

Original Research Article

Chemical soil attributes in a rotating system under salinity and nitrogen trials

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ABSTRACT

Inadequate soil management promotes changes in soil chemical attributes and, consequently, soil fertility. Therefore, the chemical attributes of the soil under crop rotation system **sunflower/maize** during 24 months in intercropping were studied, cultivating sunflower in the dry period and maize in the rainy season. A multivariate analysis was used to evaluate the behavior of soil chemical variables in the rotational system with different water salinity levels (0.8, 2.2, 3.6, 5.0 and 6.4 dS m⁻¹), nitrogen doses (0, 50, 100 and 150% of the recommended dose of N, **corresponding to 0, 25, 50 and 75 kg N ha⁻¹, respectively**), analyzing the data of the stations in a single depth (0 - 0.30 m). The variables used were: pHes, electrical conductivity of **soil saturation paste extract**, calcium, magnesium, sodium, potassium, phosphorus, potential acidity, exchangeable sodium percentage, base sum, cation exchange capacity, base saturation, saturation by Aluminum, organic carbon and organic matter. By the multivariate analysis we verified that crop rotation along with supplementary irrigation and precipitation in the rainy season ameliorated the effects of salinity along with the use of nitrogen. It was concluded that it is possible for the soil to have good cultivation conditions even in saline environments, using crop rotation and leaching of the salts in the rainy season by means of rainfall.

Keywords: Soil chemical factors, Soil management; Fertility.

1. INTRODUCTION

The advance of irrigation in the semi-arid regions in marginal land areas and the use of low quality water has increased the accumulation of salts in the soils and, consequently, their

degradation [1]. An estimated 270 million irrigated hectares, corresponding to only 15% of the cultivated land, account for 40% of the world's fiber and food production [2]. Today researchers consider that around 20% of the cultivable areas present problems of salinity.

The accumulation of salts in soils occurs due to factors such as: climatic conditions where evapotranspiration rates exceed those of precipitation (typical in arid and semi-arid climate regions), poor drainage, richness of source material. Areas affected by salts occur throughout the world, especially in regions with arid and semi-arid climate, where irrigation is essential for salt-affected areas, corresponding to more than 6% of arable soils [3].

Salinization consists of the accumulation in the soil of water-soluble salts. These salts contain potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), chloride (Cl^-), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and sodium (Na^+). The salts dissolve and circulate with the water, when it evaporates, deposits the salts in the form of residues. Generally, salinization of soils occurs more frequently with the accumulation of ions (Na^+ and Cl^- or OH^-) which are considered the main ions to impair the metabolism of plants. [4]

The predominance of these ions in the root growth medium can cause toxicity when they accumulate in plant tissues, leading to changes in the plant's ability to absorb, transport and utilize the ions necessary for its growth. Thus, deficiencies of Ca^{2+} can be induced by excessive Na^+ , K^+ deficiencies of excess Na^+ or Ca^{2+} , Mg^{2+} in high concentrations can inhibit the uptake of K^+ or Ca^{2+} [5], in addition to the high salt concentration in the medium, could affect the nitrate absorption (NO_3^-) [6]

Soil salinity is a serious problem in irrigated areas, especially when its intensity interferes with crop development, reducing plant production and productivity at uneconomic levels [7].

Despite the great importance of multivariate statistical methods for interpretations of variations in soil attributes, few studies have used this tool since most use univariate statistical methods. The use of numerical and hierarchical classification system reveals several levels of similarity and allows visualizing a variable number of clusters; Thus, variability is minimized within a group and maximized between groups in order to produce relatively homogeneous groups [8].

The objective of this study was to evaluate the dynamics of the chemical quality of the soil subjected to crop rotation (sunflower/maize) when irrigated with different saline waters (dry period) and supplementary irrigation with good quality water (rainy season) and fertilized with different nitrogen doses, having as technical statistical tools of multivariate analysis.

