

Full Length Research Paper

Yield of the hydroponic lettuce under levels of salinity of the nutrient solution

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Hydroponic cultivation is a viable alternative, given the water scarcity scenario, since this technique uses water rationally and without waste. However, it is necessary to monitor the salinity of the nutrient solution, especially in leafy vegetables such as lettuce. The aim of this research is to examine the yield of hydroponic lettuce under different salinity levels of the nutrient solution, in greenhouse. The experiment was conducted in a hydroponic system installed in a greenhouse belonging to the Federal University of Campina Grande. The experiment was carried out in a randomized block design, in a 5 x 2 factorial scheme: the first factor is five salinity levels of the nutrient solution (S1 = 1.0, S2 = 1.3, S3 = 1.6; S4 = 1.9 and S5 = 2.2 dS m⁻¹) and the second factor is two lettuce cultivars (Robusta and Bs55), with three replicates. The isolated cultivar factor did not significantly influence any of the analyzed variables of the hydroponic lettuce. The different levels of salinity of the nutrient solution positively influenced the variables analyzed: leaf area, SPAD index, chlorophyll a, b and total, and yield of leaves of hydroponic lettuce. Hydroponic lettuce can be grown up to 2.2 dS m⁻¹ of electrical conductivity of the nutrient solution without any loss in yield.

Key words: *Lactuca sativa* L., hydroponic, chlorophyll, electrical conductivity.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is one of the leafy vegetables mostly present in the diet of Brazilian population. It is a source of vitamins and minerals in the diet of the population and is notable for its low caloric value; it is widely used in balanced diets and recommended by nutritionists. It occupies an important part of the national market and acquires an increasing importance in the

country's economy (Filgueira, 2008; Lima et al., 2008; Lopes et al., 2011).

According to Aquino et al. (2007), because it is a sensitive crop to adverse climatic conditions, an alternative to minimize this situation is the cultivation in protected environment of the vegetable. In this context, hydroponic cultivation represents an advantageous

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alternative when compared to conventional cultivation, to obtain superior products, more uniform, with higher yield, lower labor costs, lower consumption of water and agricultural inputs, besides the environment preservation (Paulus et al., 2010).

In the semi-arid region of Brazil, most of the producers use water collected in surface reservoirs for the cultivation of vegetables, which can present high concentrations of salts, where values of relatively high electrical conductivity are often found (Costa et al., 2004; Souza Neta et al., 2013). According to Soares et al. (2007). A viable alternative may be the use of saline waters in hydroponic crops, since the tolerance of plants to salinity in this cultivation system is greater than the conventional system. Among the hydroponic producers, lettuce is the most widespread crop due to its short cycle and guarantee of economic return, and the most commonly used technique is the Laminar Nutrient Film (NFT = Nutrient Film Technique) (Alves et al., 2011; Paulus et al., 2012). However, specialized technical follow-up is necessary in order to have the balanced nutrient solution, that provides adequate nutrition to the plants and to avoid the effect of the toxicity of some ions to the plants.

Currently, research has been developed to provide information for the use of waters with relatively high levels of salts as an input for the leafy vegetables cultivation hydroponic system (Santos et al., 2010; Paulus et al., 2010; Alves et al., 2011; Souza Neta et al., 2013). However, there are still few studies developed for the lettuce culture submitted to saline stress, where in the already developed studies different effects were observed, thus demonstrating that more studies need to be developed.

In view of the above, the aim of this research is to examine the yield of the hydroponic lettuce under different salinity levels of the nutrient solution, in greenhouse.

