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Sunflower biometrics and chemical salinity attributes of soil irrigated with waters of different qualities

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ABSTRACT

Poor quality water, such as sewage, has become an alternative to reduce the consumption of good quality water by irrigation, especially in arid and semi-arid regions; however, water rich in salts can be harmful to agricultural systems. This research evaluated the impacts of salinity of waters of different qualities on the development of the sunflower culture and on the soil. The research was developed in the area of the Environmental Studies Team (EEA/UEFS), and the experimental design used was completely randomized, consisting of four treatments: rain water (0.20 dS m^{-1}), well water (1.50 dS m^{-1}), cesspool effluent (3.50 dS m^{-1}) and brackish water (5.00 dS m^{-1}), with the irrigation manually done and the blade calculated based on daily evapotranspiration. Irrigation with effluent promoted a better development of the sunflower crop, and the increase in the salinity of the irrigation water in the other treatments promoted a decrease in the total fresh and dry phytomasses, plant height, stem diameter, number of leaves, leaf area, internal and external diameters of the capitula and in the consumption and efficiency of water use. The use of rainwater, well water and cesspool effluent proved to be suitable for irrigation of the sunflower crop; however, the latter sodified the soil, which would already be recommended for the application of treatments for soil recovery.

Keywords: agriculture, salts, wastewater.

Biometria do girassol e atributos químicos de salinidade do solo irrigado com águas de diferentes qualidades

RESUMO

As águas de má qualidade, como os esgotos, têm se tornado uma alternativa para reduzir o consumo de águas de boa qualidade pela irrigação, principalmente em regiões áridas e semiáridas, porém, águas ricas em sais podem causar efeitos deletérios aos sistemas agrícolas. Objetivou-se com essa pesquisa avaliar os impactos da salinidade de águas de diferentes qualidades no desenvolvimento da cultura do girassol e no solo. A pesquisa foi desenvolvida na área da Equipe de Estudos Ambientais (EEA/UEFS), e o delineamento experimental utilizado foi o inteiramente casualizado, constando de quatro tratamentos: água de chuva (0,20 dS m^{-1}), água de poço (1,50 dS m^{-1}), efluente de uma fossa séptica (3,50 dS m^{-1}) e água salobra (5,00 dS m^{-1}), sendo a irrigação feita manualmente e a lâmina calculada com base na evapotranspiração diária. A irrigação com o efluente da fossa promoveu um melhor desenvolvimento da cultura do girassol, e o aumento da salinidade das águas de irrigação nos demais tratamentos, promoveu um decrescimento das fitomassas frescas e secas totais, na altura de planta, diâmetro do caule, número de folhas, área foliar e nos diâmetros interno e externo dos capítulos, no consumo e na eficiência do uso de água. O uso da água de chuva, de poço e do efluente da fossa se mostraram adequadas para irrigação da cultura do girassol, porém, a última solidificou o solo, o que já seria recomendável à aplicação de tratamentos para recuperação dos solos.

Palavras-chave: agricultura, água residuária, sais.

1. INTRODUCTION

Water characterized as wastewater and saline must always be considered as alternative sources for less restrictive uses and to maintain agricultural production in water-scarcity environments. However, the presence of salts in these irrigation waters can be a difficult scenario and an obstacle to the introduction of these waters in production systems, as these salts can influence the germination, growth, production and nutrition of plants.

Salinity affects crops in two ways: as the concentration of salts in the soil increases, so does the osmotic potential of the soil, and the more saline a soil is, the more energy will be spent by plants to absorb water and the elements vital to their development; and the toxicity of elements such as boron, sodium, bicarbonates and chloride causes physiological problems for crops (Silveira *et al.*, 2016).

When commercially exploring a crop, it is very important to take into account the effects of salts on its growth and development parameters as well as the adverse phenomena involved, as this can lead to an appropriate management of irrigation and cultivation, in order to allow the use of lower quality waters (Dias *et al.*, 2016).

However, despite its disadvantages, the use of wastewater as an irrigation source has been an effective strategy in dealing with the scarcity of water resources in arid and semi-arid regions (Azevedo *et al.*, 2013), and its use allows the recycling of water and nutrients, providing the production systems of these regions with a greater availability of water and reduced costs for fertilizers (Santos Júnior *et al.*, 2014).

Wastewater provides several micro and macronutrients for plants, mainly nitrogen, phosphorus and potassium, necessary for their growth. Nitrogen stands out for being one of the main nutrients related to increased yield and for playing a fundamental role in plant growth, being responsible for structural functions and for being part of the composition of proteins, proline and amino acids. Phosphorus has been one of the macronutrients that most limit production, while potassium favors the formation and translocation of carbohydrates and activation of enzymes involved in breathing (Aminifard *et al.*, 2010; Ahmadifard, 2014).