2. MATERIAL AND METHODS

The study was carried out in the Experimental area of the Department of Agricultural Engineering at the Federal University of Ceará, in Fortaleza ($3^{\circ}45' S$, $38^{\circ}33' W$, at an altitude of 20 m), Ceará, Brazil, during a period of 24 months (06/2011 to 06/2013). A sunflower and maize crop rotation system was used, with cultivation of sunflower during the dry seasons of 2011 and 2012, and maize in the rainy seasons of 2012 and 2013.

According to the Köppen classification, the local climate is of type Aw', rainy tropical, very hot, with a predominance of rainfall in the summer and autumn, and an average annual temperature of $27.1^{\circ}C$. Table 1 shows the physical and chemical properties of the soil, obtained before starting the experiment. According to Embrapa (2013) the soil of the experimental area is Acrisol red yellow, as shown in the table below. [9]

Table 1. Physical and chemical attributes of the soil in the experimental area

Attribute	Depth (m)	
	0 - 0.30	0.30 - 0.60
Textural Class	Sandy loam	Sandy clay loam
Soil Density (g dm^{-3})	1.39	1.42
Ca^{2+} ($\text{mmol}_c \text{ dm}^{-3}$)	8.3	12.0
Mg^{2+} ($\text{mmol}_c \text{ dm}^{-3}$)	8.2	8.0
Na^+ ($\text{mmol}_c \text{ dm}^{-3}$)	2.5	3.3
K^+ ($\text{mmol}_c \text{ dm}^{-3}$)	1.2	1.2
ESP (g kg^{-1})	50	70
$\text{H}^+ + \text{Al}^{3+}$ ($\text{mmol}_c \text{ dm}^{-3}$)	20.0	24.0
Al^{3+} ($\text{mmol}_c \text{ dm}^{-3}$)	3.0	4.5
pH in water (1:2.5)	5.60	5.40
EC _{se} (dS m^{-1})	0.20	0.28

EC_{se} – Electrical conductivity of saturation extract; ESP – Exchangeable percentage of sodium

Information on the weather variables obtained during the dry season (sunflower crop) and the rainy season (maize) are shown in Table 2.

Table 2. Climatic parameters of the experimental area and irrigation depths (ID) applied during each cultivation

Month	Maximum Temp. ($^{\circ}\text{C}$)	Minimum Temp. ($^{\circ}\text{C}$)	RH (%)	Insolation (h month^{-1})	ET _o (mm)	Rainfall (mm)	ID (mm)
First cycle (sunflower) – 2011							
Sept	31.6	22.8	59	168.4	159.4	0.0	76.87
Oct	31.0	23.6	66	288.5	258.6	23.8	166.24
Nov	31.1	24.0	68	296.5	242.4	7.3	133.53
Dec	31.2	24.3	65	202.9	163.7	2.8	45.61
Mean/sum	31.2	23.7	64.5	956.3	824.1	33.9	4222.25
Second cycle (maize) – 2012							
Feb	30.2	22.8	81	95.8	108.8	237.6	9.2
Mar	30.5	23.1	78	216.3	194.4	488.6	75.1
Apr	30.6	23.7	77	240.6	201.4	170.3	75.4
May	30.7	23.6	72	284.2	208.7	101.3	94.5
Mean/sum	30.5	23.3	77	836.9	713.3	997.8	54.2
Third cycle (sunflower) – 2012							
Sept	31.0	23.4	61	203.2	194.3	0.0	75.53
Oct	30.9	23.4	63	294.9	276.4	10.0	198.78
Nov	31.3	24.0	63	308.9	263.7	0.9	155.58
Dec	31.4	24.5	67	187.9	163.0	2.0	46.58
Mean/sum	31.1	23.8	63.5	994.9	897.4	12.9	75.94
Fourth cycle (maize) – 2013							
Apr	31.1	23.7	78	143.6	116.4	111.1	68.4
May	31.2	23.4	73	234.6	173.7	155.6	129.5
Jun	30.7	22.6	77	216.2	164.1	168	125.2
Jul	30.3	22.5	69	266.1	190.1	91.0	53.2
Mean/sum	30.8	23.0	74.2	860.5	488.3	525.7	373.3

RH – Relative humidity, ET_o – Evapotranspiration of Reference

The sunflower (*Helianthus annuus* L.) cultivar BRS 324 was used. This is an open-pollinated, early variety, displaying, on average, high oil content, around 47%, with a productivity of 1,600 kg ha⁻¹ as a rainfed crop. The other crop used was maize (*Zea mays*

L), hybrid AG1051. This has a semi-early cycle, high ear insertion, a cycle from 90 to 120 days, with a productivity of 4,500 kg ha⁻¹ under rainfed conditions.