MATERIALS AND METHODS

Characteristics of the experimental area

The experiment was carried out in a greenhouse belonging to the Federal University of Campina Grande (UFCG), located in the municipality of Campina Grande, Paraíba State, Brazil, under the geographical coordinates of 7° 13' 11" South latitude, 35° 53' 31" West longitude and altitude of 550 m. The greenhouse is of the chapel type and has a structure in galvanized arches, with dimensions of 6.0 m width, 10 m in length and 3.00 m ceilings; it is covered with glass fiber tiles, and sides wrapped with screen that allow the partial passage of the wind, softening the internal temperature. The structure has five alternative hydroponic system benches with PN40 PVC pipes, spaced from each other by 0.60 m, with initial height of 0.76 m and slope of 2%. The profiles are spaced at 0.20 m and have a length of 3.0 m as a simplified layout (Figure 1). The seedlings were produced in phenolic foam substrate for germination and rooting. These foams were previously washed with running water, to eliminate possible remaining residues of their manufacture. The development of the seedlings was done in a

hydroponic structure, called nursery. Transplanting was performed when lettuce seedlings presented four definitive leaves, seven lettuces were seedlings spaced at 0.20 m between plants, in each laminar flow profile of nutrients. During the experimental period, data were collected on the temperature and relative humidity of the air, from transplanting to harvesting, corresponding to 21 days after transplanting (DAT). Data were collected through a Digital Hygrometer installed inside the greenhouse.

Design, treatments and planting system

The experiment was organized as a randomized block design (RBD), arranged in a 5 x 2 factorial scheme. The first factor consisted of five salinity levels of the nutrient solution (S1 = 1.0, S2 = 1.3, S3 = 1.6; S4 = 1.9 and S5 = 2.2 dS m⁻¹) and the second factor, two cultivars of curly lettuce: Robusta and Bs55. Three replicates were used, corresponding to 10 treatments and 30 experimental units; each unit experimental plant was composed of 6 plants. It is necessary to mention that two plants were left as a border: the first and the last plant in each laminar flow profile of nutrients, with a total of 210 plants. The profiles were labeled with each treatment and their respective replication.

System characteristics and nutrient solution management

The profiles for each treatment were interconnected to rigid plastic reservoirs with a capacity of 100 liters (a total of 5 reservoirs), where the nutrient solutions were stored, corresponding to each treatment. Each reservoir consisted of an EMICOL Class H 322139 electro-pump, with a flow rate of 900 L h⁻¹. Each electric pump was connected to an analog timer, connected to the electric power, to keep the solution circulating automatically. The timers were programmed to start or stop the pump every 15 min.

The preparation and management of the nutrient solution was according to the recommendation of Furlani et al. (1999) for all treatments. The formulation used to prepare the solution was composed of HidrogoodFert, which contains all the macronutrients and micronutrients necessary for the proper development of the culture. The compound was added to the water along with Calcium Nitrate and Iron Chelate. For the treatments S1, S2, S3, S4 and S5 the solution was prepared with rainwater, due to the low salinity that presents 0.245 dS m⁻¹. The daily monitoring of the solutions to guarantee the electrical conductivity in each treatment was carried out. The Mca 150 benchtop conductivity meter was used twice a day. When necessary, it was adjusted by dilution of the treatment with a nutrient solution. It was previously prepared with rainwater and stored in an extra reservoir, as recommended by Furlani et al. (1999), or by addition of NaCl, if necessary to concentrate the solution further. The hydrogen potential (pH) was quantified daily through a bench pHmeter model LUCA-210, to be maintained between 5.5 and 6.5 (due to the optimal range for nutrient uptake by the crop); it can be adjusted when necessary, through a base solution composed of sodium hydroxide or an acid solution composed of sulfuric acid.

Variables analyzed

The evaluation was performed at 21 days after transplanting of the seedlings, where the following variables were analyzed: leaf area with LI 3100 portable meter; relative chlorophyll content (SPAD index); content of chlorophyll a, b, and total; carotenoids content and the yield of lettuce leaves. The relative chlorophyll content (SPAD index) was determined on the fourth fully expanded leaf, from the apex. Measurements were performed between 7 and 9

