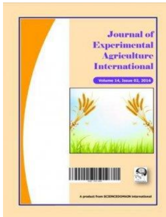

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Phytomass and Components of Sesame Grown in Different Soil Salinity Levels and Nitrogen Fertilization

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Authors' contributions

This work was carried out in collaboration between all authors. Authors VFOS, AVD and EGS conducted the experiment, data collection and statistical analysis. Authors VFOS and MHBSR wrote the manuscript. Authors JBS and CCC performed the corrections of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Sesame has an elevated productive potential especially in semiarid areas. However, these areas present abiotic factors that limit the production of agricultural cultures, and one of them is the salinity level.
Objectives: To evaluate the phytomass and production of sesame plants submitted to soil salinity and nitrogen fertilization.

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Place and Duration of the Study: The experiment was conducted in the months of December 2016 to April 2017, in an experimental area belonging to the Federal University of Campina Grande, in the Science and Food Technology Center, located in the municipal district of Pombal, Paraíba.
Methodology: The treatments were composed of five salinity levels of saturation extract (0.9; 1.7; 2.5; 3.3 and 4.1 dS m^{-1}) and five doses of nitrogen (40; 70; 100; 130 and 160%), constituting a factorial 5x5, with three repetitions and with a experimental design of randomized blocks. The cultivar employed was the BRS silk, whose sowing was made in 18-liter polypropylene vases filled with 22 kg of local soil. One hundred and ten days after the sowing process, the following parameters were analyzed: aerial part dry mass, root dry mass and total dry mass, electric conductivity of the saturation extract, number of fruits, fruit mass and seed mass.
Results: There was a significant effect for all analyzed variables. The salinity level of the soil was inversely proportional to the sesame production.
Conclusion: High doses of nitrogen reduce the culture's yielding and potentiate the deleterious effects of the soil's salinity. The nitrogen fertilization at 70% of the recommended values was the best to reduce the saline stress in the studied conditions.

Keywords: Sesamum indicum L.; saline stress; mineral nutrition; yielding.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is a species that belongs to the Pedaliaceae family, which is one of the oldest existing cultures. It is grown along the tropics and subtropics, and is considered an oleaginous culture, relevant for the productive potential of high-quality, scentless and eatable oil, with excellent nutritional characteristics and properties for industrial ends [1].

In the area of the Brazilian Northeast, it is grown by small and medium producers, mainly for subsistence, with few marketed surpluses. There are not many initiatives that encourage the semiarid producers to grow sesame because this region has physical-environmental characteristics that can reduce the productive potential of several cultures: high evapotranspiration, rainfall unevenly and badly distributed over the year, soils with reduced depth, low water retention capacity or even salinized [2].

The osmotic effect promoted by the salts reduces the water absorption capacity of the plants. Additionally, some specific ions result in functional disturbances and damages, especially in the leaves, changing the plants' physiologic and metabolic processes, jeopardizing the plants' quality [3].

Salinity is one of the abiotic factors that limit the cultures' production because it results in nutritional unbalance, absorption inhibition of other cations, osmotic potential decrease and toxicity of given ions (mainly Na^+ and Cl^-), jeopardizing essential physiologic activities of the plant [4]. Nonetheless, through a proper field management, it is possible to obtain a satisfactory productive yielding if the culture's basic demands of water consumption and nutrition are satisfied. For example, the use of fertilizers, mainly nitrogen sources, are indicated as a viable alternative to reduce the deleterious effects of the presence of salts in the soil, as stated by Anjos et al. [5], Lima et al. [6] with castor oil plant and [7] sunflower.

Nitrogen (N) is a macronutrient highly demanded by the plants, mainly because it directly partakes in their metabolism, in the composition of biomolecules (ATP, NADH, NADPH), proteins and countless enzymes. However, less than 50% of the nitrogen applied as fertilizer is usually employed by the cultures. Such loss is caused by countless processes, to which it is subject. The nitrogen is mainly lost by nitrate leaching, volatilization of ammonia and emission of N_2, N_2O and other nitrogen oxides. The lack or surplus thereof can result in nutritional disorder, causing a decrease in the production and in the oil level [8,9].