The experimental design was of randomised blocks in split plot arrangement. The plots consisted of five levels of salinity of the irrigation water, and the subplots of four doses of nitrogen fertilizer, with five replications. Irrigation with water of different salinities was only used in the sunflower crop during the dry season.

For the sunflower crop, the treatments with saline water were S1 = 0.8 (well water), S2 = 2.2, S3 = 3.6, S4 = 5.0 and S5 = 6.4 dS m⁻¹; nitrogen doses were N1 = no fertilizer, N2 = 25, N3 = 50 and N4 = 75 kg N ha⁻¹, with the dose of 50 kg N ha⁻¹ being recommended by [10] and [11]. Urea was used as the source of N.

To prepare the saline water treatments, the salts NaCl, CaCl₂.2H₂O and MgCl₂.6H₂O were added to the well water, using an equivalent ratio of 7:2:1, complying with a relationship between EC and salt concentration (mmol_c L⁻¹ = EC x 10). The characteristics of the well water were: EC= 0.8 dS m⁻¹, pH=6.9, and Ca, Mg, Na, HCO₃⁻ and Cl⁻ equal to 1.1, 1.2, 4.0, 2.7, and 3.7 mmol_c L⁻¹, respectively.

The same plots with sizes of 50 m² and subplots with an area of 12.5 m² previously cultured with sunflower, maize were used for the purpose of evaluating the residual effect of saline water treatments applied to the sunflower crop. However, supplementary irrigation with well water (EC=0.8 dS m⁻¹) was used, with the following levels of nitrogen: N1 = no fertilizer, N2 = 108.5, N3 = 217 and N4 = 325.5 kg N ha⁻¹; with N3 (217 kg N ha⁻¹) being the dose recommended for maize [12]. Urea was used as a source of nitrogen.

Sixty-five days before sowing the sunflower, liming based on soil analysis was carried out using dolomitic limestone (1.8 Mg ha⁻¹), and incorporated by ploughing followed by a single harrowing. Five days before sowing, the soil was ploughed and then cross-harrowed twice.

Water depths to be applied in irrigation were calculated using data for reference evapotranspiration, as determined by the Class A tank method, and the crop coefficients of the sunflower and maize [13], in the latter case, only for supplementary irrigation. A pressurised drip-irrigation system was used for both crops.

The sunflower was sown with four seeds per hole, at a spacing of 0.8 x 0.3 m, and a density of 41,666 plants ha⁻¹. Ten days after sowing (DAS), thinning was carried out leaving only one plant per hole. Fertilization was performed in the furrows, and was based on soil analysis and the recommendations of [12]: 80 kg ha⁻¹ of P₂O₅, 70 kg ha⁻¹ of K₂O, and 10 kg ha⁻¹ of Fritted Trace Elements BR12. The single superphosphate and the Fritted Trace Elements were applied as basal dose of sowing, while the urea and potassium chloride were divided up, with 1/3 being applied as basal dressing and 2/3 as top dressing at 31 DAS. To meet boron needs 4.0 kg ha⁻¹ of boric acid were applied, as recommended by [14].

After each crop, the plant residue was mown once, and all remaining biomass was maintained in the respective plots. At the beginning of the rainy seasons of 2012 and 2013, after sunflower crop, the maize was sown, using three seeds of the cultivar AG1051 per hole, following the same order of treatment, and following the same spacing, as the previous crop. On the tenth day after germination, the plants were thinned, leaving only one plant per hole.

