

Full Length Research Paper

Growth and physiology of peanut (*Arachis hypogaea* L.) irrigated with saline water and biofertilizer application times

Daivyd Silva de Oliveira^{1*}, Thiago Jardelino Dias², Edvania Pereira de Oliveira², Hemmannuella Costa Santos², Welliton Barros de Magalhaes², Bruno Ferreira Matos², Leandra de Melo Cavalcante Sousa¹ and Jose Sebastiao de Melo Filho¹

¹Universidade Federal da Paraiba (UFPB), Centro de Ciências Agüias (CCA), Brazil.

²Universidade Federal da Paraiba (UFPB), Centro Ciências Humanas, Sociais e Agrarias (CCHSA), Brazil.

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The peanut crop has adaptive features to high salinity levels in the soil, due to its morphological and physiological characteristics. The objective of this study was to evaluate the use of biofertilizer in reducing the effects of irrigation water salinity on the vegetative and physiological behavior of the peanut crop, as well as the crop development under saline conditions. The experiment was conducted in a greenhouse, in an experimental design with randomized blocks, adopting a 6 × 3 factorial scheme, concerning the irrigation water salinity (CEa) in six levels (0.5, 1.5, 2.5, 3.5, 4.5 and 5.5 dS m⁻¹) and three doses of biofertilizer (applied at 15, 30 and 45 days after germination), with four replications, totaling 72 experimental units. The variables analyzed were: plant height; fresh and dry weight of shoots; stem diameter; length, fresh weight and dry weight of roots; number of branches; leaf area; photosynthetic radiation, chlorophyll a, b, and total chlorophyll. The use of biofertilizer had no influence on reducing the effects of irrigation water salinity in the development of the peanut crop. Salinity negatively affected all physiological and growth variables.

Key words: Electric conductivity, salinity, organic input, *Arachis hypogaea*.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) originates from South America, belonging to the group of oil plants of the family Fabaceae. It is a plant that grows well in different types of weather and temperature, showing to be well adapted to

hot and wet seasons. In the semiarid region, it is seen as a profitable alternative for small producers (Silva et al., 2011a).

To enable the exploitation of this crop in different

*Corresponding author. E-mail: daivydoliver@hotmail.com.

ecosystems, it is necessary to know the behavior of physiological parameters when subjected to different types of stress (Erismann et al., 2006; Graciano et al., 2011).

It has great importance in the world grain market and according to the database of the United States Department of Agriculture (USDA, 2015); the world production of peanut in the 2014/2015 season was 6,654,000.00 tons, with a planted area of 23,654,000.00 ha, while Brazil contributed with 346,800.00 tons, harvested in an area of 121100 ha (Conab, 2016). Asian countries are the main producers, with outstanding leadership exercised by China, being an important product in the economy of these countries. According to the data of the Food and Agriculture Organization (FAO) of the United Nations, peanut production is led by China, India and the United States, and these countries hold about 80% of the world production (FAO, 2011). In Brazil, production is mainly concentrated in the Southeast, Midwest and Northeast (Conab, 2016).

One of the major environmental factors limiting agricultural productivity due to its effects on plant growth and development is the soil salinity, which can be ionic and/or osmotic in nature, since the electrical conductivity of saline soils is equal to or greater than 4.0 dS m^{-1} , which corresponds to an approximate concentration of 4 nM NaCl and an osmotic pressure of 0.2 MPa (Munns and Tester, 2008).

In the case of the northeast, the salinization of soils is attributed to the fact that the potential evapotranspiration usually has lower values than the rainfall (Silva and Amaral, 2007). This feature, coupled with inadequate management of water and soil, has affected the productivity of the crops grown in the region. The increase in the salt content of the irrigation or soil water decreases the osmotic potential of the solution, reducing the availability of water and nutrients to plants (Sousa et al., 2010).

According to Graciano et al. (2011), in salt stress conditions, the peanut crop develops physiological mechanisms to ensure its growth, a fact considered an adaptive strategy.

