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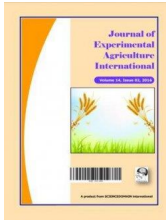
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Chemical Soil Attributes in a Rotating System under Salinity and Nitrogen Trials

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Authors' contributions

This work was carried out in collaboration with all authors. Author HOF designed the study, performing a statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CFL, ICSA and FJF managed as study analyzes. Author ICSA managed a literature researches. Authors CMC and ABM collaborated in the discussion of the results after the statistical analysis. Author CMC did all the processing of the article with the magazine. All authors read and approved the final manuscript.

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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 (*Helianthus annuus*)/maize (*Zea mays*) during 24 months in intercropping were studied, cultivating

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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: pH, 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, the 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 (Mg²⁺), calcium (Ca²⁺), chloride (Cl⁻), sulfate (SO₄²⁻), carbonate (CO₃²⁻), bicarbonate (HCO₃⁻) 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 Ca²⁺ can be induced by excessive

Na⁺, K⁺ deficiencies of excess Na⁺ or Ca²⁺, Mg²⁺ in high concentrations can inhibit the uptake of K⁺ or Ca²⁺ [5], in addition to the high salt concentration in the medium, could affect the nitrate absorption (NO₃⁻) [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. MATERIALS 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°45' S, 38°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 were used, with the 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°C. Table 1 shows the physical and chemical properties of the soil, obtained before starting the experiment. According to Embrapa, the soil of the experimental area is argisol 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

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

Month	Maximum Temp. (°C)	Minimum Temp. (°C)	RH (%)	Insolation (h month^{-1})	ETo (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, ETo – Evapotranspiration of Reference

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

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 DAS.

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.

The chemical properties were: Organic carbon (CO), exchangeable bases (Ca^{2+} , Mg^{2+} , Na^+ and K^+), available P and potential acidity ($\text{H} + \text{Al}$), Aluminum saturation – m, Exchange capacity of cations -T determined according to [15], as well as the sum of bases (SB), the cation exchange capacity (CTC) and the saturation by bases (V%). The organic matter - multiplying the organic carbon result by 1.724 according to equation. Organic matter (g kg^{-1}) = $\text{C (g kg}^{-1}) \times 1.724$. The other variables pH of the saturated, Exchangeable Sodium Percentage - ESP, Electrical conductivity of the saturation extract – ECes measured in saturation folder extract prepared second method described by [16].

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

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

The grouping analysis was carried out when the distance is calculated euclidian between the accesses in the identification of the groupings for a set of 15 variables. For the analysis of grouping of the variables, the method of Ward was used, with the measure euclidian for the distance between the cases in the groups. The result of the analysis was presented in the graphic form

(dendrogram). The statistical analyses of the data were carried out with the help of the software STATISTICA 5.0.

3. RESULTS AND DISCUSSION

Multivariate analysis of the chemical attributes of the ground was carried out in the depth of 0 – 0.30 m, unifying two dry and rainy stations. Through the analysis of component principals (CP) there are possible there observe the interaction of the variables in several forms of handling of the analysed ground, selecting two component principals (CP 1 and 2). For the choice of the component principals, there were selected those who had auto values bigger than 1 used to value the correlation between the component principals and the variables. In this way the component principals 1 and 2 explained joined 85.97% of the total variation of the data. (Table 3).

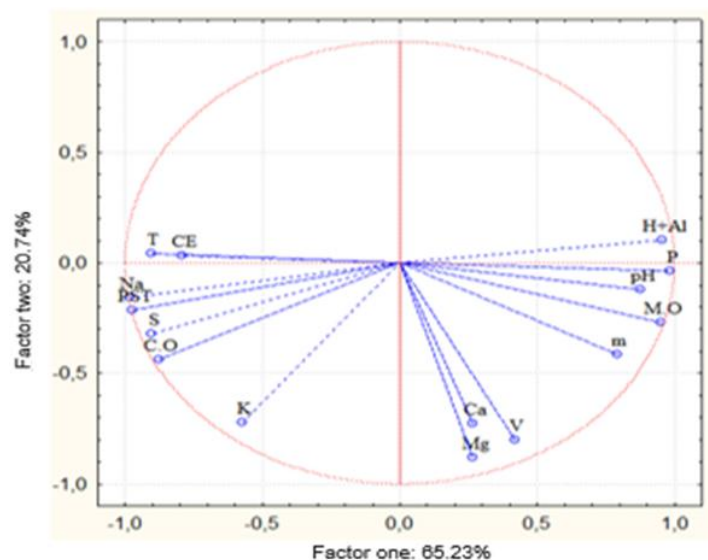
On basis of the Table 4, can observe the interaction of the variables with the respective factors in function of the treatments applied in the ground. In Yellow Red argisol the variables connected with the chemical attributes (O.C, $\text{H} + \text{Al}$, m, P and pH) had a bigger positive contribution 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.