Fertilization of the maize crop was also carried out in the furrows, using 42 kg ha⁻¹ of P₂O₅, 157 kg ha⁻¹ of K₂O and 40 kg ha⁻¹ of Fritted Trace Elements -BR12. The superphosphate and the Fritted Trace Elements were applied as basal dressing in a single application, while

the potassium chloride and the rates of nitrogen were divided, with 1/3 being applied as basal dose and 2/3 as top dressing at 35 SAD.

Soil analyses were performed before and after each cultivation, in the depths of 0-0.30 m, respectively. Four soil samples were held, two in the dry season and two in the rainy season, using five repetitions per treatment. The collections were conducted in line with the plants. After each sampling, the soil was packed in plastic bags and sent to the laboratory for analysis of soils and Plants of the Department of soil science/UFC for performing the following analysis as shown in Table 3.

Table 3. Variables chemicals analysed in soil in each experimental unit and methods used

Chemical variables	Description and method of analysis
pH of the saturated paste extract-pHes	pH of the saturation extract – measured in saturation paste extract prepared in accordance with the method described by RICHARDS (1954).
Electrical conductivity- EC (dS m^{-1})	Electrical conductivity of the saturation extract – measured in saturation folder extract prepared second method described by RICHARDS (1954).
Ca exchangeable – Ca ($\text{cmol}_c \text{ kg}^{-1}$)	Calcium - by means of logging with KCl 1N and determination titration (EMBRAPA, 1997).
Mg exchangeable – Mg ($\text{cmol}_c \text{ kg}^{-1}$)	Magnesium - by means of logging with KCl 1N and determination - titration (EMBRAPA, 1997).
K exchangeable – K ($\text{cmol}_c \text{ kg}^{-1}$)	Potassium - it was through the extraction with diluted solution of hydrochloric acid and subsequent determination for espectrofotometria of flame - (EMBRAPA, 1997).
Na exchangeable – Na ($\text{cmol}_c \text{ kg}^{-1}$)	Sodium - Through the extraction with diluted solution of hydrochloric acid and subsequent determination with espectrofotometria of flame - (EMBRAPA, 1997).
P available – Pdisp (mg kg^{-1})	Available phosphorus-extracted with Mehlich-1 and determined by Colorimetry in the presence of Ascorbic acid as catalyst (EMBRAPA, 1997).
Exchangeable Sodium Percentage - ESP (%)	Exchangeable Sodium Percentage – obtained by the formula: $\text{PST} = (\text{Na}^+) * 100/\text{CTC}$.
H+Al ($\text{cmol}_c \text{ kg}^{-1}$)	Potential acidity - can be appreciated by the use of the pH SMP, which there presents good correlation with the tenor of H + Al extracted with acetate of calcium - (EMBRAPA, 1997).
Sum of exchangeable bases - S ($\text{cmol}_c \text{ kg}^{-1}$)	Sum of the exchangeable cations – value obtained according to the formula: $S = (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{K}^+)$.
Exchange capacity of cations -T ($\text{cmol}_c \text{ kg}^{-1}$)	The exchange capacity of cations was calculated on basis of the equation - (EMBRAPA, 1997). $T (\text{cmol}_c \text{ kg}^{-1}) = S + (\text{H} + \text{Al}^{+3})$
Saturation for bases -V %	Sum of exchangeable bases expressed in percentage of cation exchange capacity: $V\% = (100*S)/T$
Aluminum saturation	The aluminum saturation - was calculated based on the equation -

- m %	(EMBRAPA, 1997). $m\% = [\text{mmolc (Al) dm}^{-3} \times 100] / [\text{cmol}_c \text{ (CTC effective) dm}^{-3}]$.
Organic Carbon – O.C g kg ⁻¹	Organic carbon - oxidation of organic matter with potassium dichromate K ₂ Cr ₂ O ₇ in sulfuric medium with external heating and titration of excess dichromate with ferrous ammonium sulfate - (EMBRAPA, 1997).
Organic matter - M.O g kg ⁻¹	Organic matter - multiplying the organic carbon result by 1.724 according to equation. Organic matter (g kg ⁻¹) = C (g / kg) x 1. 724

171

172 The data were subjected to the classic descriptive statistical analysis. This proceeding was
173 applied to check the existence of peripheric values "outliers" that were compromising the
174 middle behavior of the evaluated parameters.