Several researches have pointed out the possibility of irrigation of several plant species with poor quality water, being a widely studied practice and recommended by several researchers and water managers. From a nutritional point of view, studies have shown positive effects of irrigation with high salinity water, such as sewage, on the production and productivity of vegetables, proving the fertilizing effect of wastewater in numerous studies and in various cultures such as sunflower (Santos Júnior *et al.*, 2014; Oliveira *et al.*, 2017), pepper (Silva *et al.*, 2019), melon (Costa *et al.*, 2014), corn (Malafaia *et al.*, 2016), tomato (Jorge *et al* ., 2017) and watermelon (Salgado *et al.*, 2018).

The good adaptation of the sunflower to different climates and regions, its economic importance, and the moderate tolerance to salinity motivated the selection of the crop for research. Therefore, this study evaluated the development of sunflower culture as a function of irrigation with waters of different qualities and salinities.

2. MATERIAL AND METHODS

The research was carried out in an open field at the headquarters of the Environmental Studies Team (EEA) at the State University of Feira de Santana (UEFS), in the municipality of Feira de Santana. The municipality of Feira de Santana is located in the semi-arid region of the state of Bahia, with geographical coordinates 12º16’00 south latitude and 38º58’00 west longitude of Greenwich.

The experimental design used was completely randomized, consisting of four treatments and six replications. The tested treatments were: RW - rainwater collected in the EEA (EC = 0.20 dS m^{-1}); WW - well water (EC = 1.50 dS m^{-1}); EF - cesspool effluent (EC = 3.50 dS m^{-1}); BW - brackish water (obtained by adding commercial NaCl to well water, EC = 5.00 dS m^{-1}).

The culture used was the sunflower (*Helianthus annus* L.), genotype Anão de Jardim, supplied by the company “ISLA Sementes”, being indicated for the cultivation in pots and considered to be of small size. Sowing was carried out in sowing spots, on 07.07.2019, and 10 days after sowing (DAS), transplanting and application of treatments were carried out, ending the cycle on 09.11.2019.

The soil originated from a profile from the UEFS campus, collected in the 0 - 150 cm layer. The natural soil (NS) used in the experiment showed a granulometric composition of 20% for medium sand, 31% for fine sand, 9% for silt and 40% for clay, and using the methodology suggested by Silva (2009), it was classified as a clay-sandy soil. The chemical characteristics of the natural soil before the treatments were applied are shown in Table 1, being classified by salinity (Richards, 1954) as non-sodium and non-saline and by the degree of sodicity (Massoud, 1971) as non-sodium.

Table 1. Chemical characteristics of natural soil.

pH (salinity)	pH (in water)	Sodium /cmolc dm^{-3}	Potassium /cmolc dm^{-3}	Calcium /cmolc dm^{-3}	Magnesium /cmolc dm^{-3}	Aluminum /cmolc dm^{-3}	Potential acidity (H+Al) /cmolc dm^{-3}
6.20	6.22	0.17	0.18	1.71	1.60	0.00	1.98
Ca+Mg /cmolc dm^{-3}	**Sum of bases /cmolc dm^{-3}**	**Base saturation /%**	**Organic matter /g kg^{-1}**	**Phosphor /mg dm^{-3}**	**CEC /cmolc dm^{-3}**	**PES /%**	**CEse /dS m^{-1}**
3.31	3.66	65.00	6.00	6.00	5.64	3.01	0.81

CEC – cation exchange capacity; PES – percentage of exchangeable sodium; ECse – electrical conductivity of the saturation extract.

The chemical and biological characteristics of the irrigation water used in the sunflower cycle are shown in Table 2.

To obtain the desired electrical conductivity in the treatment with brackish water (BW) commercial NaCl was added to well water. The amount of sodium chloride (Q NaCl) used in the preparation of the water was determined from the initial electrical conductivity of the water, using the equation Q NaCl (mg L^{-1}) = 640 x (desired ECw - initial ECw), proposed by Richards (1954), in which ECw - electrical conductivity of water, in dS m^{-1}.

The calculation of the blade applied to each container was performed in a spreadsheet, using the Penman-Monteith-FAO method to quantify the reference evapotranspiration, following the calculation methodology presented by Allen *et al.* (1998) for hourly evapotranspiration data. The data from the UEFS automatic station were obtained every hour, so an evapotranspiration given in mm h^{-1} was obtained every hour. Daily evapotranspiration was obtained by calculating the sum of evapotranspiration from the 24 hours prior to the time of irrigation.

Table 2. Chemical and biological characteristics of irrigation water used in the sunflower cycle.

