dos; Lessa, C. I. N.; Gomes, S. P. Saline water and nitrogen fertilization on leaf composition and yield of corn. Revista Caatinga, v.35, p.191-198, 2022. https://doi.org/10.1590/1983-21252022v35n119rc

Sousa, G. G. de; Viana, T. V. de A.; Silva, G. L. da; Dias, C. N.; Azevedo, B. M. de. Interação entre salinidade e biofertilizante de caranguejo na cultura do milho. Magistra, v.28, p.538-547, 2016.

Sousa, H. C.; Sousa, G. G. de; Lessa, C. I. N.; Lima, A. F. da S.; Ribeiro, R. M. R.; Rodrigues, F. H. da C. Growth and gas exchange of corn under salt stress and nitrogen doses. Revista Brasileira de Engenharia Agricola e Ambiental, v.25, p.174-181, 2021. http://dx.doi.org/10.1590/1807-1929/agriambi.v25n3p174-181

Souza, L. S. B. de; Moura, M. S. B. de; Sediyama, G. C.; Silva, T. G. F. da. Requerimento hídrico e coeficiente de cultura do milho e feijão-caupi em sistemas exclusivo e consorciado. Revista Caatinga, v.28, p.151-160, 2015. https://doi.org/10.1590/1983-21252015v28n417rc

Souza, M. V. P. de; Sousa, G. G. de; Sales, J. R. da S.; Freire, M. H. da C.; Silva, G. L. da; Viana, T. V. de A. Saline water and biofertilizer from bovine and goat manure in the Lima bean crop. Revista Brasileira de Ciências Agrárias, v.14, p.1-8, 2019. https://doi.org/10.5039/agraria.v14i3a5672

Teixeira, P. C.; Donagemma, G. K.; Fontana, A.; Teixeira, W. G. (eds.). Manual de métodos de análise de solo. 3.ed. Brasília: EMBRAPA, 2017. 574p.