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ORIGINAL ARTICLE

Exogenous applications of exudates roots of common glasswort on eggplant under salt stress

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Salt stress is one of the most important problems that negatively affects crop productivity. Particularly in arid and semi-arid areas of the world. Recently, agriculture has seen some development through the use of natural biostimulants capable of improving the tolerance of plants to salt stress. The aim of this study is to evaluate the effectiveness of exudates from the cut and crushed roots *of* common glasswort (*Salicornia europaea* L.) in improving the physiological, biochemical and morphological response of eggplant (*Solanum melongena* L.) subjected to salt stress by the application of two concentrations of NaCl, 150 et 250 meq/l. Results showed that salinity significantly reduced the relative water content (RWC), root volume (RV), root dry matter (RDM) and aerial dry matter (ADM). On the other hand, the soluble sugar content of stressed *S. melongena* leaves is significantly increased. However, the addition of exudates from the roots of *S. europaea* has caused an increase in RWC and an improvement in the accumulation of soluble sugars in the leaves, and has also greatly contributed to reducing the damaging effects of salinity on RV and RDM and allowed a slight increase in the ADM of plants subjected to salinity, essentially the 250 meq concentration of NaCl.

Keywords: NaCl, Relative water content, Soluble sugars, Root volume, Root dry matter, Aerial dry matter.

Introduction

Salinity stress is one of the more prevailing abiotic stresses which results in significant losses in agricultural crop production, particularly in arid and semi-arid areas (Benslama et al., 2020). According to FAO, around 800 million hectares of land are affected by salinity worldwide (Hernández, 2019). The most affected regions are the Middle East, Australia, Eurasia and North Africa (FAO, 2008). Salinization has occurred in many arid regions in Algeria, leading to severe soil degradation (Semar et al., 2019; Benslama et al., 2020). It keeps increasing year by year because of global climate change (Shrivastava, 2014), bad management of irrigation water (Evelin et al., 2019), and excessive chemical fertilization (FAO, 2021). For soils of semi-arid regions where rainfed agriculture is practised, serious salinity problems can arise if the rainfall is only approximately equal to the evapotranspiration and soluble salts are present in the root zone (FAO, 1988). Amongst the various salts present in the soil, NaCl is the most prevalent one (Evelin et al., 2019). Salinity impairs plant growth and development *via* water stress, cytotoxicity due to excessive uptake of ions such as sodium (Na^+) and chloride ($Cl^−$), and nutritional imbalance (Isayenkov et al., 2019). Therefore, it is of vital importance to know the mechanisms of salinity tolerance in order to obtain plants with a better response to this abiotic stress. At the same time, it is necessary to achieve these objectives with sustainable agricultural practices that allow obtaining more productive crops under a future scenario of climate change (Hernández, 2019). Eggplant (*Solanum melongena* L.) is plant species in the nightshade family and commonly grown in many parts of the world (FAO, 2015). It is known for its nutritive benefits due to the abundance of various bioactive compounds, which include proteins, vitamins, minerals, carbohydrates, phenolics, and dry matter content. In addition, eggplant has significant pharmaceutical properties that have been recently recognized. Eggplant produces secondary metabolites, including glycoalkaloids, antioxidant compounds, and vitamins, which appear to be the major source of its health benefits. It has been reported that there is a considerable correlation between the regular use of phytochemicals and the defense against diseases. Therefore, researchers must analyze the biochemical composition of eggplants to obtain more information about their nutritional quality and health benefits. In this review, an attempt is made to explain the qualitative and quantitative aspects of different biochemicals present in eggplant, in addition to their beneficial health effects (Sharma, 2021). Eggplant growth is sensitive or moderately sensitive to salinity (Unukara et al., 2010; Saini, 2019). Several studies have been conducted to find alternatives that allow plants to overcome the harmful effect of salt, among which the use of plant extracts that can act as natural stimulants capable of improving the tolerance of natural ones to salt stress. Plant extracts contain a large number of bioactive compounds capable of improving various physiological processes that stimulate plant growth and development and increase the efficiency of nutrient utilization (Bulgari et al., 2015). Our work consists of studying the physiological and biochemical and morphological response of eggplant (*S. melongena* L.) subjected to salinity by the application of two concentrations of NaCl, 150 and 250 meq/l, in the presence of root exudates of *S. europaea* L.