PARAMETERS	RW	WW	EF	BW
pH	7.00	6.70	8.10	7.20
RAS	3.65 ± 0.75	8.85 ± 0.28	16.07 ± 0.94	65.54 ± 0.37
CE/dS m^{-1}	0.20	1.50	3.50	5.00
Classification by SAR	S1: Low sodium water	S1: Low sodium water	S1: Low sodium water	S4: Very high sodium water
Classification by EC	C1: Low salinity water	C3: High salinity water	C4: Very high salinity water	C4: Very high salinity water
Hardness/mg L^{-1}	0.07 ± 0.01	246.67 ± 1.15	204.00 ± 12.00	269.33 ± 2.31
Alkalinity/mg L^{-1}	2.80	30.80 ± 2.20	985.60	22.00 ± 2.20
Calcium/mg L^{-1}	0.00	230.70 ± 1.02	188.32 ± 12.00	250.78 ± 1.68
Magnesium/mg L^{-1}	0.07 ± 0.01	15.97 ± 0.54	15.68 ± 0.25	18.55 ± 1.59
Sodium/mg L^{-1}	0.67 ± 0.13	98.32 ± 3.11	162.30 ± 8.20	760.55 ± 2.76
Potassium/mg L^{-1}	0.27 ± 0.05	16.13 ± 1.36	85.35 ± 5.87	28.55 ± 1.63
Chloride/mg L^{-1}	10.00	464.00 ± 8.00	546.67 ± 11.55	2213.33 ± 23.09
Phospor/mg L^{-1}	0.00	0.00	14.47 ± 0.50	0.00
Nitrogen/mg L^{-1}	0.00	0.00	224.00 ± 28.00	0.00
BOD/mg L^{-1}	2.50 ± 0.71	3.50 ± 0.71	185.00	0.00
Total solids /mg L^{-1}	120.00	1060.00	1340.00	3330.00 ± 14.14
Total coliforms /MLN 100mL^{-1}	0.00	5.00 x 10^2	8.00 x 10^2	8.00 x 10^1
Fecal coliforms /MLN 100mL^{-1}	ABSENT	ABSENT	5.00 x 10^2	1.00 x 10^1

RW – rain water; WW – well water; EF – cesspool effluent; BW – brackish water; SAR – sodium adsorption ratio; EC – electric conductivity; BOD – Biochemical oxygen demand; MLN – Most likely number.

The culture evapotranspiration was obtained by the product of daily evapotranspiration with the culture coefficient (Initial, Kc = 0.60 for 28 days; Vegetative development, Kc = 0.95 for 15 days; Flowering, Kc = 1.09 for 27 days), values recommended by FAO. To determine the daily irrigation volume applied to each pot, the difference between the crop evapotranspiration and the daily precipitation by the pot's surface area was multiplied. On days when precipitation was higher than evapotranspiration, irrigation was not performed. Irrigation was carried out manually using graduated containers, with the soil being irrigated daily in order to maintain the container capacity.

The biometric parameters analyzed were: plant height (PLH), stem diameter (SD), internal (IDC) and external diameter (EDC) of the capitulum, number of leaves (NL), leaf area (LA), number of petals (NP), total fresh phytomass (TFF) and total dry phytomass (TDF). The parameters PH, SD, NL and LA were measured at four points along the cycle, at 20, 30, 40 and 50 DAS and the other parameters at the end of the experiment, the plants being harvested when the flower was fully opened.

The water consumption (WC) of the culture was obtained by the difference between the applied volume and the drained volume, and the water-use efficiency (WUE) by the ratio of the TFF to the WC.

At the end of the cycle, soil samples were collected to quantify the salinity parameters. The parameters analyzed were: pH, electrical conductivity of the saturation extract (ECse), content (Na^+) and percentage (PES) of exchangeable sodium.

The results obtained were subjected to analysis of variance (ANOVA), comparing the data by the Tukey Test at the level of 1 and 5% of probability with the use of the statistical software RStudio.

3. RESULTS AND DISCUSSION

Table 3 presents the chemical characteristics related to soil salinity before and after the sunflower cycle.

Table 3. Soil classification and summary of the analysis of variance of the pH averages, the electrical conductivity of the soil saturation extract (ECse), the content (Na^+) and the percentage (PES) of exchangeable sodium of the soil before and after the irrigation period.