Hence, the search for management strategies that facilitate the exploration of areas irrigated with saline water is a challenge that is being gradually overcome, highlighting the use of substances that reduce the intensity of the damaging effects of salt, allowing the use of saline water during seedling and plant growth (Sousa et al., 2008), the use of different water sources in different plant development stages (Neves et al., 2009) and the use of organic conditioners based on bovine biofertilizer (Cavalcante et al., 2010).

In the case of use of biofertilizers, research has been developed as an alternative used to mitigate the deleterious effects of salinity on soil and plants, and this use of bovine biofertilizer is shown to mitigate the effects of salt stress on the initial growth of some crops

(Medeiros et al., 2011; Cavalcante et al., 2011).

Given the earlier, the aim of this study was to evaluate application times of biofertilizer in reducing the effects of irrigation water salinity on the vegetative and physiological behavior of the peanut crop, as well as the crop development under saline conditions.

MATERIALS AND METHODS

The work was carried out in a screened greenhouse in the Agriculture Sector of the Center of Social/Human and Agricultural Sciences of the Federal University of Paraíba - Campus III, Bananeiras-PB (CCHSA/UFPB) in the period from January to May, 2014. The UFPB - Campus III is located in the meso region of the Agreste Paraibano and in the micro region of Brejo Paraibano, 130 km away from the capital João Pessoa and 70 km away from Campina Grande - PB. With an altitude of 526 m, Bananeiras-PB has wet and cold weather, with an average temperature of 28°C in the summer and 15°C in the winter (IBGE, 2006).

According to the Köppen classification, the climate is of the As' type - tropical rainy, with dry summer, irregular annual rainfall distribution (1174.7 mm), maximum annual temperature of 27°C and minimum of 18.8°C , and getting an annual average of 22°C (AESA, 2011).

The experimental design was a randomized block, adopting a 6×3 factorial scheme, referring to six levels of salinity of the irrigation water (CEa) (0.5, 1.5, 2.5, 3.5, 4.5, and 5.5 dS m^{-1}) and three biofertilizer application times (at 15, 30 and 45 days after germination), with four replications, totaling 72 experimental units.

The experimental units were comprised of pots with volume capacity of 12 dm^3 , being packaged, in these containers, 800 g of crushed stone 1 (base), and subsequently the substrate composed of humus (70%), sand (20%) and manure (10%). The substrate was analyzed for its characteristics according to the methodology described by Embrapa (1999) (Table 1). The substrate acidity correction was preceded by applying 35 g of dolomitic limestone and 32 g of phosphorus (P_2O_5) was indicated as base fertilization (Alvarez et al., 1999).

The planting was done with peanut cultivar BR1, placing five seeds per pot; after 15 days, thinning was held, leaving only one plant per pot.

Irrigation was carried out in the late afternoon, with irrigation turn of 3 days, from the sowing, up to 22 days, being reduced to 2 days in order to replace the crop evapotranspiration, estimated for each development stage of the plant from the reference evapotranspiration (ET_0) and the crop coefficient (Kc). ET_0 values were obtained in the AESA platform (Executive Agency for Water Management in the State of Paraíba), where the water depth was adjusted for each irrigation. The water preparation, with its respective salt levels (CEa), was performed weekly by diluting saline water (C_4S_1) with non-saline water ($\text{C}1\text{S}1$), stored in 50 dm^3 containers (Choi et al., 2005).

The bovine biofertilizer was prepared by anaerobic fermentation, by adding 100 dm^3 of fresh manure and 100 dm^3 of water ($\text{CEa} \leq 0.5 \text{ dS m}^{-1}$) in a container with capacity of 240 dm^3 . The system was kept sealed for 30 days until reaching a pH close to 7 (Santos and Akiba, 1996). To release the methane gas produced by the fermentation, one end of a thin tube was connected to the top of the biodigester and the other was submerged in a container with water to prevent the entry of air.