Materials and Methods

Plant material

This study includes the Classic F1 hybrid variety of eggplant (*S. melongena L.*), supplied by the company CLAUSE of Thai origin. It's characterized by its precocity, vegetative vigor and high fruit production.

Preparation of exudates from cut (ECUR) and crushed (ECR) roots of *S. europaea*

Samples of common glasswort (*S. europaea* L.) were collect in summer from around TISMSSILT city (35°38.2450'N, 2°17.3310'E). The roots of the common glasswort are washed with distilled water and kept at room temperature for 15 days to dry, which were then used to prepare the two exudate solutions used. 10 g of cut roots and crushed roots were dissolved separately with 100 ml of sterilized distilled water in ratio 1:10 and placed on the shaker at room temperature for 2 days. Then, extracts were filtered with Whatman filter paper. Finally the two solution was diluted twice and stored at 4°C (Behravan et al,. 2019).

Experimental conditions

The experiment was carried out in a semi-automatic greenhouse at the faculty of life sciences of Tiaret University (34°04′ North and 1°33′ East). Seedlings obtained from seeds disinfected with sodium hypochlorite were transplanted in PVC cylinders, 30cm diameter and 70cm depth and filled with washed sand. All 27 cylinders were irrigated at 100% of field capacity for 20 days. The irrigation water was substituted every 3 days by a commercial nutrient solution (ACTIVEG). Then the cylinders were divided into three treatments according to salinity level, control, 150meq and 250meq of NaCl. In each of these treatments, three sub-treatments were selected according to the application of S. europaea root exudates, control, crushed root exudates and cut root exudates. Each saline treatment is composed of 9 cylinders assigned to the three sub-treatments, each consisting of three cylinders.

Measurements

Relative Water Content (RWC)

Leaves excised are immediately weighed (FW) and rehydrated to full turgidity with distilled water at 4°C for 24 h and reweighed (TW). Leaves were dried at 80°C during 72 h (DW). Relative water content was determined according the method of Sangakkara et al., (1996). RWC (%)=(Fresh weight- Dry weight)/(Turgid weight-Dry weight) × 100.

Soluble sugar content

Extraction was performed on fresh leaves by ethanol at 80°C for 24 h. The absorbance of the extract was done at 585nm and the content (μg.ml^{-1}) was determined by referring to the calibration curve (Schields et Burnett, 1960).

Root and aerial dry matter

Root volume was determined by immersion in a graduated cylinder. Root and aerial dry biomass was determined by oven drying for 48 h at 80°C.

Statistical analysis

Data Statistical analysis of data was performed using the one-way analysis of variance (ANOVA) at a 5% probability level, using Statistica version 10 software.

Results and Discussion

The relative water content (RWC)

Salinity significantly affects the relative water content (Table 1). In fact, the application of NaCl at concentrations of 150 meq and 250 meq reduced the water content at rates of 31% and 46% respectively (Fig. 1). In fact, the average values of this parameter varied from 83.2%, 57.56% and 45.08%, recorded respectively in plants of the control, 150 meq and 250 meq treatments. However, the application of the root exudates under the two forms, crushed and chopped, significantly minimized the reducing effects of NaCl on this parameter. Thus, the improvement in relative water content levels of plants under 150 meq salt stress by supplying root exudates in crushed and cut forms reached 17% and 14%, respectively (Fig. 1). Under the salt stress of the 250 meq level, the increase in relative water content is about 27% and 22% following the supply of exudates from crushed and cut roots (Fig. 1). It is observed in this context that the amendment of the medium with the exudates of the crushed roots proves to be more advantageous than those of the cut roots, where the difference reached 16 and 18% under the two saline treatments. The main consequence of salinity is osmotic, due to the decrease in the water potential of the substrate.Thus, the addition of NaCl at two concentrations, 150 and 250 meq, induced a consecutive and proportional decrease in the relative water content of eggplant plants. These effects have been noted by several works including those of Ghaderi (2018), Sarker et Oba (2020), Yadav (2020), et Soni et al., (2021), who demonstrated that under saline stress, the first constraint perceptible by plants involves a consequent reduction in their relative water content. However, adding exudates from the roots of European samphire to the growing medium minimized the osmotic effect of NaCl by causing an increase in the relative content of the plants. It is observed in this respect that exudates obtained from the crushed roots was more favorable to this improvement than that of the cut roots. Similar results have been presented in the works of Parvin et al., (2020), Mutlu-Durak et al., (2021) who showed that the intake of biostimulants extracted from plants had a favorable effect on the maintenance of hydration in plants subjected to salt stress. This action is explained by a supply of bioactive substances such as phytohormones, polyphenols and primary metabolites having various actions, mainly their antioxidant activities.