	NS	SRW	SWW	SEF	SBW	MEAN SQUARES
pH (salinity)	5.50a	5.30a	5.07a	5.20a	5.10a	0.09^{ns}
CV/%	1.82	1.89	6.93	3.85	3.92	
ECse/dS m^{-1}	0.81c	0.12d	0.86c	1.85b	3.10a	4.02**
CV/%	3.70	16.67	5.26	1.62	3.23	
Na^+/cmolc dm^{-3}	0.40d	0.22e	0.53c	1.29b	2.70a	3.13**
CV/%	7.50	4.55	1.10	3.65	0.21	
PES/%	7.09c	3.20d	7.17c	15.89b	30.12a	349.43**
CV/%	6.53	7.66	0.51	2.21	1.07	
Salinity classification	Non-sodium and non-saline	Non-sodium and non-saline	Non-sodium and non-saline	Sodic	Sodic	
Classification for sodicity	Not sodic	Not sodic	Slightly sodium	Moderately sodium	Excessively sodium	

NS - Natural soil; SRW - Soil after irrigation with rain water (0.20 dS m^{-1}); SWW - Soil after irrigation with well water (1.50 dS m^{-1}); SEF - Soil after irrigation with cesspool effluent (3.50 dS m^{-1}); SBW - Soil after irrigation with brackish water (5.00 dS m^{-1}); Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ^{ns} - not significant; ** - significant at 1% probability; CV - Coefficient of variation.

It can be seen from Table 3 that there was no statistical difference between the pH of the soil irrigated with the different waters. According to Tan (1982), two factors may have contributed to the non-variation in the pH of the soil: in the chemical composition of the irrigation water, the amounts of Na^+ and Cl^- are higher than the values of $HCO3^-$ (alkalinity), prevailing the neutrality of NaCl with respect to pH, preventing the hydrolysis of Na^+ which can raise the pH, and there are no considerable concentrations of Na_2CO_3 that with water can cause alkaline reactions that can result in a pH of up to 10; Another factor is associated with the low content of organic matter present in the waters used, since, in waters with a high content of organic matter, during its degradation there is the production of carbon dioxide and release of organic acids that may come to acidify the soil, decreasing its pH.

Such behavior was also evidenced by Andrade Filho *et al.* (2013) who, when analyzing the soil salinity of cultivated areas, did not observe a significant difference in soil pH during and after irrigation. Costa *et al.* (2013) observed that the pH of the soil increased and stabilized after the middle of the cycle in all treatments in the evaluated soil layers.

The final values of the electrical conductivities of soils irrigated with brackish and wastewater, shown in Table 3, showed significance in relation to the natural soil, changing the salinity condition of the natural soil to a sodium soil, and increased the degree of sodicity of non-sodium for moderately sodic and excessively sodic for soils irrigated with cesspool effluent and brackish water, respectively. The soil irrigated with well water showed no statistical difference, keeping the conductivity close to that of the natural soil, maintaining the salinity condition of the soil in non-sodium and non-saline, with a small increase in sodicity from non-sodium to slightly sodium, different from irrigation with rainwater, which promoted the leaching of salts and promoted the reduction of the electrical conductivity of the soil, keeping the soil as non-sodium and non-saline.

It appears that, throughout the cycle, the application of well water, cesspool effluent and brackish water promoted an increase in the electrical conductivity of the soil, as shown in Figure 1. The soil irrigated with rainwater maintained the almost constant conductivity, without significant variations throughout the cycle, which may be associated with the low concentration of salts present in this water.

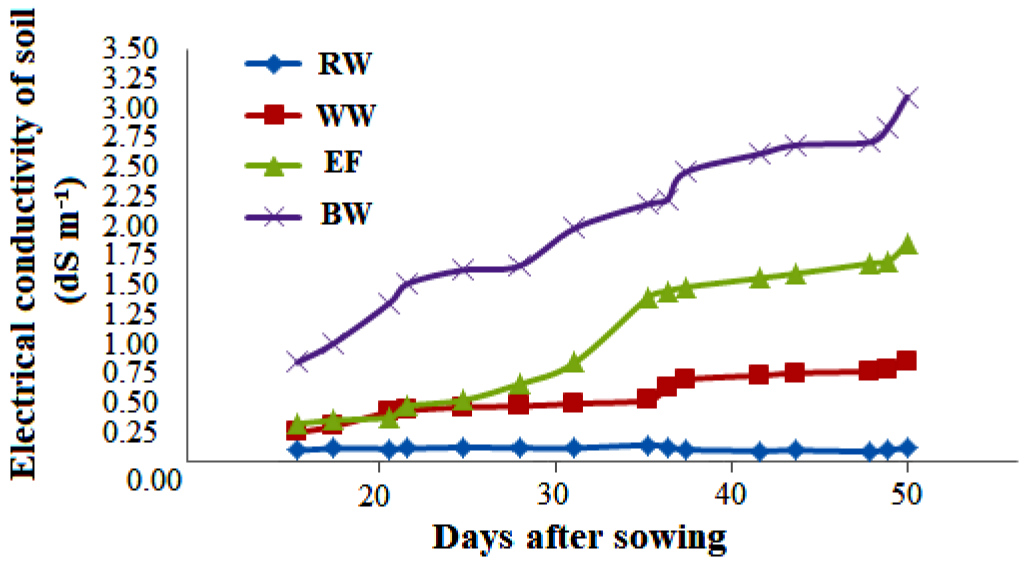

Figure 1. Evolution of the electrical conductivity of the soil along the sunflower cycle as a function of the electrical conductivity of the treatments.