175

176 For a better interpretation of the data there was used the multivaried statistic, which
177 contributed to the understanding of the interactions between variables undergone to the
178 saline effect and nitrogenous, over there, of the influence of each variable on the quality of
179 the ground. In the analysis of the component principals, 15 variables were used: pHes,
180 condutividade electric of the extract of saturation of the ground (ECes), calcium (Ca),
181 magnesium (Mg), sodium (Na), potassium (K) you were exchanging, match (P), potential
182 acidity (H+Al), percentage of exchangeable sodium (PST), sum of bases (S), exchange
183 capacity of cations (T), saturation for bases (V), saturation for aluminum (m), organic
184 carbon (O.C) and organic matter (O.M). The selected attributes were correlated in way to
185 exclude the least representative variables and, being those who more are correlated with
186 the study factors.

187

188 The grouping analysis was carried out when the distance is calculated euclidian between
189 the accesses in the identification of the groupings for a set of 15 variables. For the analysis
190 of grouping of the variables the method of Ward was used, with the measure euclidian for
191 the distance between the cases in the groups. The result of the analysis was presented in
192 the graphic form (dendrogram). The statistical analyses of the data were carried out with
193 the help of the software STATISTICA 5.0.

194

195 3. RESULTS AND DISCUSSION

196

197

198 Multivaried analysis of the chemical attributes of the ground was carried out in the depth of
199 0 – 0.30 m, unifying two dry and rainy stations. Through the analysis of component
200 principals (CP) there are possible there observe the interaction of the variables in several
201 forms of handling of the analysed ground, selecting two component principals (CP 1 and 2).
202 For choice of the component principals there were selected those who had autovalues
203 bigger than 1 used to value the correlation between the component principals and the
204 variables. In this way the component principals 1 and 2 explained joined 85.97% of the total
205 variation of the data. (4 Table).

206

207 **Table 4.Eigenvalues and percentage of variance explained by component**

Number of components	Eigenvalues Extraction of the main components
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	Eigenvalues	% Of the variation explained	Cumulative eigenvalues	% Of the cumulative explained variation
1	9.78	65.22	9.78	65.22
2	31	20.74	12.89	85.97
3	0.73	4.93	13.63	90.90
4	0.59	3.93	14.22	94.83
5	0.45	3.06	14.68	97.90
6	0.25	1.67	14.93	99.57
7	0.03	0.21	14.96	99.79
8	0.01	0.09	14.98	99.88
9	0.00	0.08	14.99	99.96
10	0.00	0.02	14.99	99.98
11	0.00	0.00	14.99	99.99
12	0.00	0.00	14.99	99.99
13	0.00	0.00	14.99	99.99
14	0.00	0.00	15.00	100.00
15	0.00	0.00	15.00	100.00

On basis of the Table 5, can observe the interaction of the variables with the respective factors in function of the treatments applied in the ground. In Yellow Red argisol the variables connected with the chemical attributes (O.C, H+Al, m, P and pH) had a bigger positive contribution for the CP1, while you were varying (Na, S, T, O.C, ECse and ESP) correlated in the negative form. In the CP2, none variable was associated in the positive form, but, the variables (Ca^{2+} , Mg^{2+} , K^{+} and V) they are the most relevant negatively, showing bigger contribution.

Table 5. Correlation of the chemical attributes analysed with the component principals (CP) obtained from all the analysed attributes

Variable	CP1	CP2
Ca	0.26	-0.72
Mg	0.26	-0.88
Na	-0.98	-0.15
K	-0.57	-0.72
H+Al	0.95	0.10
S	-0.90	-0.32
T	-0.90	0.04
V	0.41	-0.80
M	0.79	-0.41
O.C	-0.87	-0.43
O.M	0.95	-0.27
P	0.98	-0.03
pH	0.87	-0.12
ECes	-0.79	0.03
ESP	-0.97	-0.21

The condition of low haste registered in the semiarid regions is aggravated by the elevated balance of available solar energy to the process of evapotranspiration. The combination of these two natural processes with the adoption of the irrigation with saline water turns in high concentrations of salts in the ground [15]. The change of the taxes of evapotranspiration in these regions for the adoption of the irrigation, even in a

conservationist vision, turns in an addition from 3 to 5 Mg ha⁻¹ of salts to the ground explored by the irrigated agriculture [16].