In the periods corresponding to the biofertilizer application on the substrate (15, 30 and 45 days after germination - DAG), a further dilution was performed, in the ratio of 1:1 (biofertilizer and water with $\text{CEa} \leq 0.5 \text{ dS m}^{-1}$), being applied to the surface of the substrate, a quantity corresponding to the volumes of each

Table 1. Characterization chemical and fertility of the substrate used.

*pH	P	K ⁺	Na ⁺	H ⁺ Al ⁺³	Al ⁺³	Ca ⁺	Mg ⁺²	SB	CTC	V	M.O.
H ₂ O	mg dm ⁻³			cmol _c dm ⁻³						%	g kg ⁻¹
5.8	63.65	0.76	0.21	0.71	0.00	5.76	3.26	9.99	10.7	93.36	36.13

*Water pH; SB = Sum bases (Ca²⁺ + Mg²⁺ + K⁺ + Na⁺); CEC = cation exchange capacity [SB + (H⁺ + Al³⁺)]; V = soil bases exchangeable saturation (SB / CTC) 100; MO = Organic matter.

Table 2. Summary of analysis of variance related to plant height (AL), stem diameter (DM), number of branches (NR), root length (CR), fresh matter of shoot (MFPA), dry mass of (MSPA), fresh root mass (MFR), root dry mass (MSR), interaction of photosynthetic radiation (IRF), chlorophyll a (Cla), chlorophyll b (Cib) and chlorophyll (Cit) of peanut plants (*Arachis hypogaea* L.), depending on the salinity of the irrigation water and different times of application Biofertilizer.

FV	GL	Mean square											
		AL	NR	DM	CR	MFPA	MSPA	MFR	MSR	IRF	Cla	Cib	Cit
S	5	2487.82**	99.71**	23.12**	292.88**	55609.60**	3299.51**	90.70**	7.46**	0.99**	1386.08**	144.83**	2425.20**
B	2	326.26**	1.02 ^{ns}	5.83 ^{ns}	155.01 ^{ns}	9536.62 ^{ns}	672.75 ^{ns}	16.71 ^{ns}	1.02 ^{ns}	0.15 ^{ns}	376.32 ^{ns}	38.03 ^{ns}	644.92 ^{ns}
S × B	10	195.12**	25.45**	2.50 ^{ns}	13.57*	3625.70 ^{ns}	178.08 ^{ns}	6.22 ^{ns}	0.44 ^{ns}	0.03*	63.05 ^{ns}	10.88 ^{ns}	118.46 ^{ns}
R	54	54.38	4.58	2.47	49.19	5273.95	326.53	17.06	1.13	0.12	150.16	15.66	255.62
Total	71	-	-	-	-	-	-	-	-	-	-	-	-
CV (%)	-	13.91	15.96	0.71	18.85	18.44	18.09	17.23	7.55	11.92	13.51	12.66	13.25

Salinity - ECw (S) Biofertilizer (B) residue (R); CV = Coefficient of variation; ns = not significant by F test; *,**Significant respectively at 5 and 1% probability.

treatment. Growth variables (plant height, stem diameter, root length, fresh and dry weight of shoots, fresh and dry weight of roots, number of branches, leaf area index) and physiological variables (photosynthetic radiation, chlorophyll a, b and total chlorophyll) were evaluated.

The results were submitted to analysis of variance by F test at 0.05 probability and in cases of significance, polynomial regression analysis was performed (Banzatto and Kronka, 2006), using the statistical software ASSISTAT, version 7.7 beta (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

Through the data in Table 2, it is observed that the variables plant height, stem diameter, number of branches, root length, fresh weight of shoots, dry weight of shoots, fresh weight of roots, dry

weight of roots, leaf area index, photosynthetic radiation, chlorophyll a, chlorophyll b and total chlorophyll had significant effects with the different salinities in the irrigation water. Regarding the biofertilizer application times, only the variable plant height obtained significance, while the others showed no significant effect. The different salinity × biofertilizer ratios showed significant interaction effect only for the variables plant height, number of branches, root length and photosynthetic radiation.