The increase in soil salinity after the use of water rich in salts, maintaining the same irrigation management conditions, is expected, since the greater the electrical conductivity of the water for the same applied volume, the more salts are increased in the soil (Porto Filho *et al.*, 2011).

Regarding the increase in EC of soils irrigated with BW and EF, it is concluded that under these conditions it would be advisable to apply leaching blades to carry excess salts, since in the Northeast region rainfall is irregular and may not be sufficient to cause the necessary leaching. Similarly, Lima Neto *et al.* (2015) and Souto *et al.* (2016) observed that the electrical conductivity of the soil saturation extract increased linearly as a function of the salinity of the irrigation water.

It can be seen from Table 3 that, except in the soil irrigated with rainwater, there was an increase in the concentrations and in the percentage of exchangeable sodium in the irrigated soils in relation to the natural soil. The highest PES was obtained in soil irrigated with brackish water, followed by soil irrigated with the effluent from the well. There was no statistical difference between the PES of the soil irrigated with well water and the natural soil, whereas in the soil irrigated with rain water the PES was statistically inferior to the PES of the natural soil due to the low salinity of this water. Likewise, Nascimento and Fidelis Filho (2015) and Costa *et al.* (2013) found a significant increase in the PES of cultivated soils when applying water rich in salts.

The significant and growing increase in Na^+ levels in soils that received WW, BW and EF can be attributed to the chemical composition of these waters, as they contained considerable values of the Na^+ ion in their composition.

According to the analysis of variance, as shown in Table 4, there was a significant effect at all times of evaluation for the plant height variable, showing the superiority of the average height of plants irrigated with cesspool effluent. Vrânceanu (1977) states that the presence of nitrogen can cause an excessive growth of some biometric parameters of the sunflower, such as plant height, something that can be observed in the present work, where the nitrogen concentrations in the wastewater showed considerable values, which supposedly resulted in the highest average plant height, unlike the other treatments, in which nitrogen was absent.

Table 4. Summary of the analysis of variance and plant height averages (PLH), in cm, at 20, 30, 40 and 50 DAS, depending on the salinity of waters of different qualities.

EVALUATION SEASON	RW	WW	EF	BW	MEAN SQUARES
20 DAS	9.12b	8.80bc	15.30a	7.23c	52.07**
CV/%	11.53	5.75	6.45	19.97	
30 DAS	13.64b	13.20b	22.40a	10.85b	83.66**
CV/%	11.39	6.34	14.96	17.25	
40 DAS	18.54b	16.68b	33.88a	14.28b	377.75**
CV/%	12.70	10.34	13.54	7.44	
50 DAS	29.68b	23.93bc	48.70a	20.00c	785.93**
CV/%	8.76	7.82	16.38	8.75	

RW - rainwater (0.20 dS m^{-1}); WW - well water (1.50 dS m^{-1}); EF - cesspool effluent (3.50 dS m^{-1}) and BW - brackish water (5.00 dS m^{-1}). Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ** - significant at 1% probability; CV - Coefficient of variation.

It is observed that even with the second highest salinity, the effluent from the well provided the highest average plant height in all periods of evaluation. Studies have shown that the increase in nitrogen, an organic solute, increases the plants' osmotic adjustment capacity to salinity, also increasing the tolerance of crops to water and salt stress (Lacerda *et al.*, 2003).

For the other treatments tested, there was a decrease in the average plant heights between the periods of evaluation. According to Ayers and Westcot (1999), this occurs due to the addition of salts imposed on the culture, causing negative effects on physiological processes, reducing water absorption by the roots, inhibiting merismatic activity and cellular elongation and reducing plant growth. Likewise, Freitas *et al.* (2012) observed a positive effect when irrigating sunflower with treated domestic sewage, whereas Maciel *et al.* (2012), observed that the increase in the electrical conductivity of irrigation water negatively affected the plant-height parameter of the sunflower.

