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Effects of Salinity on the Vegetative Growth of Tuberose (*Polianthes tuberosa* L.)

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Abstract: Tuberose (*Polianthes tuberosa* L.) is one of the most important bulbous ornamental crops of tropical and subtropical areas. It is an important plant economically because of its use as an ornamental plant and its essential oils, which are highly appreciated for the manufacture of perfumes and other essences. The objective of the study was to examine the effects of salinity of nutrient solution on growth of tuberose. An experiment was conducted in a greenhouse at the University of Eswatini, Luyengo Campus, Horticulture Department to determine the highest level of salinity in irrigation water that can limit production of tuberose. The experiment had five treatments which were 0.07 (Control), 2, 4, 8 and 16 dS/m. Treatments were replicated four times and were laid out in a Randomized Complete Block Design (RCBD). The results indicated that tuberose irrigated with 0.07 dS/m water had the best result in terms of vegetative growth i.e., [Leaf area (56.2 cm^2), plant height (31.8 cm), number of leaves (35), number of shoots (7), chlorophyll content (52.2 mg/g) and it decreased as the concentration of sodium chloride increased. Irrigating with 16 dS/m salt concentration had a very negative impact on the growth of tuberose. The growth parameters exhibited significantly reduced tuberose plant growth above 4 dS/m salinity level. In case of leaf chlorophyll content, it decreased with increasing salinity level. From these results it can be concluded that tuberose is sensitive to salinity stress above 4 dS/m. Based on the results, tuberose was found to be a moderate salinity sensitive plant. It is recommended that tuberose cut flowers be grown as long as salinity in irrigation water does not exceed 4 dS/m.

Key words: Electrical Conductivity · Irrigation Water · NaCl · Salinity · Tuberose · Vegetative Growth

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) belongs to the subfamily Agavoideae of the Asparagaceae family [1]. The common name tuberose, is derived from the Latin word *tuberosa* through French *tubereuse,* meaning swollen or tuberous in reference to its root system [2]. The genus is endemic in Mexico and comprises about 15 species, among them *P. tuberosa* L. The tuberose is a night-blooming plant native to Mexico, as is every other species of *Polianthes* [3]. According to Petruzzello [4] tuberose grows in elongated spikes up to 45 cm long that produce long bright green leaves clustered at the base and smaller clasping leaves along the stem. The fragrant waxy white flowers are borne in a cluster at the tip of the stem and bloom at night. The roots are fleshly and tuberous [4].

Once introduced to Europe, it became part of the moon garden, a collection of white or pastel flowers, which release an intense fragrance after dusk [5]. These gardens were popular among the sun-shunning Victorian ladies, who valued a milky pale complexion [6]. The plant did fall out of favour when it became much over used at funerals [3]. It has an intense fragrance and one or two open blossoms will fill the air of an entire garden [7]. It is believed that tuberose was brought to India via Europe in 16th century [8]. It represents sensuality and is used in aromatherapy for its ability to open the heart and calm the

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nerves, restoring joy, peace and harmony [6]. Furthermore, fragrant flowers are added along with stimulants or sedatives to the favourite beverage prepared from chocolate and served either cold or hot as desired [2]. Tuberose bulbs contain an alkaloid lycorine, which causes vomiting. The bulbs are rubbed with turmeric and butter and applied as a paste over red pimples of infants [8]. Dried tuberose bulbs in powdered form are used as a remedy for gonorrhoea [9]. In Java, the flowers are eaten along with the juices of the vegetables.

Abiotic stresses such as high and low temperature, drought and salinity cause considerable degradation of tuberose flower quality and severely affect plant growth and development, resulting in reduced total production worldwide [10]. Therefore it is important to develop tuberose cultivars with biotic and abiotic stress resistance to protect and conserve its resources worldwide [11]. The aim of the study, therefore, was to determine the highest NaCl concentration in irrigation water, tuberose can tolerate without significant reduction in vegetative growth and development.