Therefore, an appropriate supply of N for oleaginous plants is extremely important for productivity in environments with higher levels of salt because the efficiency thereof in the soil is related to the recovery degree of the plants, considering the losses that usually happen, enabling greater economical returns to the producer due to the decrease of the production costs and the increase of productivity. Consequently, the purpose hereof was to evaluate the phytomass and the production components of sesame grown in soil of different salinity levels and nitrogen fertilization.

2. MATERIALS AND METHODS

The experiment was carried out in an experimental area of the Federal University of Campina Grande, in the Science and Food Technology Center (UFCG/CCTA), located in the municipal district of Pombal, PB, located at 6º48'16" S, 37º49'15" W and average height of 144 m.

The treatments consisted of five salinity levels of the saturation extract with the following electric conductivities - CEes: 0.9; 1.7; 2.5; 3.3 and 4.1 dS m^{-1} and five nitrogen doses (40; 70; 100; 130 and 160%), based on the recommendation of Novais et al. [10]. The salinity levels were obtained through the dissolution of sodium chloride (NaCl), considering the initial soil salinity (0.9 dS m^{-1}), the soil weight per vase (22 kg) and the saturation percentage (32%). The statistical design was a completely randomized block design in a 5 x 5 factorial outline, with three repetitions.

Seeds of the sesame cultivar BRS Silk were sowed in 18-liter polypropylene vases, filled with 22 kg of local soil. Thirty seeds were deposited per container at a medium depth of 0.5 cm, properly distributed at a distance of 0.9 m between rows and 0.7 m between plants. Fifteen days after sowing - DAS, the first thinning was performed, after which only 6 plants per vase remained. The second thinning was performed 20 days after sowing, after which only 2 plants remained. The third and last one was performed 30 days after sowing, after which only the most vigorous plant remained.

The soil used to fill the vases was collected at a depth of 0-20 cm, which was later smashed and sieved. Their chemical characteristics (Table 1) were ascertained in the Laboratory of Irrigation and Salinity of the UFCG, according to the methodologies proposed by Donagema et al. [11].

Still according to the recommendation of Novais et al. [10], the fertilization was performed with simple superphosphate, in the dose of 300 mg of P_2O_5 kg^{-1} of soil, applied at the base one day before sowing, and potassium nitrate, as the potassium source, at the dose of 150 mg of K_2O kg^{-1} of soil. The last one was divided into three applications, corresponding to a fourth at sowing and three fourths in two equal portions at 20 and 40 DAS. As for the nitrogen fertilization, it was applied according to the treatments and divided into three applications, similarly to the potassium fertilization, using ammonium sulfate as its source.

The irrigation was performed according to the daily irrigation sheet, elaborated through the hydric balance of the root zone, which was obtained by subtracting the drained volume from the applied volume (VI = VA - VD) in the previous irrigation.

Table 1. Chemical characteristics of the soil used in the experiment

Chemical characteristics of the soil	Chemical characteristics		
	Values	**Saturation extract of the soil**	**Values**
pH (H_2O) (1:2,5)	6.46	pH	6.44
OM (g kg^{-1})	21.20	CEes (dS m^{-1})	0.90
P (mg dm^{-3})	2.40	Chloride ($mmol_c$ L^{-1})	4.75
Ca^{2+} ($cmol_c$ kg^{-1})	9.07	Carbonate ($mmol_c$ L^{-1})	0.00
Mg^{2+} ($cmol_c$ kg^{-1})	3.47	Bicarbonate ($mmol_c$ L^{-1})	7.50
K^+ ($cmol_c$ kg^{-1})	0.60	Calcium ($mmol_c$ L^{-1})	5.50
Na^+ ($cmol_c$ kg^{-1})	0.10	Magnesium ($mmol_c$ L^{-1})	4.62
Al^{3+} ($cmol_c$ kg^{-1})	0.00	Potassium ($mmol_c$ L^{-1})	0.86
H^+ ($cmol_c$ kg^{-1})	1.52	Sodium ($mmol_c$ L^{-1})	1.73
SB ($cmol_c$ kg^{-1})	13.24	RAS (mmol L^{-1})$^{1/2}$	0.76
T ($cmol_c$ kg^{-1})	14.76	Saturation percentage	32.00
V (%)	89.70	Salinity	Non saline
PES (%)	0.68	Class of the soil	Normal