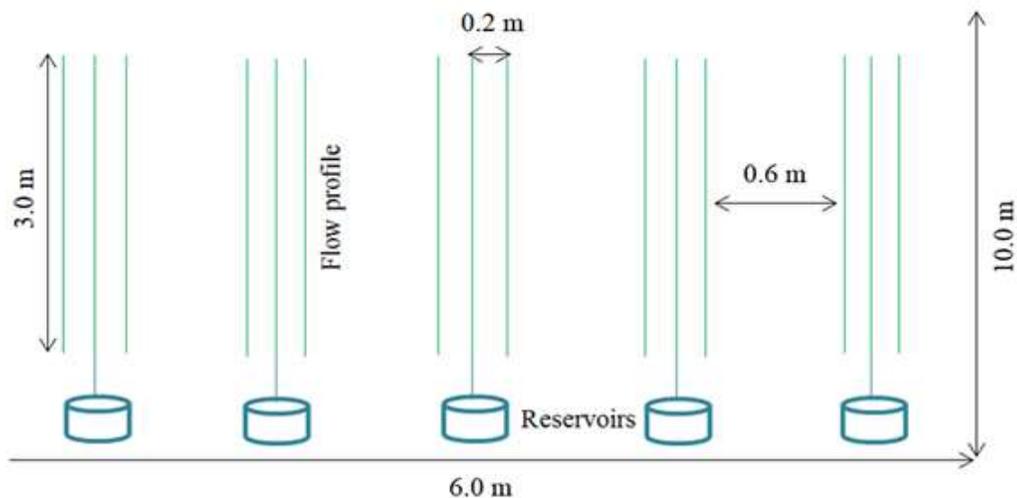


Figure 1. Layout of the hydroponic cultivation system.

o'clock in the morning, using the portable chlorophyll meter SPAD-502. Three measurements of the SPAD index per leaf were performed in the central region of the leaf limb of each plant of the useful plot, in each treatment, and the mean was used to represent the treatments. For determination of chloroplastidic pigments (chlorophyll "a", "b", total and carotenoids), the leaves were collected and immediately packed in aluminum envelopes, stored in thermal insulated containers containing chemical ice and transported immediately to the laboratory. Then, with the aid of a circular nozzle, circles of vegetable tissue were removed from the middle third of the leaves, and each material was weighed.

Subsequently, the material was macerated and placed in aluminum-coated containers, adding 6.0 ml of 80% acetone. The containers were refrigerated at 8.0 °C for 24 h and thereafter were paper filtered for 5 min according to methodology proposed by Arnon (1945). Absorbance readings were obtained by spectrophotometry at wavelengths of 470 (A470), 647 (A647) and 663 nm (A663), using 80% acetone as white In the quantification of chlorophyll "a", "b", total and carotenoids. The equations described by Lichtenthaler (1987) were used. The yield of the lettuce leaves was determined based on the total fresh and commercial weight. That is, those leaves superior to 10.0 cm in length and that did not present any physical defect were weighed in a precision scale, where this procedure was realized in treatment.

Statistical analysis

The variables were analyzed statistically by F test, unfolding the analysis whenever the interaction was significant. The quantitative factor of the salinity levels was statistically analyzed by means of polynomial regression (linear and quadratic). The cultivars were analyzed using the Tukey test at 5%, with the computer program Sisvar, according to Ferreira (2011).

RESULTS AND DISCUSSION

Temperature and air relative humidity

The data of temperature and relative humidity of the air

observed within the greenhouse from transplanting to harvest of the lettuce are shown in Figure 2. The mean air temperature during the experimental period was 26.7°C, the mean maximum temperature was 30.3°C and the mean minimum was 23.1°C. While the mean air humidity during the 21 days of cultivation was 68.4%, the average maximum was 77.3% and the mean minimum was 59.6% (Figure 2A and B). The climatic conditions assured inside the greenhouse were favorable for the development of lettuce. These temperatures are favorable to the growth and development of lettuce (Paulus et al., 2010; Silva et al., 2018).

Salinity levels

In the conditions under which the experiment was developed, when using rainwater in the preparation of the nutrient solution, it was verified that there was a slight reduction of the salinity of the nutrient solution due to the nutrient consumption. In this case it was superior to the accumulation of dissolved nutrients in the nutrient solution (Table 1). Corroborating with Paulus et al. (2010) who verified a similar effect for the treatment with non-saline water, they found that nutrient consumption is higher than the accumulation of salts dissolved in water.