MATERIALS AND METHODS

Experimental Site: The experiment was conducted at the University of Eswatini, Faculty of Agriculture, Luyengo Campus in the Horticulture Department greenhouse. The farm is located at Luyengo, in the Manzini region, in the Middleveld agro-ecological zone in the Kingdom of Eswatini, southern Africa. According to Murdoch [12] Luyengo is located on latitude 26°4´S and longitude 31°4´E. The average altitude of the area is 750 m above sea level. The mean annual precipitation is 980 mm with most of rain falling between October and April. Drought hazard is about 40%. The average summer temperature is 27°C and winter temperature is about 15°C. The soils at Luyengo are classified under Malkerns series. They are ferrasolic or mainly a ferralitic soil integrated to fersialitic soils or typical ultisols. The soil in the experimental area is sandy loam. The experiment was conducted from October 2018 and terminated on February 2019.

Plant Materials: Tuberose was propagated by use of bulbs of about 2.1 cm in diameter which were obtained from the Horticulture Department Farm. The bulbs were dug-up, separated manually from each other and planted in prepared media. The bulbs were planted on the 5th of October and irrigated with just tap water for six weeks. On the sixth week after planting, the plants were then watered with different concentrations of sodium chloride solutions. Application of NPK [2.3.2 (22)] fertiliser was done on monthly basis, by applying 20 g in each polythene bag. During the growing period, tuberose plants were affected by red spider mites, which were controlled by spraying with an insecticidal soap.

Growing Media: The growing media used was a mixture of garden soil and kraal manure at a 1: 1 ratio in all the experimental units. Both media components were obtained on campus in the Horticulture Department Farm. The growing media was filled in five-litre-black-perforated polythene bags, which was a mixture of garden soil and kraal manure. The garden soil and kraal manure were mixed at a 1:1 ratio.

Data Collection: Data were collected every two weeks from 8-14 weeks after planting (WAP). Sample size of five plants per treatment was used in collection of data. The plants were randomly selected from each treatment. From the five plants randomly selected, the following parameters were measured: number of shoots and leaves which was determined by counting; chlorophyll content (mg/g), which was measured by use of a chlorophyll content meter (SDAD-502, Tung Yung Ltd, Beijing, China); plant height (cm), which was determined by use of a meter ruler (100 cm); leaf area (cm^2) was determined by formula according to Ahmed and Morsy [13] where by leaf length and width are multiplied and the product is multiplied by the correction factor (0.53). Data was also collected based on fresh masses of shoots and roots (g), weighed using a balance scale and dry masses of shoots and roots (g) by drying them in the oven at 72°C for 72 hours and then weighing them using a balance scale, at the end of experiment, at 14 WAP.

Satistical Data Analysis: Data collected were subjected to analysis of variance (ANOVA) using Genstat statistical package [14]. Where significant differences were detected, means were separated using Duncan's New Multiple Range Test (DNMRT) at 5% level of significance [15].

RESULTS AND DISCUSSION

Leaf Area: There were significant ($P<0.05$) differences in leaf area of tuberose, in different concentrations of saline irrigation water. At 14 WAP, plants irrigated at (0.07 dS/m), which was the control had the highest leaf area (56.2 cm^2) and the ones irrigated at 16 dS/m water had the lowest leaf area (40.4 cm^2). An increase of sodium

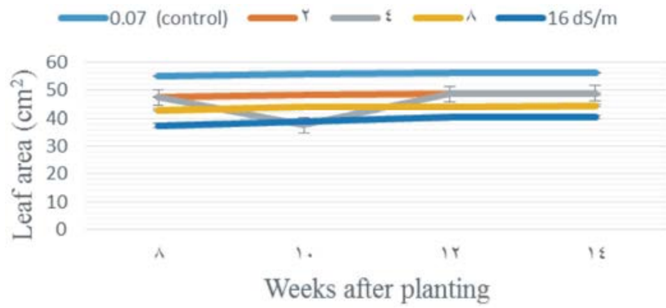

Fig. 1: Effects of different concentrations of sodium chloride in irrigation water on the leaf area of tuberose. Vertical bars are standard error (SE) below and above the mean.