Table 5 presents the summary of the analysis of variance of the stem diameter of sunflower plants at different times of assessment, where it can be seen that irrigation with cesspool effluent provided an increase in the mean diameter of the stem at all times of evaluation with respect to the averages of the other treatments, even with a conductivity of 3.50 dS $m^{-1;}$ this may be related to the presence of nutrients in the effluent, such as nitrogen, phosphorus and potassium. Such elements are essential for the development of crops and do not exist in other treatments. This characteristic was also observed by Andrade *et al.* (2012), who observed that the diameter of the sunflower stem irrigated with wastewater was greater than that of those irrigated with water supply.

In the treatments with rain, well and brackish water there is a decreasing trend in the average stem diameter with increasing salinity. This characteristic was also observed by Maciel *et al.* (2012) and Santos Júnior *et al.* (2016) when verifying a linear decrease in the diameter of the sunflower stem with the increase in salinity.

According to Table 6, it is noted that the number of leaves of plants irrigated with cesspool effluent varied from 12.67 to 27.17 units, statistically higher than the other treatments. It is also noted that the increase in salinity of irrigation water did not cause changes in the development of leaves, presenting conditions of similar evolution throughout the cycle for the number of leaves of plants irrigated with rain, well and brackish water. Similar behavior was observed by Morais *et al.* (2011), who found that the leaf number parameter was not influenced by the different salinities, showing similar evolution throughout the cycle. Gomes *et al.* (2015) and Oliveira *et al.* (2017) observed that the number of sunflower leaves decreased linearly with the increase in irrigation water salinity.

Table 5. Summary of the analysis of variance and means of stem diameter (SD), in mm, at 20, 30, 40 and 50 DAS as a function of the salinity of waters of different qualities.

EVALUATION SEASON	RW	WW	EF	BW	MEAN SQUARES
20 DAS	5.67ab	4.94b	6.89a	4.90b	5.21**
CV/%	17.75	9.35	13.54	14.41	
30 DAS	5.88b	5.73b	8.67a	5.69b	12.70**
CV/%	16.25	9.19	7.41	12.13	
40 DAS	6.32b	6.27b	10.81a	5.99b	32.12**
CV/%	10.24	10.10	6.42	11.69	
50 DAS	6.70b	6.46b	11.88a	6.10b	45.11**
CV/%	10.03	10.31	9.29	12.10	

RW - rainwater (0.20 dS m^{-1}); WW - well water (1.50 dS m^{-1}); EF - cesspool effluent (3.50 dS m^{-1}) and BW - brackish water (5.00 dS m^{-1}). Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ** - significant at 1% probability; CV - Coefficient of variation.

Table 6. Summary of the analysis of variance and means of the number of leaves (NL), in units, at 20, 30, 40 and 50 DAS, depending on the salinity of waters of different qualities.

EVALUATION SEASON	RW	WW	EF	BW	MEAN SQUARES
20 DAS	10.17b	10.17b	12.67a	8.67b	16.50**
CV/%	9.67	11.50	9.56	9.42	
30 DAS	13.50b	13.83b	22.33a	12.83b	121.04**
CV/%	20.29	9.61	8.34	11.47	
40 DAS	15.00b	16.33b	27.17a	15.50b	202.11**
CV/%	16.87	7.41	17.49	13.38	
50 DAS	14.67bc	17.67b	23.83a	13.83c	123.22**
CV/%	16.51	8.52	12.28	16.75	

RW - rainwater (0.20 dS m^{-1}); WW - well water (1.50 dS m^{-1}); EF - cesspool effluent (3.50 dS m^{-1}) and BW - brackish water (5.00 dS m^{-1}). Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ** - significant at 1% probability; CV - Coefficient of variation.

According to Morales *et al.* (2001), not all parts of the plant are affected by salinity, each part of its structure may behave differently and the adaptation to salt stress varies between species, genotypes and phenological stages.

In the leaf-area parameter, it is observed that the plants irrigated with EF were the ones with the highest averages (Table 7). When comparing these plants with those irrigated with brackish water, with a smaller leaf area, there is a superiority in the leaf area of 131.68; 464.61; 762.14 and 965.87% for the evaluation periods of 20, 30, 40 and 50 DAS, respectively. Likewise, Santos Júnior *et al.* (2014) observed that plants irrigated with wastewater obtained the highest values of leaf area in irrigated sunflower plants in relation to plants irrigated with water supply.

Leaf size is associated with the availability of nitrogen, responsible for cell division and/or elongation, and this element not only influences the rate of expansion, but mainly cell division, resulting in the final size of the leaves, making nitrogen the main factor responsible due to the rate of biomass accumulation (Taiz and Zeiger, 2013). This explains the fact that the leaves irrigated with effluent present a higher average, even presenting the second highest salinity, unlike the other treatments, where nitrogen was absent. According to Jácome *et al.* (2005), leaves with a larger leaf area result in a greater photosynthetic surface and in the elevation of the assimilation surface, which results in a higher yield and water control, a fact that may explain the better performance of the parameters previously analyzed of plants irrigated with wastewater.

