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Process of soil salinization as a function of watermelon mineral fertilization

Manoel Fernandes da Costa[1], Graciene de Souza Silva[1], Eden Cavalcanti de Albuquerque Júnior[2], Cícero Antônio de Sousa Araújo[1], Fabio Freire de Oliveira[1], Gilberto Saraiva Tavares Filho[3]*

[1]Federal Institute of the Sertão Pernambuco, Petrolina, Brazil
[2]Pernambuco Institute of Technology, Recife, Brazil
[3]Federal University of the San Francisco Valley, Petrolina, Brazil
*Corresponding author, e-mail: gilfilho753@hotmail.com

Abstract

The watermelon (*Citrullus lanatus L.*) is a cucurbitaceous plant of great social and economic importance in Brazil, especially in the north-eastern region. However, anthropic actions through the practice of irrigation, fertigation and fertilization in an inadequate way, have potentiated the salinization of the soil becoming this one of the main factors that limit the production and the quality of the fruits. In this work, the effects of the application of mineral fertilization on the salinization of soil cultivated with watermelon were evaluated. The experiment was performed in the city of Petrolina-PE, with four repetitions, using five treatments: (T0) no fertilization, (T1) NPK fertilization, (T2) average dose of NPK practiced by producers, (T3) maximum dose of NPK from producers having potassium chloride as a source of potassium and (T4) maximum dose of NPK from producers having potassium sulfate as a source of potassium, at two different depths: 0.00 - 0.20 m and 0.20 - 0.60 m. The soil chemical attributes analyzed were pH, electrical conductivity (EC), organic matter, phosphorus, potassium, sodium, calcium and magnesium. The increase in the continuous application of mineral fertilizers raised the electrical conductivity values of the soil to levels prejudicial to the crop.

Keywords: residual effect of fertilizers, salinity, soil management

Introduction

The watermelon (*Citrullus lanatus L.*) belongs to the Curcubitaceae family, cultivated worldwide on 3.5 million hectares with a production of 118 million tons (Yavuz et al., 2020). It is one of the primaries vegetables produced and consumed in Brazil, been the northeast, the main producing region, with approximately 35% of national production (Oliveira et al., 2016). This is due to the soil and climate conditions of the region, that when complemented with fertilization and irrigation allow the fruit to be grown all year round.

The northeastern semiarid is characterized by presenting dystrophic soils of low natural fertility, becoming essential the use of mineral fertilization for the achievement of satisfactory productions, once the watermelon is too demanding and exports a large amount of the nutrients accumulated over the cycle (Salviano et al., 2017; Silva Júnior et al., 2017). Furthermore, these areas present intense evapotranspiration demand and limited rainfall, making irrigation an indispensable practice for economically viable cultivation (Tavares Filho et al., 2020).

These conditions when associated to areas of lower degree of weathering and poor drainage, have contributed to the occurrence of salinization and/or sodification of soils, especially Na^+ and Cl^-, which in turn do not leach out and accumulate on the soil surface (Paiva et al. 2016).

The salinity in the soil can compromise the water and nutrients availability to the plants, directly affecting the osmotic potential of the soil solution (Nóbrega et al., 2018). In addition, the high level of exchangeable sodium causes degradation of the soil structure, clay dispersion, and plant toxicity and can even hinder seed germination and root development (Pedrotti et al., 2015).

The increase of salinization problems at irrigated

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perimeters in the semi-arid regions, has become a reason of great concern, specially, because of the high investments in infrastructure during implementation. Consequently, there is a need in define specifically, studies on the causes of salinization in irrigated areas in order to contain the negative effects of salinity caused by excessive use of mineral fertilizers.

In view of the relevance of the above theme, the aim of this work was to evaluate the effect of mineral fertilization, in watermelon cultivation, on soil salinization, in the irrigated perimeter Senador Nilo Coelho, Petrolina-PE, Brazil.

Materials and methods

The experiment was conducted at the Institute of the Sertão Pernambucano, Rural Area Campus Petrolina, located in the Senador Nilo Coelho Irrigation Perimeter (PISNC), in the municipality of Petrolina - PE (09º 09' S, 40º O and 365.5 m altitude).

The region's climate, according to the Köppen classification, is of the hot semi-arid type BSWh', with annual rainfall of less than 800 mm, distributed irregularly between the months of November and April. Temperatures in the cooler months of the year are above 18ºC, with an annual average of 27ºC, and evapotranspiration is in the order of 2700 to 3000 mm annually. The climatic data for the experiment period were obtained from the meteorological institute, Inmet (2020).