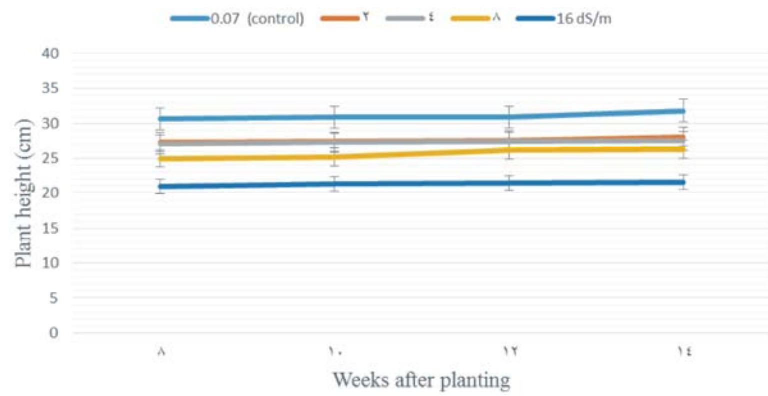

Fig. 2: Effects of different concentrations of sodium chloride in irrigation water on the plant height of tuberose**.** Vertical bars are standard error (SE) below and above the mean.

chloride in irrigation water resulted in decrease in leaf area of plants (Fig. 1). The second highest leaf area (48.9 cm^2) was obtained in plants irrigated with 2 dS/m saline water (Fig. 1).

Leaf area decreased as salinity increased. This concurs with the results by Niu *et al.* [16] who reported that plants subjected to salt stress had their leaf area reduced, due to the delay in leaf production, which decreases as the area available for photosynthesis and the effect is even more accentuated when the time of exposure to the stress is prolonged. Leaf area decreased in response to water salinity especially the ones irrigated at 16 dS/m water.

Plant Height: There were significant ($P<0.05$) differences in plant height of tuberose, in different concentrations of saline irrigation water. At 14 WAP, plants irrigated at (0.07 dS/m), which was the control had the longest plants (31.8 cm) and the ones irrigated at 16 dS/m water had the shortest plants (21.6 cm). Each increase in NaCl concentration in irrigation water resulted in corresponding decrease in plant height of tuberose (Fig. 2). The second highest plant height (27.5 cm) was obtained from plants irrigated with 2 dS/m saline water (Fig. 2).

The increment of in EC levels inhibited the growth in plant height, probably due to the reduction of the osmotic potential in the root environment, which can cause physiological water deficit. It can also cause toxicity, through the specific action of the ions, especially Na+ and Cl^-, on the protoplasm [17]. Further, explaining the mechanism of salt tolerance in plants, Cabrera [18] stated that, due to increasing EC, probably resulting into limited expansion, reduction in cell elongation and division in plant cell reduce their final size, resulting in decrease in plant height.

Number of Leaves: There were significant ($P<0.05$) differences in number of leaves of tuberose, in different concentrations of saline irrigation water. At 14 WAP, plants irrigated at (0.07 dS/m), which was the control had the highest number of leaves (35) and the ones irrigated with 16 dS/m water had the least number of leaves (11).

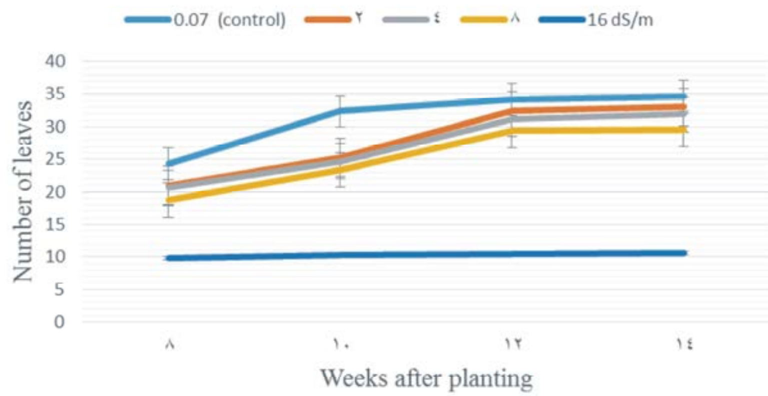

Fig. 3: Effects of different concentrations of sodium chloride in irrigation water on the number of leaves of tuberose. Vertical bars are standard error (SE) below and above the mean.