Table 7. Summary of analysis of variance and averages of leaf area (LA), in cm², at 20, 30, 40 and 50 DAS, depending on the salinity of waters of different qualities.

EVALUATION SEASON	RW	WW	EF	BW	MEAN SQUARES
20 DAS	195.56b	184.78b	377.43a	162.91b	32661.43**
CV/%	16.11	5.90	14.27	16.09	
30 DAS	251.34b	234.98b	973.67a	172.45b	834524.71**
CV/%	18.67	5.76	15.30	9.44	
40 DAS	295.66b	280.69b	1854.37a	215.09b	3698384.72**
CV/%	14.72	9.39	17.22	11.88	
50 DAS	282.87b	265.03b	2014.61a	189.01b	4689202.93**
CV/%	13.32	14.39	11.86	15.70	

RW - rainwater (0.20 dS m^{-1}); WW - well water (1.50 dS m^{-1}); EF - cesspool effluent (3.50 dS m^{-1}) and BW - brackish water (5.00 dS m^{-1}). Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ** - significant at 1% probability; CV - Coefficient of variation.

In the treatments with rain, well and brackish water, there is a decreasing trend in the leaf area of the plants, also observed by Nobre *et al.* (2011) and Santos Júnior *et al.* (2016). According to Tester and Davenport (2003), when there is a decrease in the leaf area of plants in saline conditions, this may be related to a mechanism of adaptation and defense of the plant to saline stress, reducing the volume of cells, the transpirant surface and the loss of water by transpiration, conserving the water supply in the soil for a longer time. However, this reduction decreases productivity by capturing less CO_2 and intercepting less light. In addition, the osmotic effect of salt stress can be supported by osmotic regulation of cells, favored by the loss of leaf area and the concentration of organic and inorganic osmoregulators.

Table 8 shows a greater growth of the capitulum and a greater amount of petals in plants irrigated with the cesspool effluent, generating an increase, when compared to plants irrigated with rain water, which obtained the second best yield of 110.69% in IDC, 57.47% in EDC and 53.93% in NP, a fact that may be associated with the nutritional superiority of wastewater, mainly due to the presence of nitrogen and phosphorus absent in other treatments.

The results obtained by Oliveira *et al.* (2017) corroborate the present research, where the superiority of the parameters of the internal and external diameter of the capitulum and the number of petals of plants irrigated with wastewater in relation to those irrigated with water supply was also evident.

Freitas *et al.* (2012) state that the diameter of the sunflower capitulum is highly sensitive to salinity, thus being the variable that best expresses the effects of salinity on the sunflower. Thus, the conclusion was that the diameter of the capitulum responded satisfactorily to the salinity of the wastewater effluent of the cesspool, which can be used in irrigation for the cultivation of sunflowers.

Except for the treatment with cesspool effluent, there was a decreasing trend in the IDC and EDC averages with the increase in the electrical conductivity of irrigation water, which may have been caused by the harmful effects that salt stress causes on plants, generated by the difficulty of water entering plant cells due to the reduction of the osmotic potential of the soil due to the presence of salts, affecting the development of crops (Tester and Davenport, 2003). Corroborating the results of the present research, Dos Santos *et al.* (2017) observed that both the internal and the external diameter were reduced linearly with the increase in salinity of irrigation water.

Table 8. Summary of the analysis of variance and means of the internal (DIC) and external diameter (DEC) of the capitulum in cm, and the number of petals (NP), in units, as a function of the salinity of waters of different qualities.

	RW	WW	EF	BW	MEAN SQUARES
IDC	3.18b	3.07b	6.70a	2.30c	23.15**
CV/%	13.09	11.42	7.90	12.30	
EDC	10.18b	9.77b	16.03a	8.38c	68.67**
CV/%	5.81	4.96	4.74	2.96	
NP	24.20b	21.17b	37.25a	21.60b	246.95**
CV/%	14.73	1.93	10.60	9.02	

RW - rainwater (0.20 dS m^{-1}); WW - well water (1.50 dS m^{-1}); EF - cesspool effluent (3.50 dS m^{-1}) and BW - brackish water (5.00 dS m^{-1}). Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ** - significant at 1% probability; CV - Coefficient of variation.

In the statistical analysis of phytomass, as shown in Table 9, it is observed that in the parameters of fresh and dry phytomass, the means of plants irrigated with cesspool effluent were significantly higher than the other treatments, which is in agreement with the studies by Lucas Filho *et al.* (2002), who stated that the higher content of nutrients in the soil due to irrigation with wastewater can lead to a better development of the plant, obtaining a greater production of fresh and dry matter. Such superiority in the phytomass of plants irrigated with wastewater was also observed by Oliveira *et al.* (2017).