The soil of the experiment area was classified as Inceptisols of loamy texture, the relief of the area varies from steep to slightly mobile. The analysis of the chemical attributes of the soil, before mineral fertilization, is shown in (**Table 1**).

For the cultivation, watermelon seedlings of the 'Crimson Sweet' variety were produced in expanded polyethylene bottles. A commercial substrate based on crushed organic compost and vermiculite was used for the germination and development of the seedlings in a 50% light cover for 16 days.

Later, the seedlings were transplanted to the field in plots previously plowed, harrowed, and fertilized with simple superphosphate, applied by plowing, as recommended by soil analysis, and one liter of organic compost, applied per pit and incorporated at a depth of 15 cm.

In the field, the treatments: (T0) witness without fertilization, (T1) NPK fertilization according to the fertilization manual of the state of Pernambuco, (T2) average dose of NPK practiced by the producers, (T3) maximum dose of NPK of the producers having potassium chloride as potassium source and (T4) maximum dose of NPK of the producers having potassium sulfate as potassium source, were arranged in randomized blocks, with four repetitions. The fertility levels of each treatment are shown in (**Table 2**). Each experimental unit consisted of a 7x4 m plot, where 24 seedlings were planted, at a spacing of 3.5 between rows and 0.5 between plants. The experiment was conducted during four crop cycles, with a 10 days interval between transplanting the seedlings.

The nitrogen fertilization, applied as cover, around the plants, was divided into four applications, with a 10 days interval between each, the first being made 15 days after planting. The potassium fertilization started 45 days after planting, in three applications, at 10 days intervals.

The irrigation was performed by conventional sprinkling, using sprinkler with flow rate of 680 L.h^{-1} and radius of reach of five meters. The whole area was irrigated with five changes in the irrigation network and one hour of operation per position, obeying a two-day irrigation shift during the 72-day crop cycle, applying a volume of water per crop in the order of 612.000 L.

The cultural treatments such as pruning of branches, thinning of fruits and cleaning of the area through manual weeding, were carried out as needed. Four fungicide and insecticide sprays were made per season to control powdery mildew (*Sphaerotheca fuliginea*) and whitefly (*Bemisia tabaci*), respectively.

From 65 to 75 days after planting the seedlings, the fruits were harvested and then the soil was collected at a depth of 0 to 60 cm, in order to verify its chemical characteristics after cultivation. The soil samples were sent to the soil and plant analysis laboratory of the Institute of the Sertão Pernambucano, Rural Area Campus Petrolina, for determination of pH, Electrical Conductivity (EC), Organic Matter (OM), Phosphorus (P), Potassium (K^+), Calcium (Ca^{++}), Magnesium (Mg^{++}) and Sodium (Na^+), as recommended by Teixeira et al. (2017). The data were analyzed using the F test and the means were compared using Tukey's test at $p<0.05$ significance level using the SISVAR 5.3 program (Ferreira, 2011).

Table 1. Soil chemical analysis, before mineral fertilization, as a function of depth

Depth	pH	OM	P	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	BS	T	ESP
(cm)	H_2O	g kg^{-1}	Mg dm^{-3}	dS m^{-1}	----------------cmol$_c$ dm^{-3}----------------						%
0.0-20	6.26	15.5	6.2	0.9	0.1	0.4	2.1	0.4	3.1	4.9	2.0
20-60	6.31	11.3	2.3	0.9	0.1	0.3	2.0	0.4	2.8	4.6	2.4

pH (H_2O), OM (Wet Digestion), EC (Saturation Paste Extract) P, K^+ and Na^+ (Melich-1), Ca^{++} and Mg^{++} (KCl 1 mol L^{-1})

Table 2. Fertilizer doses as a function of treatments

Treatments *	Urea	Single superphosphate	Potassium chloride	Potassium sulfate
	--------------------------------	kg ha^{-1}	--------------------------------	
T1	0.0	0.0	0.0	0.0
T2	267	444	67	0.0
T3	257	503	194	0.0
T4	400	762	339	0.0
T5	400	762	0.0	407

(T1) no fertilization, (T2) NPK fertilization according to the fertilization manual of the state of Pernambuco, (T3) average dose of NPK practiced by the farmers, (T4) maximum dose of NPK of the farmers with potassium chloride as the source of potassium and (T5) maximum dose of NPK of the farmers with potassium sulfate as the source of potassium.