In the Figure 1 is represented the plan factorial when from 0 to 0,30 formed by the factors (F1 and F2), at disposal of the loads of the chemical attributes and the values (scores) of the different treatments devoted to the ground, in the dry and rainy period, both in the layer m. When the vertical F1e is considering the horizontal dislocation to correlation with with the F2, there is observed the graphic location of the loads of the attributes and the values (scores) of the different studied experimental unities. We check that the biggest values for H+Al, m, O.M, pH and P they presented bigger influence in the F1, since it has highly positive correlation, while, it Na⁺, S, T, C.O, ECse and ESP are quite relevant to this factor, with negative antagonism.

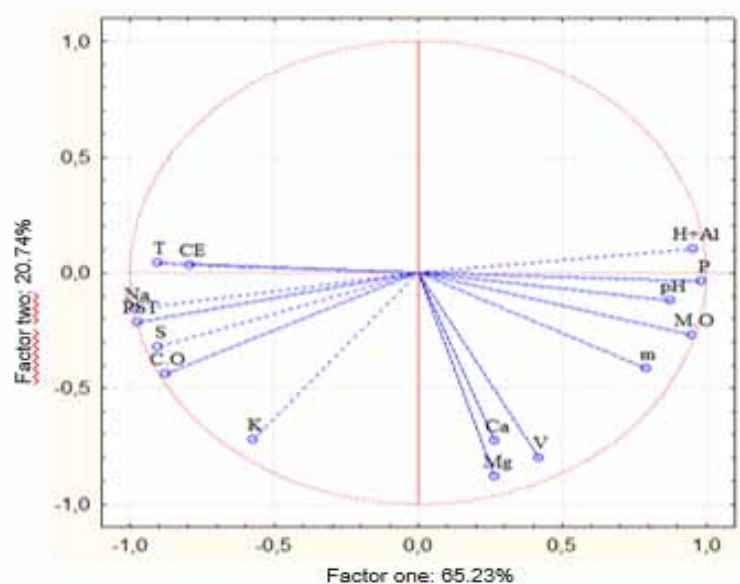


Figure 1. Dispersal of the chemical attributes of the ground cultivated with sunflower and maize during 24 months, in different saline conditions and nitrogenous, in the ground layer (0 – 0.30m).

As for the F2, it was observed that only a negative correlation with the variables (Ca²⁺, Mg²⁺, K⁺ and V), affirming that the variables related to soil fertility are those that have the greatest influence may be regarded as an important factor to define a good quality that soil.

In this way, it is possible to infer that the ACP has identified the main sources of variation in the number of observed data. In addition, made it possible to reduce the number of variables without the loss of important information.

With bases in the obtained results referring to variability of the chemical attributes it is possible to draw strategies of handling, from the establishment of the priorities of interventions to be adopted. In this way, in function of the high contribution of K and P (first and main component second) in the variability of the areas, theoretically, one should prioritize applications of these nutritious ones in specific sieges, through the variable tax, if it to homogenize his levels in the ground. However, having in mind what, in general, the tenors of these nutritious ones present if above the critical tenors, in other words, they are not considered limitations to the plants development.

260 In a planning focusing on long-term results, the strategy is to seek intensively the increase
261 in levels of O.M, from management practices conservationists. Whereas the O.M is one of
262 the best indicators of soil quality, the increase in the fat, will favor the chemical balance of
263 the soil. In addition, contribute in the improvement of physical, chemical and biological
264 properties of the soil.