Leaf area

The isolated factor cultivars did not significantly influence the variables studied at the 0.01 and 0.05% probability level by the F test. However, the factor salinity levels of the nutrient solution influenced all the variables analyzed in this experiment. The mathematical fit that best fits the lettuce leaf area was the linear type (Figure 3). As the

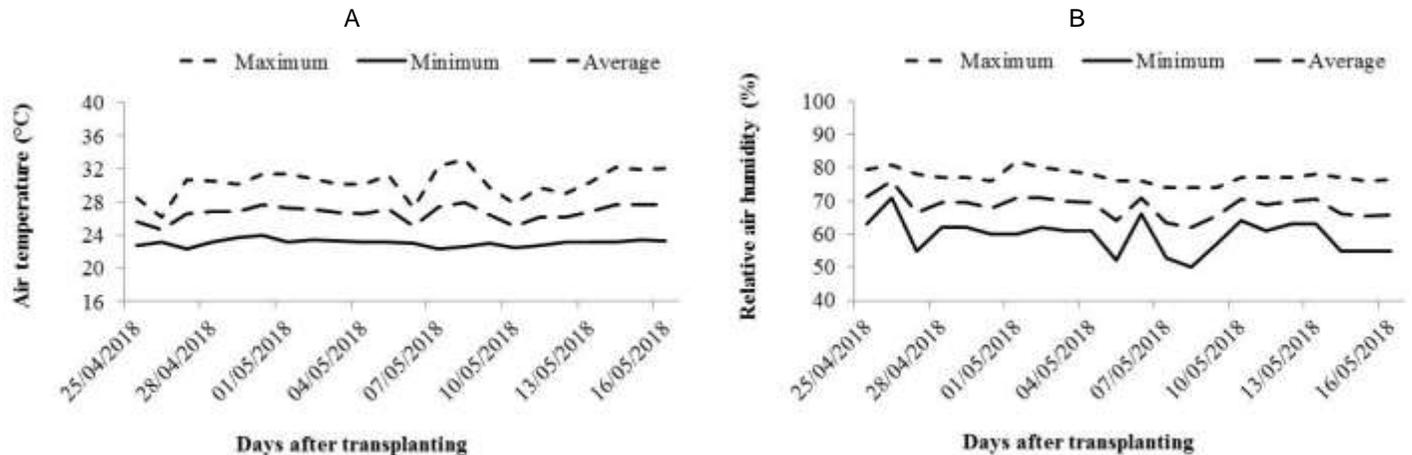


Figure 2. Temperature (A) and relative air humidity (B), maximum, minimum and average daily, observed during the period of conduction of the experiment.