Results and discussion

The pH values in the 0 to 20 cm layer from the second cycle of watermelon production (**Figure 1**A) were higher in the control (T1) than in the other treatments with mineral fertilization. There was no difference in pH values between the other treatments that received mineral fertilization until the third cycle. After the fourth cycle there was a lower pH value, caused by the highest dose of potassium sulphate fertilization (T5), in relation to the other levels of fertilization. In the depth of 20 to 60 cm (Figure 1D), only from the third cycle onwards, the highest doses of mineral fertilization caused a reduction in pH values, which was more visible in the fourth cycle, where the lowest pH values were observed in treatments 4 and 5, which did not differ. This is possibly due to the greater quantity of potassium used in these fertilizers, regardless of the potassium source.

The balance presented in the cycles can be attributed to the addition of organic compost, since OM exerts buffering power on the soil (Rosa et al., 2017). In the other treatments, the reduction in soil pH over the fertilization cycles can be explained by the acidification caused by nitrogen fertilizers, when a source of nitrogen applied to the soil, before becoming available to plants, undergoes the nitrification phase, thus causing reactions that release H^+, as well as loss of cations to deeper layers, accompanying the anion NO^{3-} (Arnuti et al., 2017; Medeiros et al., 2017).

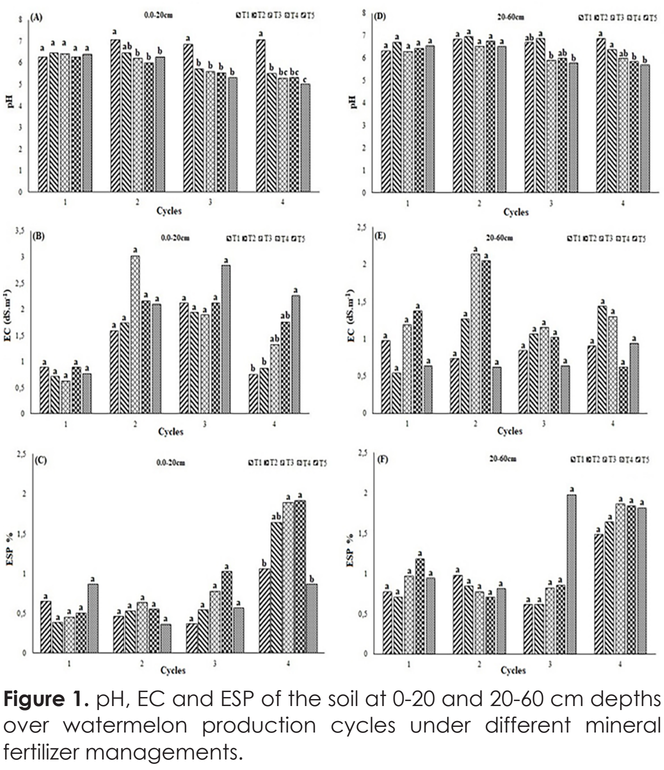

Figure 1. pH, EC and ESP of the soil at 0-20 and 20-60 cm depths over watermelon production cycles under different mineral fertilizer managements.

The classification of soils as to the presence of salts is based on the electrical conductivity and the percentage of exchangeable sodium. EC values between 2.1 and 4.0 dS.m^{-1}, by the saturated paste method, are classified as slightly saline in all textures and below this result as not saline (Smith and Doran, 1997).

The electrical conductivity in the saturation extract varied according to fertilization only in the 4th cycle, at a depth of 0 to 20 cm, with the highest value recorded at T5, which did not differ, $p<0.05$, from T4 and T3, by Tukey's test (Figure 1B). The lowest values of EC found in the control and fertilization based on the recommendation of the state of Pernambuco (T1 and T2, absence and lower dose of mineral fertilization, respectively). This reveals that the variation in EC is proportional to the dose of mineral fertilization applied. The EC at depth 20 - 60 cm (Figure 1E) was not influenced by the treatments and did not show a tendency to increase over the four cycles of watermelon cultivation. The large variations, which were not significant, recorded in cycle 2 may be attributed to the high coefficient of variation of the data.

According to Lucena et al. (2011) and Silva Júnior et al. (2017), watermelon is classified as moderately sensitive, in relation to tolerance to salinity, however, there are no losses in the potential yield of the crop when subjected to irrigation with water from 1.5 to 2.0 dS.m^{-1}. However, when salinity reaches 4.2 dS.m^{-1} there is 50% yield reduction. Brito (2021) observed that increasing levels of salinity in irrigation water promoted a significant decrease in the agronomic parameters and quality of Crimson Sweet watermelon.