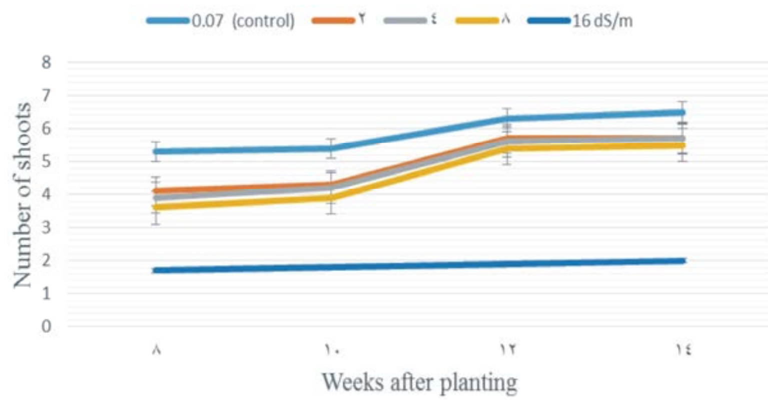

Fig. 4: Effects of different concentrations of sodium chloride in irrigation water on the number of shoots of tuberose**.** Vertical bars are standard error (SE) below and above the mean.

Each increase in NaCl concentration in irrigation water resulted in decrease in leaf number of plants (Fig. 3). The second highest number of leaves (32) was obtained from plants irrigated with 2 dS/m saline water (Fig. 3).

Number of Shoots: There were significant (P<0.05) differences in number of shoots of tuberose, in different concentrations of saline irrigation water. At 14 WAP, plants irrigated at (0.07 dS/m), which was the control had the highest number of shoots (7) and the ones irrigated with 16 dS/m water had the lowest number of shoots (2). Each increase in NaCl concentration in irrigation water resulted in decrease in number of shoots of tuberose plants (Fig. 4). The second highest number of shoots (6) was obtained from plants irrigated with 2 dS/m saline water (Fig. 4).

In this study, there was a reduction in number of shoots per plant with increasing salinity levels in the irrigation water. Similarly, the highest number of leaves was obtained from plants in the control and the lowest among those irrigated at 16 dS/m. This findings were consistent with those of Allkaverdiev *et al*. [19] who studied the effects of water salinity on six heliconia genotypes and observed that EC higher than 0.8 dS/m negatively affected leaf production and plant growth, causing losses related to size and to the desirable features in ornamental plants, such as colour of leaves and plant size, in all genotypes.

Chlorophyll Content: There were significant (P<0.05) differences in chlorophyll content of tuberose, in different concentrations of saline irrigation water at 10 WAP only. There were no significant (P>0.05) differences at 8, 12 and 14 WAP, in chlorophyll content of the tuberose plants. At 14 WAP, plants irrigated at (0.07 dS/m), which was the control, had the highest chlorophyll content (52.2 mg/g) and the ones irrigated with 16 dS/m water had the lowest chlorophyll content (31.3 mg/g).

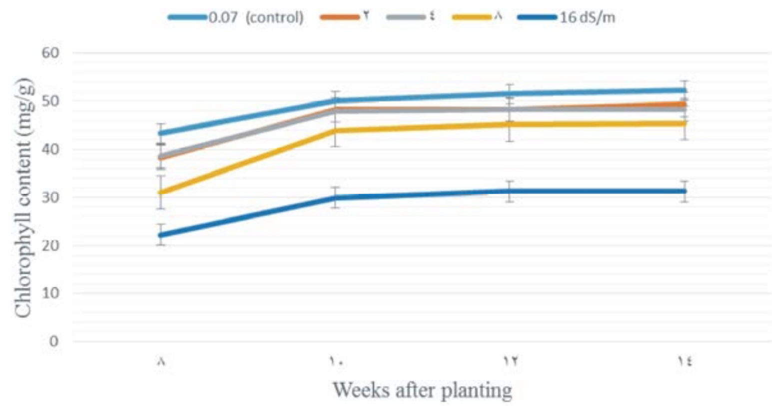

Fig. 5: Effects of different concentrations of sodium chloride in irrigation water on the chlorophyll content of tuberose**.** Vertical bars are standard error (SE) below and above the mean.