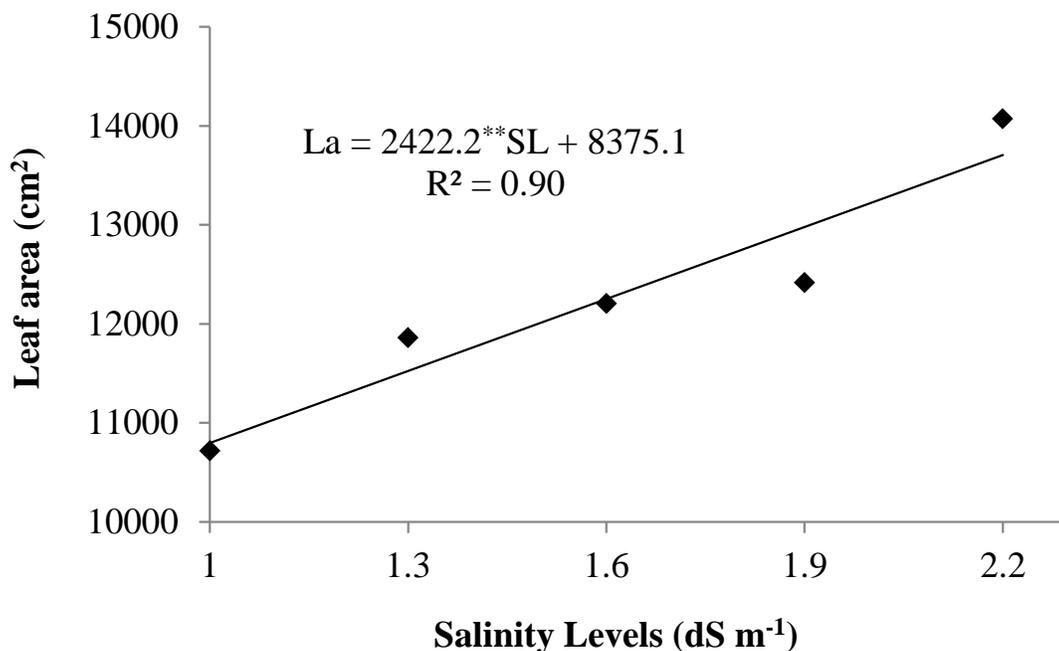


Figure 3. Averages of lettuce leaf area as a function of salinity levels of the nutrient solution.

salinity level of the nutrient solution increased, there was a positive increase in leaf area of lettuce, and the maximum yield was obtained in 2.2 dS m⁻¹ of the nutrient solution, corresponding to 13703.94 cm² per plant. Magalhães et al. (2010), when evaluating different levels of water electrical conductivity in lettuce yield found satisfactory results for leaf area in the case of the electrical conductivity up to 3.0 dS m⁻¹. This is consistent with the results obtained in the present study.

The leaf area has great relevance for lettuce, since it is a growth variable indicative of leaf yield, and the

photosynthetic process depends on the interception of the light energy and its conversion into chemical energy, a process that occurs directly on the leaf (Taiz and Zeiger, 2017). Cordeiro et al. (2017), when evaluating tolerance of lettuce cultivars to the saline water of the fish culture, observed that, in general, there was an increase in the leaf area with the increase of the salinity up to the levels of 2.48 and 2.83 dS m⁻¹; maximum leaf area values of 1,989.5 and 1,499.5 cm² per plant were observed, but these values are lower than those obtained in the present study, possibly because they are other lettuce cultivars.

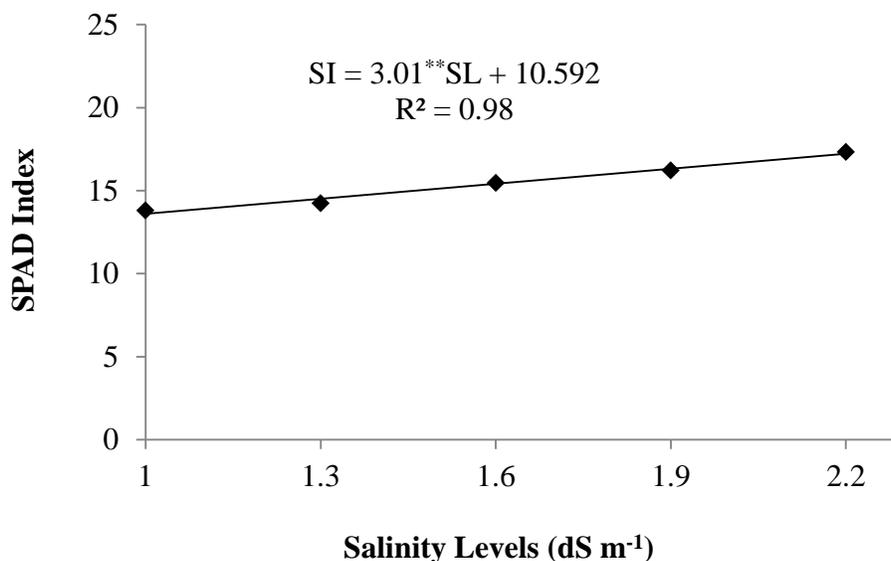


Figure 4. SPAD index as a function of the salinity levels of the nutrient solution.

SPAD index

Regarding the SPAD index, there was an increase when the salinity levels of the nutrient solution increased (Figure 4). Maximum SPAD yield was obtained in 2.2 dS m⁻¹ of the nutrient solution, corresponding to 17.21. This fact can be related to a gradual effect provided by the water used to prepare the nutrient solution (rainwater 0.24 dS m⁻¹) and the short cycle of lettuce. This fact corroborates with the results of Soares et al. (2010), which showed an average SPAD index of 15.90, when submitted to different levels of salinity.