The treatments (T2, T3 and T4) whose potassium source had chloride as a companion ion promoted higher values of the exchangeable sodium percentage (ESP) only in the fourth cycle of cultivation, where they were higher than those without mineral fertilization and fertilization with potassium in sulphate form (Figure 1C). This allows us to hypothesize that the accompanying anion of potassium in mineral fertilization may contribute to the decrease in adsorbed sodium, in the case of SO_4^{2-}, by the formation of strong ionic pairs in the soil solution, with Na^+

displaced from the exchange complex. This explains the higher value of EC, in the fourth cycle, in T5, which had potassium sulfate as a source of K_2O (Figure 1B).

The ESP in the 20-60 cm layer was not influenced by the fertilizers in any of the crop cycles, but there was a tendency for the ESP to increase in the fourth crop cycle, regardless of the type of fertilizer and fertilizer sources (Figure 1F). According to Ribeiro et al. (2016), the results of ESP are considered normal and there is no risk of sodicity due to the non-use of Na^+ based fertilizers.

The values of organic matter (OM), (**Figure 2**A and 2C), were not influenced by mineral fertilization at any of the depths throughout the four cycles of study, at $p<0.05$, by the Tukey test. However, there was a tendency of reduction in OM content, in the fourth cycle, in the 0 - 20 cm layer, with values less than 15 $g.kg^{-1}$ in T1, T3, T4 and T5. According to Coulas et al. (2021), the reduction in OM content is caused by the high microbiological activity of the soil that decomposes it quickly, since this behavior is enhanced by the climatic conditions of the region. However, in the 20-60 cm depth there is a tendency to increase the OM content, independent of fertilization, due to the inversion of the soil layer at the time of ploughing, thus incorporating organic material (Figure 2C).

The P content of the soil at a depth of 0-20 cm (Figure 2B) increased gradually, from the second cycle of cultivation, as a function of mineral fertilization, independent of the source of potassium fertilizer. A $p<0.05$, by Tukey test. In the depth of 20-60 cm the contents of P were not affected by mineral fertilization throughout the cycles of cultivation, at the same probability and mean test. The lowest levels were observed at T1, until the 3rd cycle, which did not receive any type of fertilizer (Figure

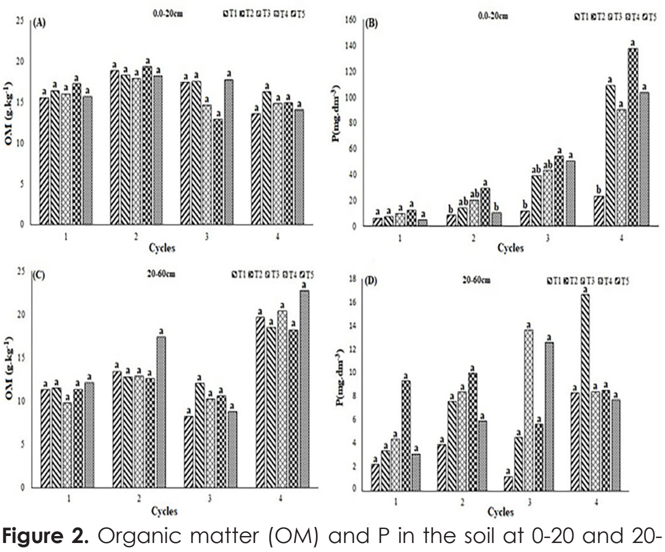

Figure 2. Organic matter (OM) and P in the soil at 0-20 and 20-60 cm depths throughout watermelon production cycles under different mineral fertilizer managements.

2D).

The continuous applications of fertilizer resulted in the increasing accumulation of available P on the soil surface. This is due to the low mobility of this element in the soil, where part of the soluble P applied is used by plants and the other part is adsorbed in a labile form because it is a cambisol. The average levels of Ca^{++} these soils favor the precipitation of P as calcium phosphate (Andersson et al., 2019; Cabeza et al.,2017; Souza et al., 2020).