From the regression analyses concerning plant height, depending on the electrical conductivity of water (CEa) under different biofertilizer application times (Figure 1), it was found that the increase in CEa reduced plant height in the three applications

of the organic input, with higher decrease from CEa = 4.5 dS m⁻¹. The application at 45 DAG showed major development of plants with CEa values between 0.5 and 1.5 dS m⁻¹. Researchers state that the decrease in plant height can occur due to decreased osmotic potential of the soil solution due to the increase in salinity levels (Graciano et al., 2011). To confirm this statement, Sousa et al. (2012), irrigating the peanut crop with saline water, reported trends similar to this study for this variable.

Regarding the number of branches, plants showed a decrease with increasing CEa (Figure 2). The growth inhibition is caused, mostly, by the toxic effects of the salts absorbed by plants, by the low osmotic adjustment capacity of the crop

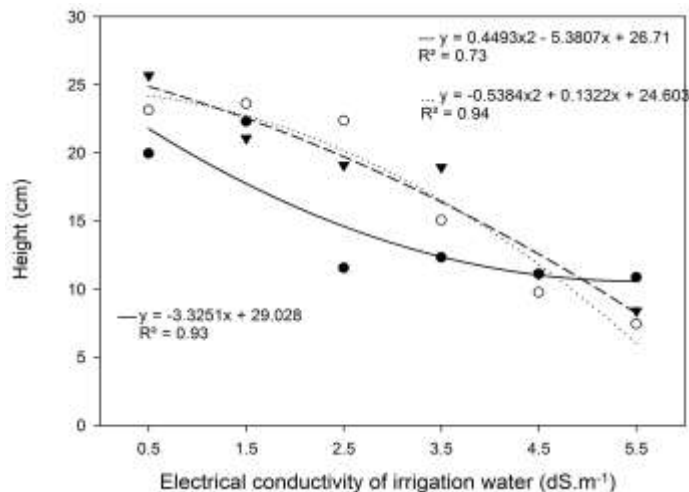


Figure 1. Height of peanut plants irrigated with saline water and bio-fertilizer application times to 15 (-), 30 (--) and 45 (··) days after germination.

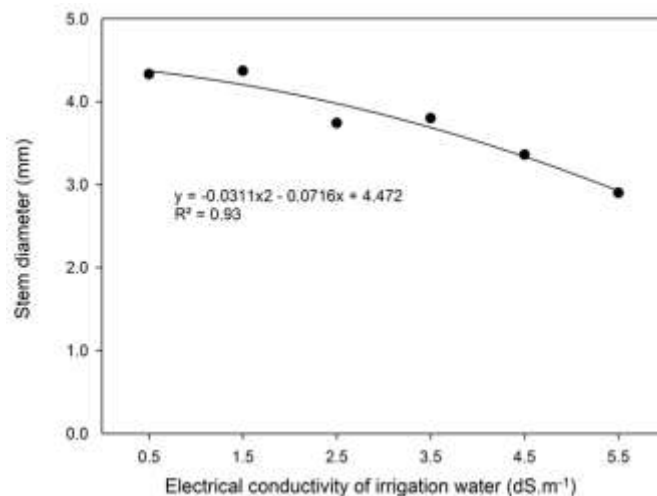


Figure 3. Stem diameter of peanut plants irrigated with saline water.