Table 1. Effects of NaCl, extracts of the exudates of crushed and cut roots of and their interactions on the water status of eggplant (*S. melongena* L.), its content of soluble sugars, its root volume and its root dry matter and Aerial.

Setting RWC Source of variation		SSC RV RDM		ADM
NaCl	236.96***	1493.81***	6.265** 3.6312**	5.912**
Exudates	29.04***	192.55***	1.327^{ns} 1.3865^{ns}	0.459^{ns}
NaCl*Exudates	4.29**	68.32***	0.286^{ns} 0.3133^{ns}	0.330^{ns}

RWC:relative water content; SSC:soluble sugar content; RV:root volume; RDM:root dry matter; ADM:aerial dry matter
*** significant at the 0.01% level; ** significant at the 1% level; ns not significant least significant difference at 5% level;

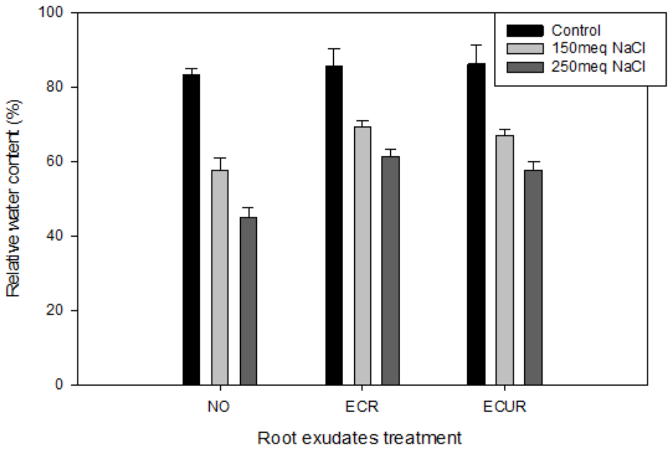

Fig. 1. Effect of root exudates supply on reltive wter content of eggplanst of plants sujected to different salinity levels by NaCl application.

The soluble sugars content

The application of NaCl at 150 and 250 meq, induced a significant increase in the soluble sugar content of eggplant leaves (Table 1).The average content in the control treatment is about 5.736 µg.ml^{-1}, while it increases at rates of 9.604 µg.m^{l-1} and 11.064 µg.ml^{-1} following the application of NaCl at concentrations of 150 meq and 250 meq inducing respective increases of 40 and 48% (Fig. 2). Application of the aqueous extracts of the crushed and cut roots further caused an improvement in the accumulation of simple sugars under both salt conditions (Fig. 2). Thus, these increases in the batch subjected to 150 meq NaCl, are of the order of 30 and 7%, respectively after the addition of the crushed and cut exudates. This increase was even greater in the plants subjected to 250 meq NaCl. It reached levels of 32 and 26% caused by the crushed and cut root exudates, respectively (Fig. 2). These results indicate that the application of the exudates obtained from the crushed roots was more advantageous than that of the cut roots where it reached differences of 25 and 7%, respectively in the plants of the 150 and 250 meq NaCl treatments. Present work demonstrate that under salt stress, plants react by accumulating soluble sugars whose role is justified by their action in osmotic adjustment. This result is confirmed by those obtained by Hannachi et al., (2017), Bouassaba et Chougui (2018), Yadav (2020), et Elhakem A (2020), who found that under salinity, the synthesis and accumulation of simple sugars constitute one of the strategies to combat the osmotic effects of this stress. The present work proves that the addition of root exudates contribute effectively, under these conditions, to increasing the accumulation capacities of these solutes.In more than their roles in osmotic adjustment, solubles sugars also contribute to the protection of biological membranes (Bulgari et al., 2015; Hegazi et al., 2015; Latif, 2016; Abd el-mageed et al., 2017; Dehkordi et al., 2021) and the mitigation of biomolecule oxidation by scavenging reactive oxygen species (Kaplan et Guy, 2004; Rosa et al., 2009; Bhattacharya, 2020).