265
266 About the effect on the availability of P another important factor is the release of exudates
267 that may interfere in the setting of P by soil. This availability is influenced by factors, among
268 which stands out the soil texture. To the extent that increases the soil clay content, are high
269 in cation exchange capacity and the capacity factor or power-plug of soil for cations and
270 anions, expressed by the reduction of P values remaining. [16]

271
272 [17] found that management that involves enrichment with species more efficient in
273 producing quality vegetable mass seems to be efficient in contributing nutrients through the
274 litter forming material in their study on the nutrient contribution by the litter of different tree
275 legumes in Degraded area. In the present research, sunflower and maize crops are able to
276 produce above 5 and 10 Mg ha⁻¹ dry mass, respectively, which reinforces the results of the
277 above authors.

278
279 We believe that the variability among these variables is related to the leaching of the salts
280 during the rainy season, but also by the increase of O.C and O.M compared to the dry
281 season. The mean values of the semi-arid regions present unfavorable climatic conditions
282 for the maintenance of CO in the soil, with values as low as 1.05 dag kg⁻¹ [18], 0.4 g kg⁻¹
283 [18].

284
285 Obviously, such observations for C.O of soil do not depend essentially on the climate in
286 question and this idea is confirmed by [19], who concluded that the factors that most
287 affected the changes in soil O.C, among the several studies included in their work besides
288 climate, were the type of previous use and the species implanted to the soil, which in our
289 previous research Maize intercropped with beans was cultivated and its biomass (8 Mg ha⁻¹)
290 was incorporated into the soil.

291
292 According to [20] the (NaAlSiO₃) may be potential sources of Na⁺ to the soil system during
293 the weathering process, as well as the anortita (CaAl₂Si₂O₈) is source of Ca and microcline
294 and orthoclase (KAlSi₃O₈) are Sources of K, which are present in soils in the Northeast
295 region of Brazil.

296
297 These results are largely due to the composition of saline water used in irrigation, which
298 had a 7: 2: 1 ratio of Na⁺ to the major divalent cations (Ca²⁺ and Mg²⁺). ESP values
299 decreased during the rainy season, with the lowest PST values found in the soil surface
300 layer. This result reinforces the need to use a management strategy, such as the
301 alternating application of low and high salinity waters throughout the crop cycle [21] use of
302 leaching fractions [22], The application of plaster and the use of different cultures in the
303 same area. These strategies contribute to the coexistence with salinity and sodicity
304 problems in irrigated agriculture [23] and [24].

305
306 According to Figure 2, it is possible to observe that we have the formation of two groups in
307 the analyzed soil, however each variable was grouped according to the characteristics
308 presented in the soil. By means of the dendrogram, the cut established to 20% of the
309 dissimilarity measure to differentiate the formation of two groups: Group 1 (composed of
310 the treatments applied in the dry period) and group 2 (represented by the treatments
311 applied in the rainy season), both in the The same depth (0.0 to 0.30 m). However, it can
312 still be seen that within each group there are two subgroups represented by the treatments

of smaller and higher concentrations of salts in the irrigation water, in both dry and rainy periods.

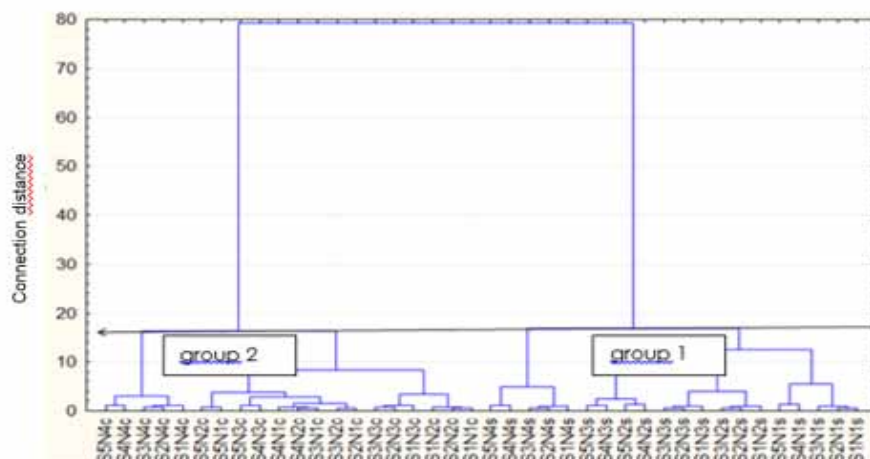


Figure 2. Dissimilarity between the groups established by Euclidean distance of the saline effects and nitrogen doses from the chemical attributes of a Yellow Red Argisol cultivated with sunflower and maize