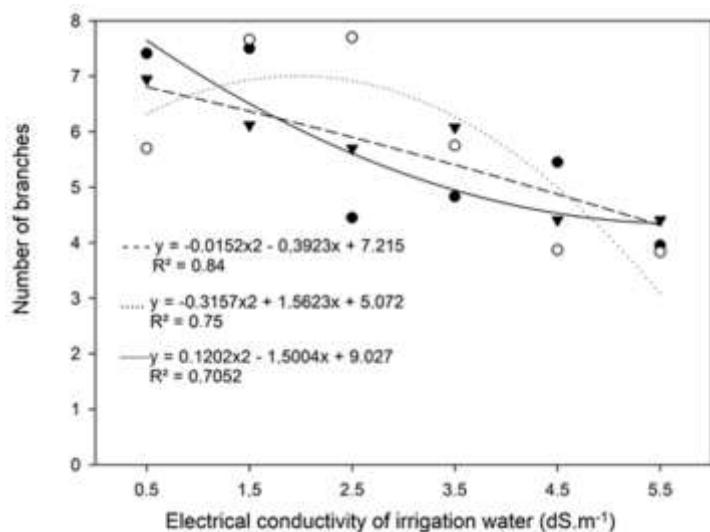


Figure 2. Number of branches of peanut plants irrigated with saline water and bio-fertilizer application times to 15 (-), 30 (--) and 45 (··) days after germination.

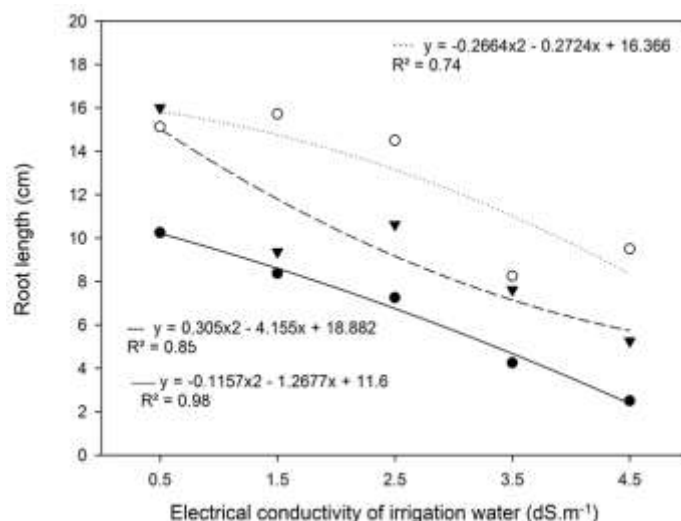


Figure 4. Root length of peanut plants irrigated with saline water and bio-fertilizer application times to 15 (-), 30 (--) and 45 (··) days after germination.

and by the reduction of the total water potential caused by increased salt concentration (Lacerda et al., 2006; Silva et al., 2011b).

With respect to stem diameter (Figure 3), increasing CEa reduced the development thereof in the presence of biofertilizer. Correia et al. (2005) found similar behavior of this variable for the peanut crop, testing increasing levels of salinity in the irrigation water. Moreover, Campos et al. (2009), in castor beans, Medeiros et al. (2011), in cherry tomato, and Nascimento et al. (2011), in pepper, found superiority of this variable in plants irrigated with increasing levels of salt in the irrigation water in the

presence of biofertilizer.

The root length of the peanut was inhibited for the three biofertilizer applications (Figure 4), however, the application at 45 DAG provided favorable conditions for further development of roots. To the extent that the CEa increased, the root length of plants decreased. Work involving biofertilizers and saline water showed no significant effect for this variable, as reported by Campos et al. (2009), in castor beans, and Medeiros et al. (2011), in cherry tomato.

According to the data of Figure 4, it was observed that the fresh weight of shoots (Figure 5A) showed a decrease.