OM - Organic matter; T - Cation exchange capacity - [SB + (H^+ + Al^{3+})]; SB - Sum of bases (Ca^{2+} + Mg^{2+} + K^++ Na^+); V - Saturation for bases = (SB/CTC) x 100; CEes - Electric conductivity of the saturation extract; PES - Percentage of exchangeable sodium (Na^+ x 100/CTC)

The following variables were determined 110 DAS:

Number of fruits per plant (NFP): through the counting of the total number of fruits for plant; Fruit mass per plant (MFP): weighting all fruits in an analytical precision scale (0.001); Seed mass per plant (MSP): obtained after the manual removal of the seeds from the inner part of the green bean and their weighting in an analytical scale; Aerial part (MDAP), root (MDRP) and total dry mass (MTDP) per plant: the aerial and root parts of the plants were separated, put in paper bags, separated for treatment, previously identified and dried in a muffle set at 65°C until a constant weight was reached (48 hours). Then, the samples were weighted in an analytical scale of a precision of 0.001 g. The total dry mass was determined by the sum of the aerial part dry mass and root dry mass. All results were expressed in grams per plant.

Electric conductivity of the soil's saturation extract: was obtained through the methodology of Richards [12]. The soil was used to prepare 300 g of saturation paste. Distilled water was poured into it until it reached a paste consistency. Then, the samples rested for 24 h, after which they were submitted to a vacuum system to obtain the extracts. Afterwards, the CEes of each solution was evaluated with the assistance of a conductivity meter and for the automatic correction of temperature.

The data were submitted to the analysis of variance by the 'F' test at the probability levels of 0.01 and 0.05 and, when significant, a regression analysis was performed with the assistance of the statistical software SISVAR 5.6 [13].

3. RESULTS AND DISCUSSION

One hundred and ten days after sowing, it was verified that the electric conductivity of the saturation extract, root and total dry mass, fruit mass and number of fruits were significantly affected ($p < 0.05$) by the interactive effect of both factors (soil salinity and nitrogen doses). In other words, both acted simultaneously in the sesame plants. On the other hand, the seeds' dry mass was significant ($p < 0.01$) for isolated factors (Table 2).

While comparing the greatest (4.1 dS m^{-1}) and lower (0.9 dS m^{-1}) saline levels, the electric conductivity of the saturation extract (CEes) at the end of the sesame cycle greatly increased (116,68%) with the fertilization at 160% of N (Fig. 1). The dose of 40% of N was also directly proportional to the increase of the salinity in the soil, corresponding to 94% in comparison with the conductivity 0.9 to 4.1 dS m^{-1}. In the other N dosages (70, 100 and 130%), the minimum values were 3.59, 4.17 and 4.71 dS m^{-1} at the soil salinities of 2.32, 2.24 and 2.02 dS m^{-1}, respectively.

Therefore, the soil's electric conductivity was directly proportional to the use increase of N, which is explained by the presence of salts in the fertilizer also, resulting in the accumulation of toxic ions. The alterations of the electrolytic concentration in the proportional solution increase the amount of ions [14]. Ammoniacal sources, can also acidify the soil through local applications and consequent interfere with the nitrification process because such resulting acidity hinders the activity of bacteria responsible for the nitrification, therefore reducing the conversion of ammonium to nitrate, which is the assimilable form of N for the plants [15]. A similar effect was reported by Lima et al. [16], while evaluating the saturation extract's electric conductivity in different salinity levels and doses of nitrogen for castor oil plants. Therefore, the minimum conductivity values, mainly at the dose of 70% of N, can be possibly explained by the fact that this concentration did not interfered that much in the acidification of the soil.