Table 9. Summary of analysis of variance and averages of total fresh (TFF) and dry (TDF) phytomass, in grams, water consumption (WC), in L $plant^{-1}$, and water use efficiency (WUE) in kg m^{-3}, depending on the salinity of waters of different qualities.

	RW	WW	EF	BW	MEAN SQUARES
TFF	42.52b	38.30b	208.90a	25.97b	42144.17**
CV/%	20.78	16.63	16.71	4.45	
TDF	7.37b	5.87b	34.01a	3.89b	1123.17**
CV/%	18.67	15.40	20.89	3.21	
WC	8.00b	7.42b	9.04a	6.67c	9002072.69**
CV/%	2.68	2.09	3.49	3.82	
WUE	1.02b	0.89b	3.67a	0.58c	7.65**
CV/%	4.20	6.95	2.17	3.21	

RW - rainwater (0.20 dS m^{-1}); WW - well water (1.50 dS m^{-1}); EF - cesspool effluent (3.50 dS m^{-1}) and BW - brackish water (5.00 dS m^{-1}). Means followed by lowercase letters on the same line do not differ statistically by the Tukey test. ** - significant at 1% probability; CV - Coefficient of variation.

It is noted that the application of wastewater provided an increase of 391.30%, 445.43% and 704.39% in relation to the treatments with rain water, well water and brackish water, respectively, in the TFF. As for the TDF parameter, the cesspool effluent was higher in relation to rain, well and brackish water, about 361.47%, 479.39% and 774.29%, respectively, which reinforces the use of wastewater in irrigation, and may exempt the need for additional costs with fertilizer and manures to increase the development and productivity of the crop.

The study of dry plant phytomass constitutes one of the most important parameters to be evaluated in a crop subjected to different treatments because it represents the result of photosynthetic activity and the absorption of mineral elements in the soil; that is, it represents the product of liquid photosynthesis, which is the difference between crude photosynthesis (everything that is produced inside chloroplasts) and what is consumed by breathing, and this parameter is related to the leaf area, becoming crucial for understanding the development of the culture (Peixoto and Peixoto, 2009).

Regarding the water consumption of sunflower, it is observed that wastewater was the one that presented the highest consumption, which may be related to the greater development of the crop due to the high nutritional content of the sewage, which generated larger plants in size and weight, which consequently generates a higher consumption of water by the crop. The analysis of variance for the water use efficiency parameter (WUE) shows the superiority of the total dry phytomass production per cubic meter of water applied with the cesspool effluent, presenting a better yield over the other treatments, where the wastewater provided an increase in dry mass of 259.80%, 312.36% and 532.76% with respect to rain, well and brackish water, respectively, which may have induced the plants to a higher water consumption. This reinforces the statement by Lucas Filho *et al.* (2002), that the introduction of nutrients in the soil may increase the dry mass production of the crops, as well as result in a better production yield; that is, a better capacity to convert the volume of water applied in dry mass.

It is observed in Table 9 that in all parameters evaluated, except for the treatment with effluent from the cesspool, there was a reduction in the averages with the increase in salinity, which is in accordance with Munns (2005), who states that the increase of salts in the root zone tends to reduce the levels of water consumption by plants, causing water stress and decreasing the osmotic potential of the soil solution and in the flow of water, in the sense of soil-plant-atmosphere. The same author also states that, by increasing the electrical conductivity of the water, the strain necessary for the plant to remove water from the soil is also increased, making the soil potential increasingly negative, making it difficult to absorb this water, which despite presence in the soil is not fully available to plants.

Centeno *et al.* (2014) and Travassos *et al.* (2012) observed reductions in phytomasses with increased salinity. Travassos *et al.* (2019) observed a decrease in water consumption with an increase in the electrical conductivity of irrigation water. Nobre *et al.* (2014) and Medeiros *et al.* (2012) found a decrease in the efficiency of water use with the increase in salinity.

4. CONCLUSIONS

The irrigation waters did not affect the soil pH; however, they promoted an increase in the electrical conductivity, in the content and in the percentage of exchangeable sodium of the soils, except for the soils irrigated with rainwater.

For the treatments with rain water, well water and brackish water, a decreasing trend was observed with the increase in salinity in the parameters of phytomass, PLH, SD, NL, LA, IDC, EDC, WC and WUE.

The use of brackish water reduced the majority of sunflower growth parameters, and its use for crop irrigation is not advisable.

Rainwater, well water and wastewater can be used in irrigation in environments of water scarcity, such as arid and semi-arid regions.

Wastewater provided the best crop development for the parameters of growth, consumption and water use efficiency.

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