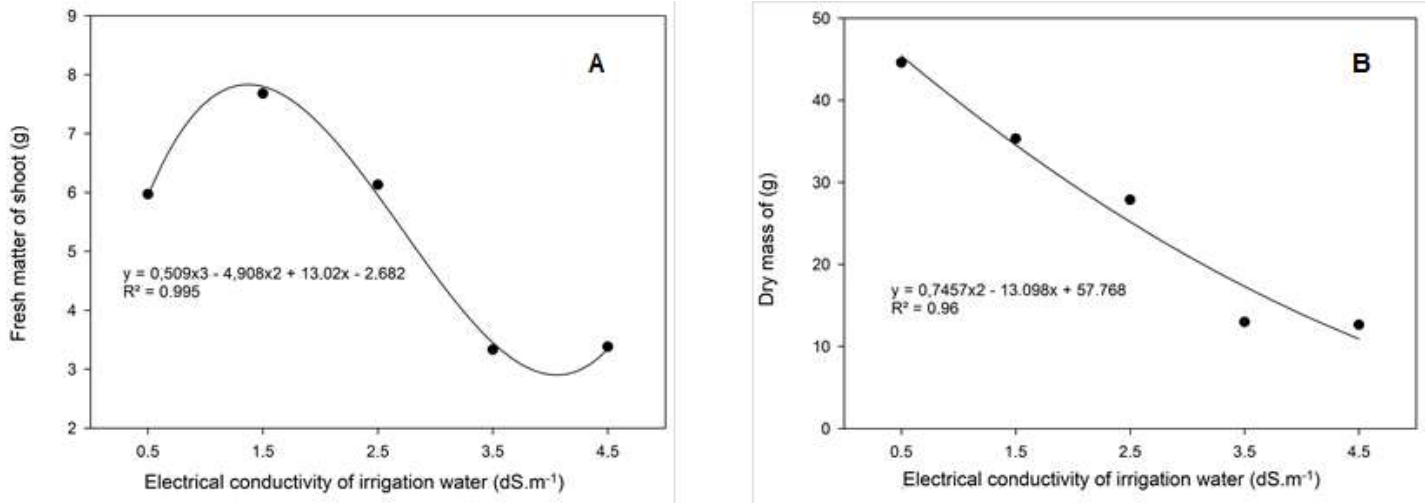


Figure 5. Fresh matter of shoot (A) and dry mass of (B) of peanut plants irrigated with saline water.

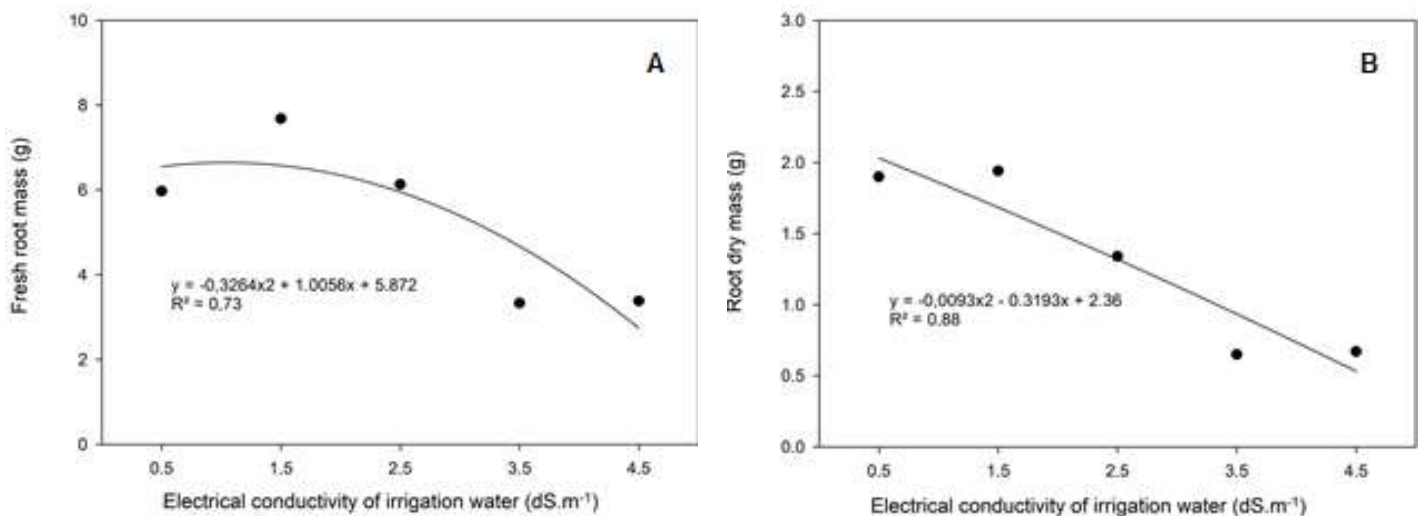


Figure 6. Fresh root mass (A) and root dry mass (B) of peanut plants irrigated with saline water.