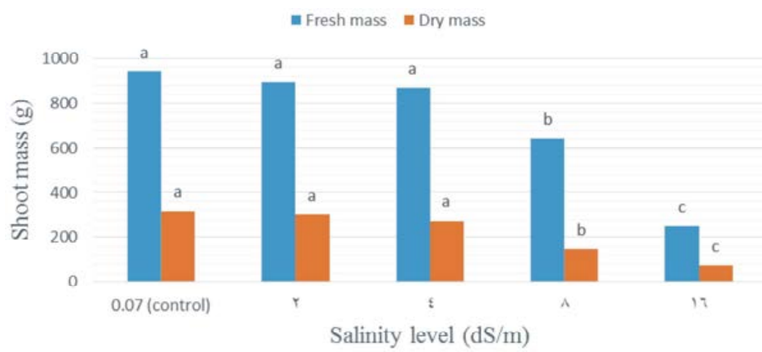

Fig. 6: Effects of different concentrations of sodium chloride in irrigation water on the fresh and dry mass of tuberose shoots**.** Bars of the same parameter followed by same letter for each parameter not significanlty different. Mean separation by DNMRT at P = 0.05.

An increase in NaCl concentration in irrigation water resulted in decrease in chlorophyll content of tuberose plants (Fig. 5). The second highest chlorophyll content (48.2 mg/g) was obtained from plants irrigated with 2 dS/m saline water (Fig. 5).

Chlorophyll content of leaves decreased with increasing salinity levels compared to the control. The results of the experiment are in agreement with those of Delperee [20] who stated that the observations might be due to the increased thickness of leaves and compacted mesophyll cells of stressed leaves, consequently, more chloroplasts per unit area, as often is the case under stress conditions. Mamnouie [21] also reported that the amount of salinity in soil after long irrigation interval with saline water increased and induced oxidative osmotic stress, which resulted in reduction of chlorophyll content in plants. High salinity could affect stroma volumes of chloroplasts and the protein bonds of green pigments, thus causing a decrease in chlorophyll content in plants [22].

Fresh and Dry Mass of Shoots: There was no significant ($P>0.05$) difference in fresh mass of tuberose shoots at 0.07, 2 and 4 dS/m treatments (Fig. 6). Increasing salinity level to 8 dS/m resulted in a significant ($P<0.05$) reduction in shoot fresh mass (Fig. 6). Further increase in salinity to 16 dS/m resulted in a significant ($P<0.05$) reduction in shoot fresh mass. Plants irrigated at (0.07 dS/m), which was the control had the highest fresh mass (943.7 g) and the lowest fresh mass (251.2 g) was obtained among those irrigated at 16 dS/m (Fig. 6). The second highest shoot fresh mass (893.9 g) was obtained from plants irrigated with 2 dS/m saline water (Fig. 6). There were significant ($P<0.05$) differences in dry mass of tuberose shoots, in different concentrations of saline irrigation water (Fig. 6). Plants irrigated at 0.07, 2 and 4 dS/m had no significant ($P>0.05$) difference in shoot dry mass. However, further increase of salinity to 8 dS/m resulted in a significant ($P<0.05$) reduction in shoot dry mass (Fig. 6). Plants irrigated with (0.07 dS/m) saline water, which was the control had the highest dry mass (316.1 g)

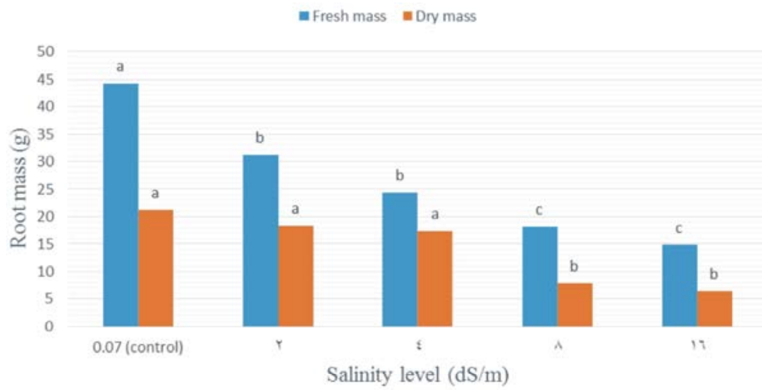

Fig. 7: Effects of different concentrations of sodium chloride in irrigation water on the fresh and dry mass of tuberose roots. Bars of the same parameter followed by same letter for each parameter not significanlty different. Mean separation by DNMRT at P = 0.05.

and the lowest shoot dry mass (73.4 g) was obtained among those irrigated at 16 dS/m (Fig. 6). The second highest shoot dry mass (301.6 g) was obtained from plants irrigated with 2 dS/m saline water (Fig. 6).