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 [17]. 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 [18].

In the Fig. 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 F1 is considering the horizontal dislocation to correlation with the F2, there is

Table 3. Eigenvalues and percentage of variance explained by component

Number of components	Eigenvalues			
	Extraction of the main components			
	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


Fig. 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 – 0.30 m)

observed the graphic location of 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, ECES and ESP are quite relevant to this factor, with negative antagonism.

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.

Table 4. 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

With bases in the obtained results referring to the variability of the chemical attributes, it is possible to draw strategies for 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.

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

About the effect on the availability of P another important factor is the release of exudates that may interfere in the setting of P by soil [18]. This availability is influenced by factors, among which stands out the soil texture. To the extent that increases the soil clay content, are high in cation exchange capacity and the capacity factor or power-plug of soil for cations and anions, expressed by the reduction of P values remaining [18].

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

We believe that the variability among these variables is related to the leaching of the salts during the rainy season, but also by the increase of O.C and O.M compared to the dry season. The mean values of the semi-arid regions present unfavorable climatic conditions for the maintenance of CO in the soil, with values as low as 1.05 g kg⁻¹ [18], 0.4 g kg⁻¹ [20].

Obviously, such observations for C.O of soil do not depend essentially on the climate in question and this idea is confirmed by [21], who concluded that the factors that most affected the changes in soil O.C, among the several studies included in their work besides climate, were the type of previous use and the species implanted to the soil, which in our previous research Maize intercropped with beans was cultivated and its biomass (8 Mg ha⁻¹) was incorporated into the soil.

According to [22] the (NaAlSiO₃) may be potential sources of Na⁺ to the soil system during the weathering process, as well as the anortita (CaAl₂Si₂O₈) is source of Ca and microcline and orthoclase (KAlSi₃O₈) are Sources of K, which are present in soils in the Northeast region of Brazil.

These results are largely due to the composition of saline water used in irrigation, which had a 7: 2: 1 ratio of Na⁺ to the major divalent cations (Ca²⁺ and Mg²⁺). ESP values decreased during the rainy season, with the lowest ESP values found in the soil surface layer. This result reinforces the need to use a management strategy, such as the alternating application of low and high salinity waters throughout the crop cycle [23] use of leaching fractions [24], The application of plaster and the use of different cultures in the same area. These strategies contribute to the coexistence with salinity and sodicity problems in irrigated agriculture [25] and [26].

According to Fig. 2, it is possible to observe that we have the formation of two groups in the

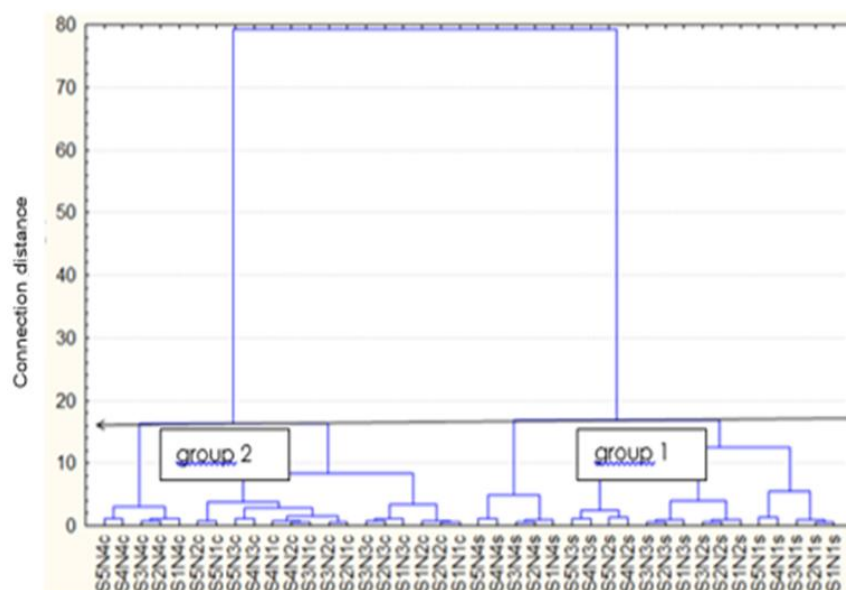


Fig. 2. The dissimilarity between the groups established by Euclidean distance of the saline effects and nitrogen doses from the chemical attributes of a Yellow Red Argisol cultivated with sunflower and maize

analyzed soil, however, each variable was grouped according to the characteristics presented in the soil. By means of the dendrogram, the cut established to 20% of the dissimilarity measure to differentiate the formation of two groups: Group 1 (composed of the treatments applied in the dry period) and group 2 (represented by the treatments applied in the rainy season), both in the same depth (0.0 to 0.30 m). However, it can 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.

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, Ca^{2+} , Mg^{2+} and ECes 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 [21].

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 [27], 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 [28].

[29] 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 the 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 [30], 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 [31].

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 the rainy season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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