This occurred due to the use of saline water for irrigation, as this water influences the development of the plant. This negative effect of salinity results in lower efficiency of plants in photosynthetic processes and in the transport of organic solutes in plant tissues, and as a consequence, in the growth and development of their tissues (Figueiredo, 2012). The dry weight of shoots (DWS), as a function of the irrigation CEa (Figure 5B), was influenced by the conductivity of the water. It showed a decrease at all salinity levels. Similar results were shown by Graciano et al. (2011) for the peanut crop. Corroborating this information, Morais et al. (2011), in sunflower plants, and Silva et al. (2011b) in cowpea, also reported reduction in DWS when increasing concentrations of salts were applied in the irrigation

water.

The fresh weight of roots was similar for water doses of 0.5 and 1.5. In starting this conductivity, a greater decrease was presented (Figure 6A). This reduction is justified by the fact that excessive salinity reduces the growth of all parts of the plants, as it causes an increase in energy expenditure to absorb water from the soil and perform biochemical adjustments necessary for their survival under stress conditions (Larcher, 2006). Regarding the dry weight of roots, it decreased with increasing electrical conductivity of the water used for irrigation (Figure 6B). These results are contrary to those reported by Silva et al. (2011a), which showed an increase in the accumulation of dry root mass with increasing biofertilizer doses in the cotton crop. This

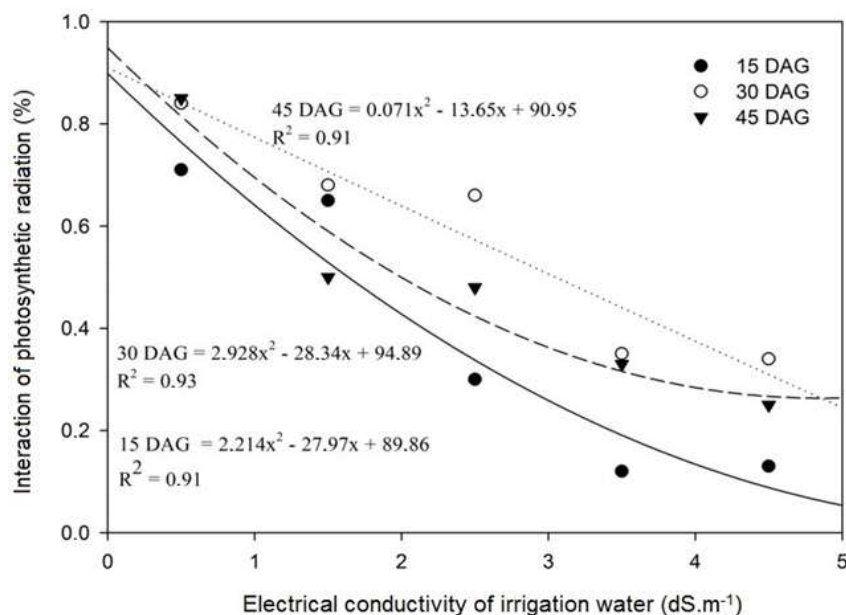


Figure 7. Interception of photosynthetic radiation of peanut plants irrigated with saline water and bio-fertilizer application times to 15 (-), 30 (-) and 45 (·) days after germination.

evidence of reduction in the dry weight of roots has been a classic behavior seen in other studies when plants are subjected to salt stress (Blanco et al., 2008; Medeiros et al., 2011; Maciel et al., 2012).