For the sesame's root dry mass over the increasing doses of nitrogen and soil salinity (Fig. 2A), it was observed that doses of 40 and 100% of N presented a decreasing lineal behavior with their respective reductions of 42 and 67% in comparison with the greatest (4.1 dS m^{-1}) and the lower (0.9 dS m^{-1}) saline levels of the soil. At the doses of 70 and 160% of N, it was verified that the data were adjusted to quadratic equations, reaching an estimative of 95 maximum values and 105 g of root dry mass in the soil salinity of 1.7 and 1.2 dS m^{-1}, respectively, which was drastically reduced over the addition of salts. As for the dose of 130% of N, a quadratic tendency was verified, with a minimum of 41 g in the soil salinity of 4.1 dS m^{-1}.

The total dry mass was also influenced by the evaluated treatments, in which the doses of 40 and 130% of N presented a descending lineal behavior, with a reduction of 25.14 and 95.85%, reaching the minimums of 146.8 and 129.07 g at the concentration of 4.1 dS m^{-1}, respectively (Fig. 2B). As for the doses of 70 and 100%, a quadratic behavior was reported, reaching minimum values of 125.15 and 111 g at the salinity of 4.1 dS m^{-1}. On the other hand, the dose of 160 g of N presented a positive effect at the salinity of 1.7 dS m^{-1}, with a maximum of 212 g. However, the soil salinity's unitary increase presented a negative effect. Consequently, the salinity of 4.1 dS m^{-1} resulted in the lower values (100 g).

The reduction observed in the root and total dry mass is equally related to the soil salinity and to the elevation of the N doses, which also can elevate the soil's salinity or quickly increase the concentration of ammonium ions in the soil, resulting in toxicity to the plants and in physiologic disorders, which results in cellular division, growth and, consequently, in the amount decrease of photoassimilates for the plants, which hinders the production [17].

Sousa et al. [18], while studying the influence of the saline water in the sesame culture cultivated in vases, verified that the unitary increase of salinity causes the decrease in biomass accumulation, with a reduction of 59.78% for root dry mass and 56.96% for total dry mass between the intervals of 0.8 to 4.5 CEes. Lima [19] reported that the fertilization with nitrogen does not reduce the deleterious effects of saline stress on the growth and production in cotton plants, cv. 'BRS Rubi.' It merely increases their development.

Table 2. Summary of the F test for the electric conductivity of the saturation extract (EC), number of fruits per plant (NF), fruit mass per plant (FMP), seed mass per plant (SMP), aerial part dry mass (DAPM), root dry mass per plant (RDMP) and total dry mass per plant (TDMP) of sesame 110 days after sowing (DAS) in different soil salinity levels and nitrogen fertilization

Variation source	F Test						
	EC	NF	FMP	SMP	DAPM	RDMP	TDMP
Salinity (S)	**	**	**	**	ns	**	**
Linear Reg.	**	**	**	**	ns	**	**
Quadratic Reg.	ns	ns	ns	ns	ns	Ns	Ns
Deviation	ns	ns	ns	ns	ns	Ns	Ns
Nitrogen (N)	**	ns	ns	**	ns	Ns	Ns
Linear Reg.	**	ns	ns	**	ns	Ns	Ns
Quadratic Reg.	ns	ns	ns	**	ns	Ns	Ns
Interaction (S x N)	**	*	*	ns	ns	**	**
Block	ns	ns	ns	ns	*	Ns	*
CV (%)	8.72	18.06	20.35	22.38	18.54	33.77	21.58

*ns, **, * respectively, no significant, p <0.01 and p <0.05 significant; CV = variation coefficient*

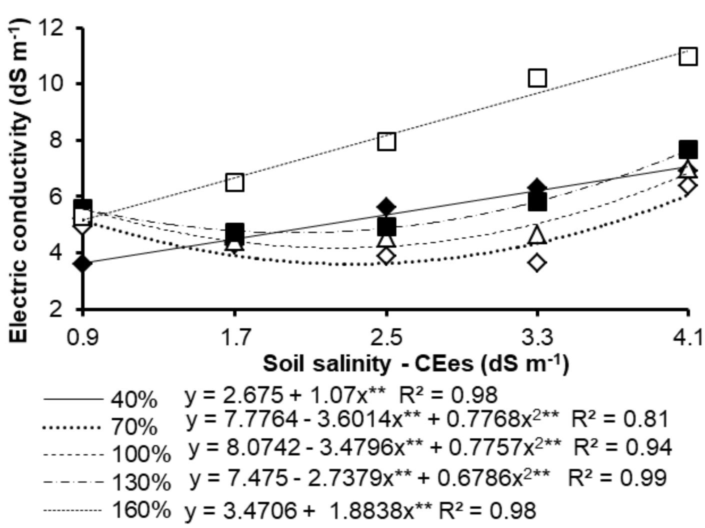

Fig. 1. Electric conductivity of the soil's saturation extract at the end of the sesame cycle submitted to different soil salinity levels and nitrogen fertilization. UFCG, Pombal, 2018