S1, S2, S3, S4 e S5 (0,8; 2,2; 3,6; 5,0 e 6,4 dS m⁻¹) e, N1, N2, N3 e N4 (0; 50; 100 e 150%) de N According to the recommendation for both crops, in the soil layer (0 - 0.30 m).

Thus, it is evident the similarity of the treatments within each group, and the dissimilarity between the evaluation periods, so that the treatments applied with different amounts of salts in irrigation water and nitrogen doses during the dry season in soil cultivated with sunflower Presents difference when cultivated with maize during the rainy season where it applies supplementary irrigation with water of low salinity and doses of nitrogen.

The dendrogram shows clearly that the similarity of the soil salinity to the studied stations was defined by the spatial variability of the concentrations of the investigated attributes, with a greater influence of the temporal variability of Na⁺, K⁺, ESP, O.M, O.C, Ca²⁺, Mg²⁺ and ECse the arrangements occurred independently of the sampling date, but rather by the season (dry and rainy).

This fact expresses that the saline concentrations within each group do not present statistically significant variations with respect to the space, characterizing the state of equilibrium of the same. However, in terms of time there is statistical variability, implying that in this group there is no equilibrium due to the high salt content. Similar results were found by other researchers in studies of the impact of soil irrigation in semi-arid regions of the Brazilian Northeast [19].

This separation of groups, characterizes the existence of an accumulation of salts highly significant in soils irrigated, expressing that the total precipitation in the region was sufficient to promote the leaching of salts added by irrigation. The opposite results were reported by [14], in other municipalities in the state of Ceará, where the rainfall was not sufficient to promote the leaching of salts present in the soil.

The cation exchange capacity of the ground and the stocked carbon was correlated positively with most of the variables, like match. That demonstrates the importance of the

handling and vegetable covering on the cation exchange capacity of the ground and in the maintenance of the tenors of carbon. The [25], this variability can be attributed, in part, to the located application of fertilizers and to the residual effect of the fertilizing. The cation exchange capacity (CEC) is a characteristic chemical-physically basically to the appropriate handling of the fertility of the ground, the bigger the cation exchange capacity of the ground, bigger the number of cations what this ground can keep.

The knowledge of the space variability of the chemical attributes of the ground becomes basic to perfect the located applications of punishments and fertilizers, reducing the environmental degradation provoked by the excess of this, improving the control of the system of production of the cultures [26].

[27] reinforce that, in irrigated areas, the process of salinization can happen even in grounds with good characteristics, in special in the situations in which there is not appropriate handling of ground and water. In fact, the concentration of salts in the irrigated grounds presents straight relation with the annual total haste, with the physical characteristics of the ground and with the conditions of drainage.

Therefore, the type of management is of paramount importance to the so-called modern agriculture development, for soil compaction process through improper handling by derail the exploitation thereof. For [28], places where the precipitation is normal, but the soils are compacted and as consequence the salts may not be leached by water, do not allow the infiltration of the same, as much as heat stroke is enough to warm the soil and cause evaporation.[29]

4. CONCLUSION

1- Multivariate statistics allowed showing the interaction of chemical soil attributes and may state that the Ca^{2+} , Mg^{2+} , Na^+ , ESP, O.C and O.M exerted a major influence on the dynamics of soil under the conditions laid down, in addition, to enable the Division of groups with same characteristics in the soil between the periods of study as in-depth;

2 - The crop rotation (sunflower/maize), was able to promote changes in the chemical properties of the soil, so as to provide better soil under cultivation conditions.

3 - In the study conditions it is possible that the applied management can attenuate the effect of the salinity along with the precipitations during rainy season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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