“a”, “b” and total chlorophyll

The content of “a”, “b” and total chlorophyll as a function of the electrical conductivity of the nutrient solution of the lettuce is shown in Figure 5. It is noted that the lowest concentration of chlorophyll was obtained in the treatment with 1.0 dS m⁻¹. It is observed in the figure that the levels of chlorophyll “a”, chlorophyll “b” and total chlorophyll are increasing linearly as the salinity levels of the nutrient solution increase (Figures 4A, B and C). It is also noted that the highest concentration for chlorophyll a, b, and total was obtained with a salinity level of 2.2 dS m⁻¹, which are 0.55, 0.22 and 0.73 mg g⁻¹ mf⁻¹.

Generally, photosynthetic pigments are adversely affected by saline stress, accelerating their degradation rapidly or reducing their biosynthesis (Ashraf and Harris, 2013). However, in this study the levels of “a”, “b” and total chlorophylls increased significantly when salinity levels of the nutrient solution increased, a fact that is possibly related to the nutrients being supplied in a

readily assimilable way by the culture. Sarmiento et al. (2014), evaluating the use of salt rejected in the cultivation of hydroponic lettuce, also observed that the salinity of the nutritive solution raised the chlorophyll levels of the plants. Increased chlorophyll content in response to increased salinity was also observed by Paulus et al. (2010), who worked with two lettuce cultivars in hydroponics using different saline solutions and found an increase of chlorophyll under conditions of higher salinity.

Carotenoids

For the carotenoid variable, it was observed that the highest value was obtained with salinity of nutrient solution of 2.2 dS m⁻¹, corresponding to 0.13 mg g⁻¹ mf⁻¹ (Figure 6). Possibly, this fact occurred due to the higher nutritional supply for this level of salinity, since these salinity levels were established taking into consideration the application of fertilizers to water. These photosynthetic pigments known as carotenoids are derived from secondary metabolism, and have antioxidant activity; they act in the intercellular communication in the activity of the immune system providing the preventive capacity of diseases (Skibsted, 2012).

Vegetables are the major sources of carotenoids, including vitamin A precursors (Haskell, 2013). They are compounds classified as xanthophylls (lutein and zeaxanthin) and carotenes (α-carotene, β-carotene and lycopene) (Britton, 2008). The vegetables that have green color in their composition have different types of carotenoids, such as β-carotene, neoxanthin, lutein, violaxanthin and others. β-carotene and lutein are