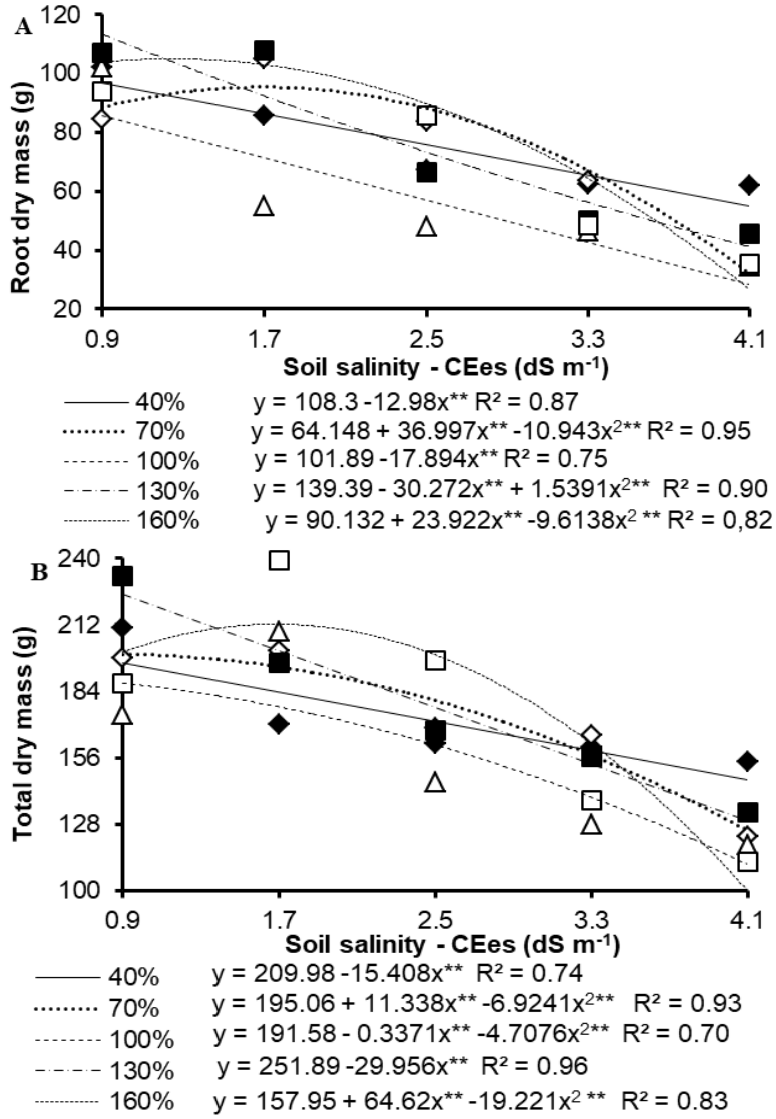

Fig. 2. Root dry mass (A) and total dry mass (B) of sesame submitted to different soil salinity levels and doses of nitrogen fertilization. UFCG, Pombal, 2018

The fruit yielding was significantly affected by the increase of the salt level and N doses. The fruit mass for the percentages of 40, 100, 130 and 160% of N was inversely proportional to the increase of salt in the soil, decreasing from 39.89 to 26.91 g (40% N), 48.24 to 30.81 g (100% N), 49.67 to 20.01 g (130% N), 44.85 to 29.99 g (160% N) between the lower and greater saline level (Fig. 3A). On the other hand, the use of the 70% dose of N presented an increase of 3.98% in the conductivity 1.65 dS m^{-1} CEes, decreasing from these saline levels in the soil onwards. According to Silva et al. [20], there is probably a competition in the absorption of the plant for nitrate and chloride. Therefore, an increase in the nitrate concentration at the roots can inhibit a greater absorption of chloride, which consequently optimizes the plant's production, even under stress conditions, which explains why it happened at the dose of 70% of nitrogen.