In the second cycle, the lowest Ca^{++} content in the 0 -20 cm layer was observed in T3, differing from T1, at $p<0.05$, by Tukey's test; the other treatments did not differ (**Figure 3**A). In the first cycle of cultivation, Ca^{++} contents above 9 $cmol_c.dm^{-3}$ were recorded in all fertilizers tested. The Ca^{++} content of the soil tended to decrease over the cycles, reaching values around 4 $cmol_c dm^{-3}$, except for T4, in the fourth cycle. This decrease is due to the absorption by the plant without replacement and inactivation of Ca^{++} by precipitation in the form of calcium phosphate (Soares et al., 2018). At a depth of 20-60 cm the soil calcium content varied with mineral fertilization only in cycle 2, with the lowest value at T5, possibly due to precipitation with SO_4^{2-} (Figure 3D).

Fertilization did not cause variation in Mg^{++} content in the 0-20 cm layer, in cycles 1 and 3, at $p<0.05$, by Tukey test. In cycles 2 and 4, in the same soil layer, the Mg^{++} content tended to be higher in T1 than in the treatments with mineral fertilization, however, the treatments T3 and T5, in the 2nd cycle, and T4, in the 4th cycle, were lower than the control (T1), at $p<0.05$, by Tukey test (Figure 3B). At the depth of 20 - 60cm the Mg^{++} content in the soil was not influenced by the treatments in any of the crop cycles (Figure 3E). Also in this figure, it is observed that in cycles 1, 2, 3 and 4 the Mg^{++} content of the soil remained close to 2 $cmol_c.dm^{-3}$, which when compared with the respective values of the layer 0 - 20cm, it is verified that there was a slight displacement of this nutrient to the layer 20 - 60cm, due to the presence of sulfate, forming ionic pairs, thus facilitating the displacement to the deeper layers, as a result of high mobility (Nora et al., 2017).

The treatments affected the K^+ contents of the soil, in the 0 - 20cm layer, in cycles 2 and 4, at $p<0.05$, by Tukey's test. Fertilization based on the recommendation of the state of Pernambuco contributed the lowest K^+ content in the soil in the second cycle, differing from the other treatments. In the 4th cycle the lowest K^+ content in the soil was recorded in the control, which did not receive mineral fertilization. The other treatments did not differ, $p<0.05$, by the Tukey test (Figure 3C). In the 20 - 60 cm layer, the treatments had no effect on the K^+ contents,

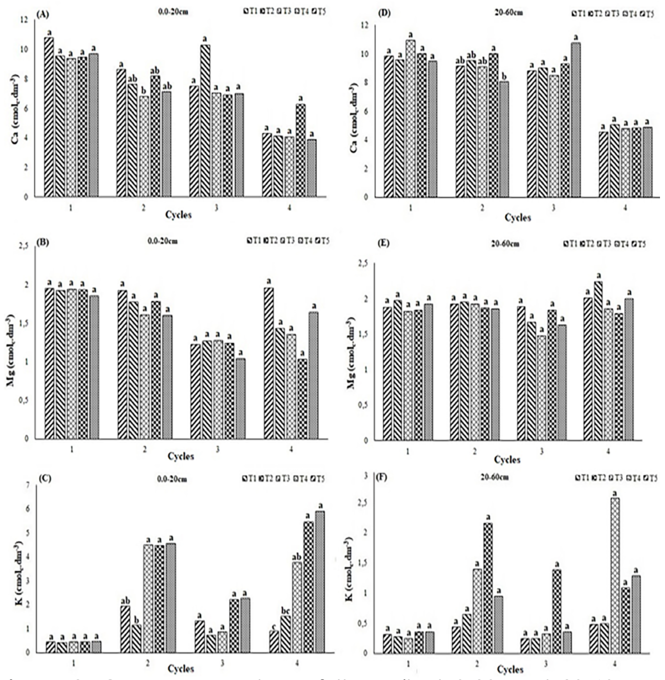

Figure 3. Ca^{++}, Mg^{++} and K^{+} of the soil at 0-20 and 20-60 cm depths along watermelon production cycles under different managements of mineral fertilization.

at p<0.05, by the Tukey test, throughout the crop cycles (Figure 3F). Evaluating the magnitude of the K^{+} contents in the 0 - 20 cm layer with those in the 20 - 60 cm layer, the values in this deeper layer were lower, but higher than those found in the soil characterization, indicating the occurrence of K^{+} leaching over the cycles.

Conclusions

After three consecutive cycles of conventional watermelon cultivation the soil reaches a level of salt concentration considered harmful to the crop under the soil conditions studied.

These results reinforce the need for greater attention to the suitability of soils for irrigated cultivation, as well as adequate management of water and nutrients.

Potassium sources showed no difference in salinity.

The potassium dose based on the fertilization manual showed lower salinization compared to the doses practiced by farmers.

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