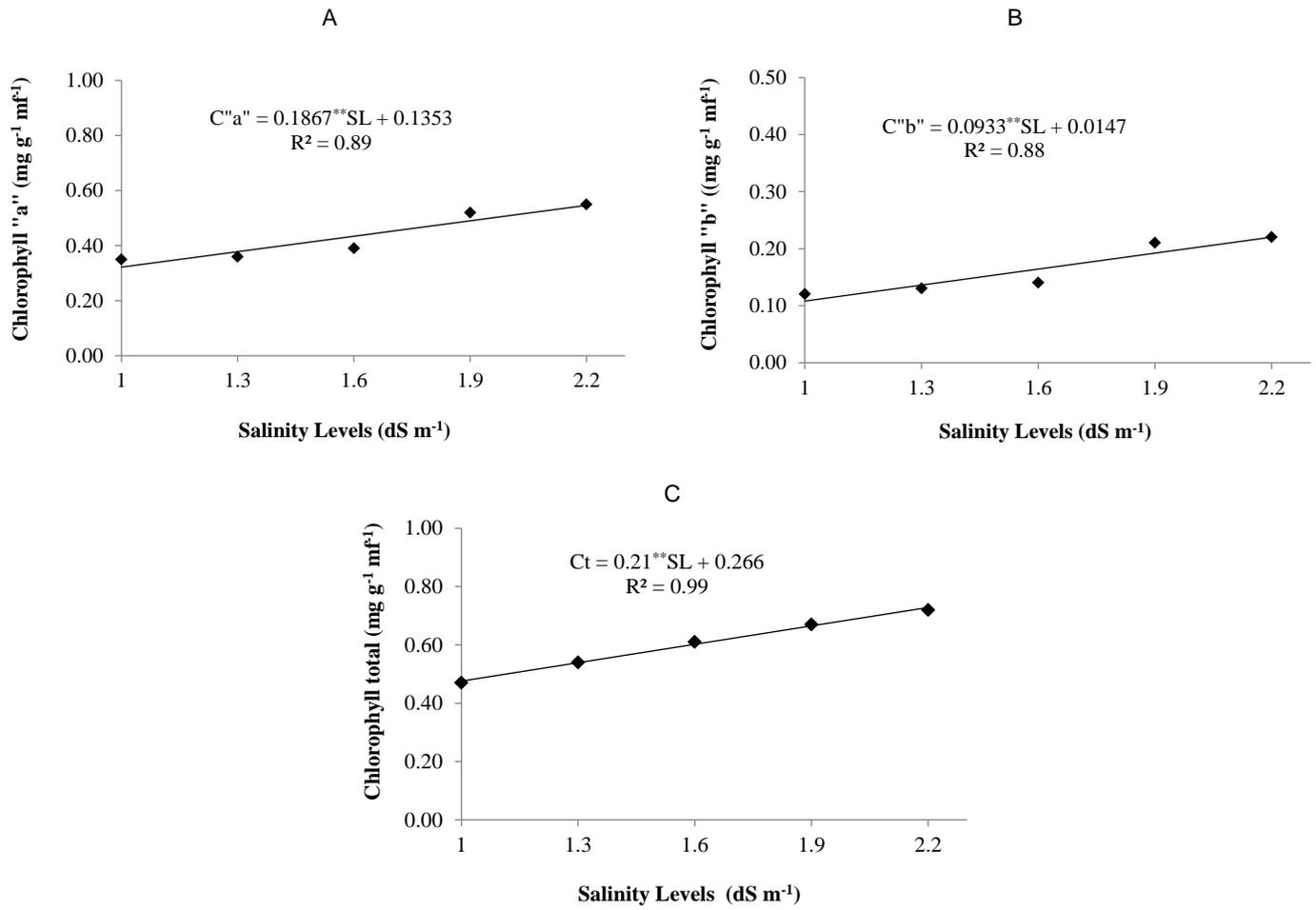


Figure 5. Chlorophyll a (A), b (B) and total (C) averages of lettuce as a function of salinity levels of the nutrient solution.

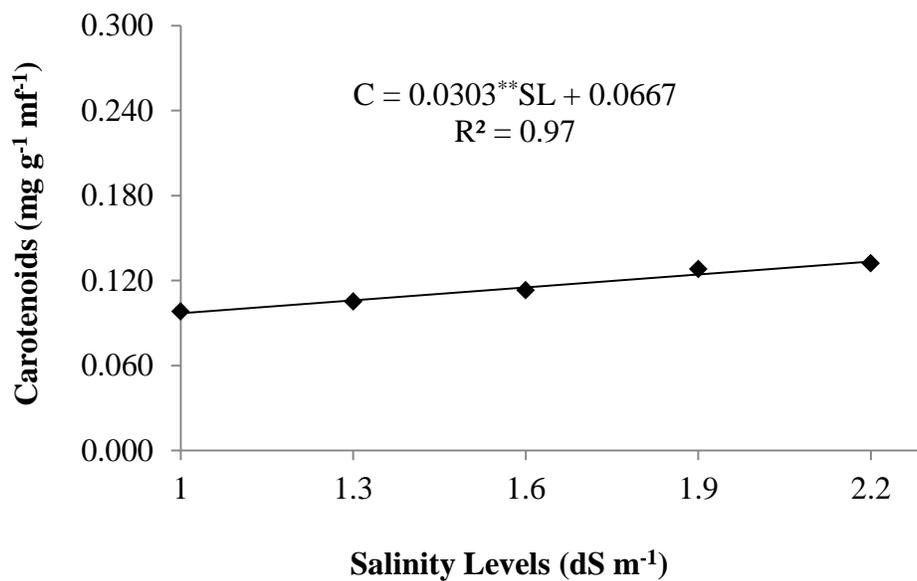


Figure 6. The carotenoids pigments averages of lettuce as a function of the salinity of the nutrient solution.