Similarly, the number of sesame fruits decreased to 30.17; 32.75; 56.26 and 23.58% at the doses of 40, 100, 130 and 160% of N, respectively, at the interval between 0.9 and 4.1 dS m^{-1} of the soil's saturation extract (Fig. 3B). However, the nitrogen fertilization at 70% presented a quadratic behavior, increasing until the conductivity of 1.43 dS m^{-1}, corresponding to 129.54 fruits per plant, and decreasing with greater saline levels of the soil.

The reduction of the number of fruits is related to physiologic disturbances caused by the increase of salinity, which changes the osmotic potential and, consequently, reduces the plant's water consumption and its absorption of nutrients. It directly affects the fixation index of the fruits [21]. Dias et al. [22], while evaluating the influence of saline stress and different levels of nitrate and ammonium on the emergence, growth and production of sesame, reported a reduction of 31.45% in the number of fruits for every unitary increase of the irrigation water's electric conductivity. However, they did not report any beneficial effect in the evaluated doses of N.

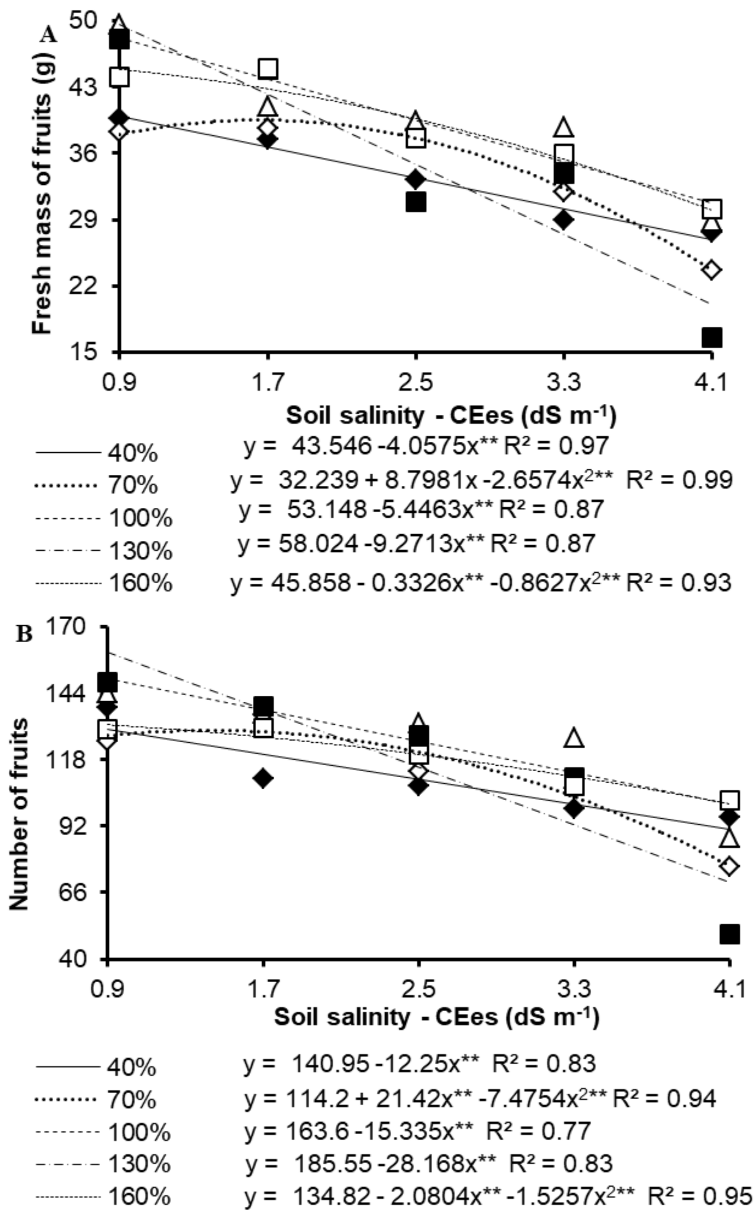

Fig. 3. Fresh mass of fruits (A) and number of fruits (B) of sesame submitted to different levels of soil salinity and doses of nitrogen fertilization. UFCG, Pombal, 2018