There was no significant difference in the fresh mass of tuberose irrigated at 0.07, 2 and 4 dS/m. A significant decrease in fresh mass was observed on the plants irrigated with more than 4 dS/m water. This result acquiesces with those of Katembe [23] who stated that osmotic differences could explain this phenomenon where by lower sodium chloride salinity levels (0.07, 2 and 4 dS/m) positively influences solutes to readily cross the cell membranes into the cytoplasm of the cells but at higher salinity levels, active metabolic pumps prevents accumulation of these ions. In addition, Heidari *et al.* [24] while studying the effects of sodium chloride concentrations on *Helianthus annus,* suggested that reduction in plant growth is due to decreasing turgor pressure in the soils under saline environment.

There was reduction in dry mass of tuberose shoots as the salinity level increased. This result concurs with those of Ferreira [25] who stated that absorption of chloride and sodium ions affects the synthesis and translocation of hormones between roots and shoots, resulting in reduction of leaf area, since these are essential for cell metabolism and, consequently, reduction in plant dry biomass. Reduction in tuberose shoot dry mass with increased salinity was significant. Besides the reduction in leaf area, salinity causes inhibition in root system growth, delay in the production of apical buds and chlorosis with subsequent necrosis on leaf areas [26]. Besides, reduction in root biomass due to salinity has also been indicated as a factor impeding flowering by affecting energetic reserves [27].

Fresh and Dry Mass of Roots: There were significant ($P<0.05$) differences in the fresh mass of tuberose roots, in different concentrations of saline irrigation water (Fig. 7). Plants irrigated at (0.07 dS/m), which was the control had the highest root fresh mass (44.2 g) and the lowest root fresh mass (14.8 g) was obtained among those irrigated at 16 dS/m (Figure 7). The second highest root fresh mass (31.2 g) was obtained from plants irrigated with 2 dS/m saline water (Fig. 7). There were significant ($P<0.05$) differences in the dry mass of tuberose roots, in different concentrations of saline irrigation water (Fig. 7). Plants irrigated with 0.07, 2 and 4 dS/m saline water showed no significant ($P>0.05$) difference in root dry mass. However, increasing the salinity to 8 dS/m resulted in a significant ($P<0.05$) reduction in root dry mass (Fig. 7). Further salinity increase to 16 dS/m resulted in a significant ($P<0.05$) reduction in root dry mass. Plants irrigated at (0.07 dS/m), which was the control had the highest dry mass (21.2 g) and the lowest root dry mass (6.4 g) was obtained among those irrigated at 16 dS/m (Fig. 7). The second highest root dry mass (18.3 g) was obtained from plants irrigated with 2 dS/m saline water (Fig. 7).

There were singificant defferences in both fresh and dry masses of tuberose roots with increase in salinity level. Root growth was strongly inhibited by salinity, leading to a reduction of root biomass. This results acquiesces with those of Munns [28] who reported that Na^+ content strongly increases in all plant tissues with increasing NaCl concentration in the nutrient solution. The salt-induced inhibition of rot growth could be further explained by either a direct Na^+ or Cl^- toxicity [29]. The plasmalemma of root cells is thought to be alterd by high Na^+ content leading to an inability to maintain cell turgor. Therefore, the reduction of root elongation by salinity could be due to an inhibition of cell expansion as cell turgor decreased [30]. In the study conduted, reduced root growth was more likely a consequence of ion toxicity or ion imbalance on wall metabolism or cell plasmalemma rather than a direct effect of a salt-induced osmotic stress.

CONCLUSION

An increase in salinity, in irrigation water, reduced the vegetative growth of tuberose. Reduction in growth was proportional to the concentration of sodium chloride in the irrigation water. A huge decline in vegetative growth parameters measured was observed in plants irrigated with 16 dS/m saline irrigated. The reduction in vegetative growth in plants irrigated with 16 dS/m saline water was more than double when compared to the ones irrigated with 0.07 dS/m (Control). Tuberose irrigated with 0.07 dS/m saline water gave the best results in terms of vegetative growth. The EC higher than 4 dS/m induced a significant reduction in shoot fresh and dry masses. However, there was no significant difference in these parameters in plants irrigated at 0.07, 2 and 4 dS/m saline water.

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