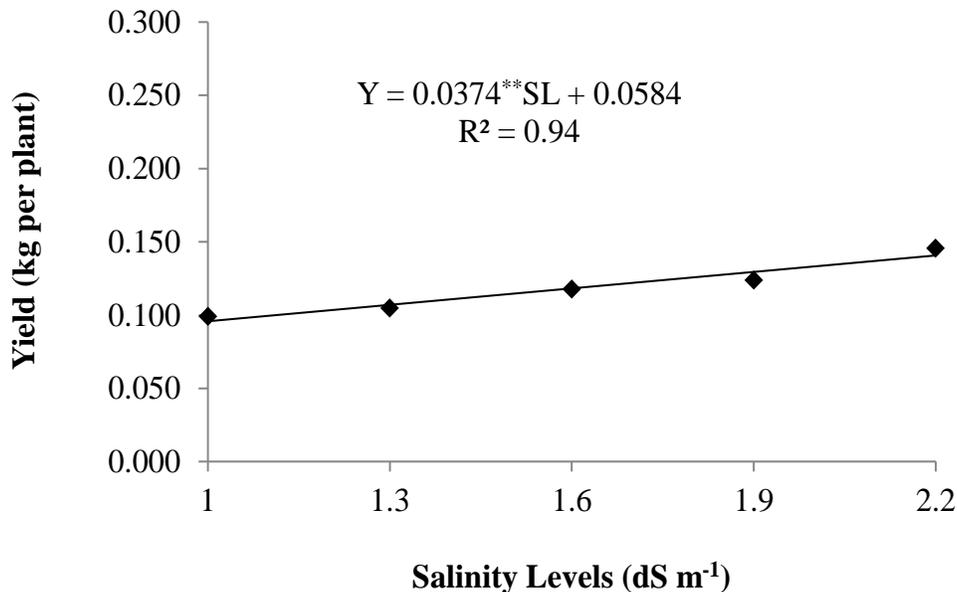


Figure 7. Average yield of lettuce leaves as a function of salinity levels of the nutrient solution.

considered the most important nutritional carotenoids (Wang et al., 2010), having a photoprotective and antioxidant action (Lee et al., 2013).

Yield

The mathematical model that best fit the yield of lettuce leaves in kg per plant at the end of the crop cycle was linear; it functioned as the salinity levels of the nutrient solution (Figure 7). It was observed that as the salinity level of the nutrient solution increased, there was a positive increase in the yield of lettuce leaves, and the maximum yield was obtained in 2.2 dS m⁻¹ of the nutrient solution, corresponding to 0.140 kg per plant.

Vasconcelos et al. (2014) studied the development of coriander in salt solutions and observed that in the nutrient solution recommended by Castellane and Araújo (1994), the maximum yield estimated at the highest level of the nutrient solution, corresponding to 2.07 dS m⁻¹, and in the solution nutritional composition of Furlani et al. (1999), the estimated maximum yield in fresh matter was when the electrical conductivity (EC) of the nutrient solution was 1.63 dS m⁻¹. Results of other authors are similar to those obtained in the present study and, possibly, this fact is related to the salinity levels of the nutrient solution being based on the addition of fertilizing salts. Dias et al. (2011) found that salinity higher than 2.3 dS m⁻¹ makes it difficult to produce leaves in hydroponic lettuce plants. Regarding salinity, the values observed in all treatments studied remained below this level and were not considered harmful to the development of the studied culture.

Conclusions

The isolated cultivar factor did not significantly influence any of the analyzed variables of the hydroponic lettuce. The different levels of salinity of the nutrient solution positively influenced the variables analyzed: leaf area, SPAD index, chlorophyll a, b and total, and yield of leaves of hydroponic lettuce. Hydroponic lettuce can be grown up to 2.2 dS m⁻¹ of electrical conductivity of the nutrient solution without any loss in yield.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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