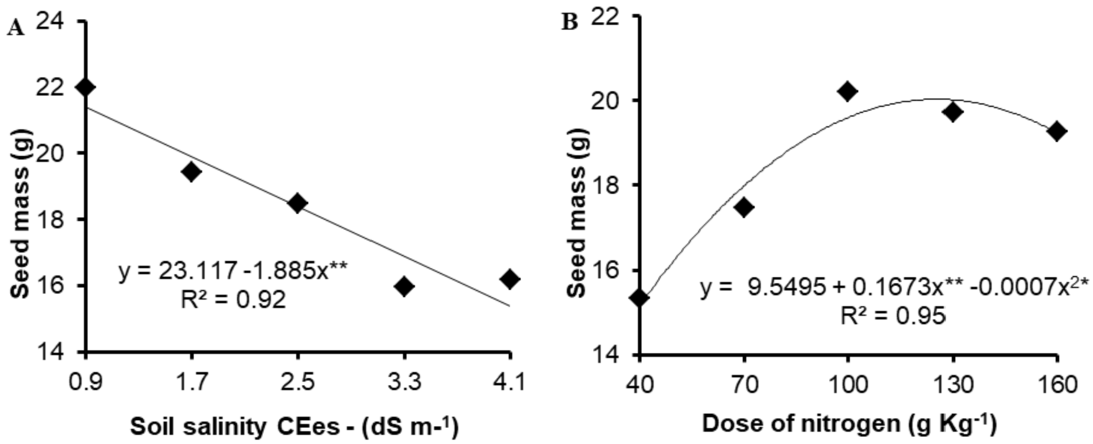

Fig. 4. Mass of sesame seeds submitted to different soil salinity levels (A) and doses of nitrogen fertilization (B). UFCG, Pombal, 2018

A decreasing lineal behavior was reported during an isolated analysis of the soil's salinity on the seed mass, with a reduction of 28.1% for the plants cultivated with a soil salinity level of 4.1 dS m^{-1} (CEes) in comparison with the plants cultivated at 0.9 dS m^{-1}, reaching a minimum of 15.38 g of seeds per plant when submitted to 4.1 dS m^{-1} (Fig. 4A).

Such inversely proportional behavior at the increase of the saturation extract electric conductivity is related to growth inhibition and, consequently, with biomass accumulation, which is caused by the deleterious effects of the salts absorbed by the plants, which result in a low osmotic adjustment capacity of the species and in a reduction of the total water potential caused by the saline concentration increase, resulting in seed production losses [23].

A similar behavior was reported by Dias et al. [22], who evaluated the sesame production under saline stress. A decrease of 26.04 g in seed mass was reported when the plants were submitted to 4.4 dS m^{-1} of CEes, in comparison with the ones grown at a salinity level of 0.4 dS m^{-1}. Therefore, salinity has deleterious effects in the seed production of plants of this species.

The use of nitrogen fertilization resulted in a quadratic behavior for seed mass, with a maximum point at the dose of 119.5 g Kg^{-1} of Nitrogen, with 19.54 g, decreasing 5.87% from this concentration of N onwards (Fig. 4B). Consequently, this dose tends to favor the production of seeds because nitrogen, besides of elevating the plants' osmotic adjustment capacity to the saline stress, favors the resistance of the different cultures to other abiotic stresses [24]. Therefore, the use of the nitrogen fertilization increased the production, corroborating with Santos et al. [25], who evaluated irrigation with saline water and nitrogen fertilization on sunflower growth, in which the increase of the nitrogen supply resulted in a greater production of achenes.

4. CONCLUSIONS

The soil salinity level was inversely proportional to the sesame phytomass accumulation and production;

High doses of nitrogen caused the reduction of sesame yielding and potentiate the deleterious effects of the soil's salinity;

The nitrogen fertilization at 70% of the recommended values was considered the best one for the reduction of saline stress in the evaluated conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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