The biofertilizer application did not influence the analyzed variables; notwithstanding, there was interaction between the water doses and the biofertilizer. Possibly, in view of the decrease in the size of plants and leaves, the plant reduced the transpiration surface and the exposed area in order to intercept photosynthetically active radiation (Figure 7), probably due to the increase of the ABA (abscisic acid) concentration in the xylem. This induces stomatal closure in the leaf and reduced leaf expansion, as these are extremely sensitive to lack of water, being affected, even before there is interference in the leaf water potential, by the phytohormone balance (Kramer and Boyer, 1995). Water absorption is also sensitively affected by abiotic factors such as the salinity of the medium, because as the water transport is mediated by aquaporins, these channels are selective to water and independent of energy expenditure for their operation (selection via molecular size) (Stedtle and Henzler, 1995), which will reduce their photosynthetic potential and hence their productivity (Ávila et al., 2007). The peanut has C3 photosynthetic metabolism and features maximum net photosynthetic rate at 30°C. The maximum dry matter production rate, or crop yield, is 19.6 gm⁻² day (Embrapa, 2009).

Increased CEa provided a reduction in the index of chlorophyll a, b and total chlorophyll (Figure 8). This may be related to physiological conditions of stress, such as

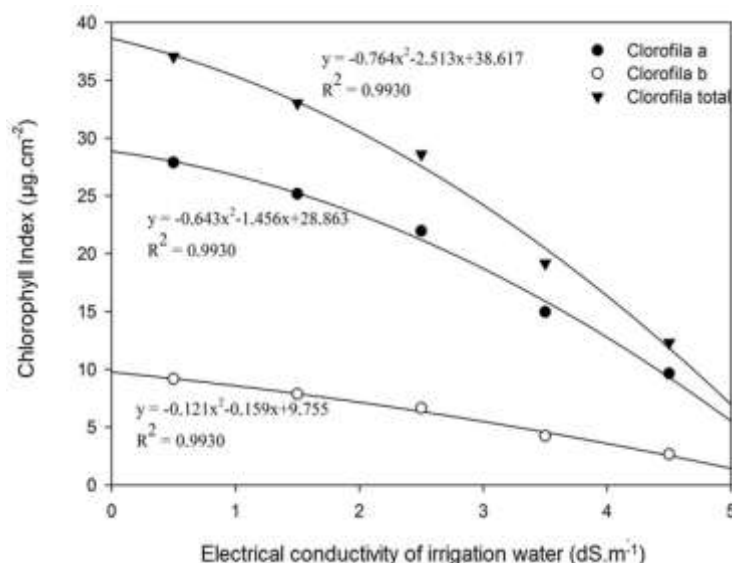


Figure 8. Chlorophyll a, chlorophyll b and chlorophyll total of peanut plants irrigated with saline water.

salinity, lack of water and nutrient deficiency; it is possible, in these cases, that the ferredoxin transfers its e⁻ to the molecular O₂, forming H₂O₂, which must be reduced by catalase, generating more ATP without NADPH, which is the pseudo-cyclic electron transport. This process also has the function of producing additional ATP and consuming molecular O₂, in photoinhibition

conditions. O₂ has two antagonistic effects on photosynthesis, one protective, by the use of NADPH and ATP when produced in excess under photoinhibition, by photorespiration and by Mehler reaction; and one destructive, by the action of active oxygen species such as H₂O₂. These active oxygen species destabilize the membranes, for example, the thylakoids (Vácha, 1995), which may cause a decrease in the content of photosynthetic pigments, as CEa reduces the chlorophyll content in plants sensitive to salinity (Jamil et al., 2007; Silva et al., 2008; Graziano et al., 2011). The reduction in the chlorophyll content as a function of the salinity effect was also observed in sugarcane (Willadino et al., 2011). High concentrations of NaCl increase chlorophyll degradation via chlorophyllase and decrease its synthesis, by virtue of the competition for nitrogen with other compounds, such as proline (Ibarra and Maiti, 1995). The chlorophyll degradation may cause a considerable reduction in the photosynthetic rate and, as a result, decreased productivity (Santos, 2005).

Conclusions

The use of biofertilizer had no influence on reducing the effects of irrigation water salinity in the development of the peanut crop. The application of biofertilizer at 45 days after germination promoted more vegetative growth and increased photosynthetic activity in the peanut crop. Salinity adversely affected all physiological and growth variables, which showed a decrease with increasing electrical conductivity of the irrigation water (dS m⁻¹).

Conflicts of Interests

The authors have not declared any conflict of interests.

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