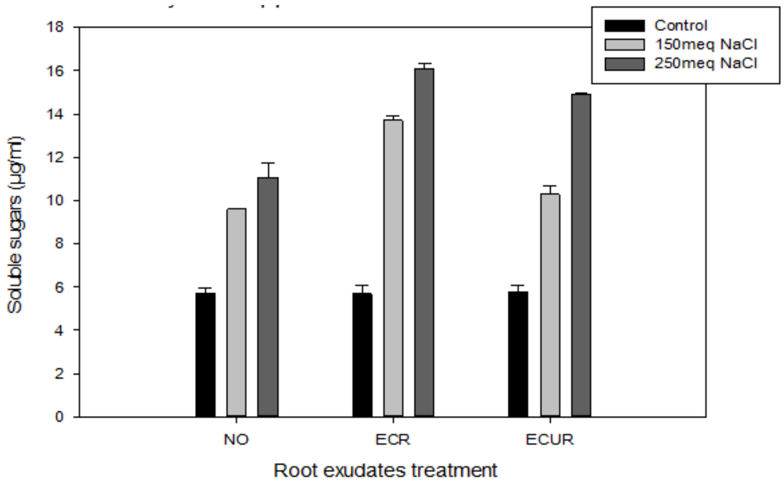

Fig. 2. Effect of root exudates supply on soluble sugars content of eggplants of plants sujected to different salinity levels by NaCl application.

Root volume

Salinity also reduced plant root volume (Table 1) at rates of 9 and 11% respectively in the 150 and 250 meq treatments. Thus, the volumes obtained reached 54.97, 49.97 and 48.98 cm^3, obtained in order in the plants of the control treatments (0 meq NaCl), 150 meq and 250 meq NaCl. The contribution of exudates from the crushed and cut roots limited this devaluation of the volume of the roots under the effect of salinity. Thus, increases in root volume were observed following the application of exudates from the roots of common glasswort in the crushed and cut forms and which reached respective levels of 2 and 7% under the acuity of 150 meq NaCl and 2 and 6% in plants subjected to 250 meq NaCl (Fig. 3).

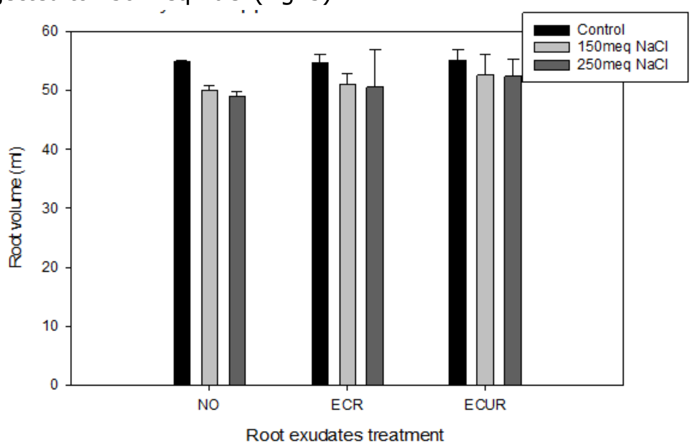

Fig. 3. Effect of root exudates supply on root volume of eggplants of plants sujected to different salinity levels by NaCl application.

Dry root and aerial biomass

The development of dry root biomass is significantly reduced by salinity. In fact, the application of NaCl at concentrations of 150 meq and 250 meq caused a decrease in the dry matter of the roots at a rate of 17% compared to the values recorded in the plants of the control batch. Thus, the average results obtained are of the order of 12.40 g, 9.95 g and 9.88 g, measured respectively in the plants of the control treatments, 150 meq NaCl and 250 meq NaCl. However, it is noted that the application of salicornia root exudates increased the root biomass of plants subjected to salinity. So by this practice, under application of 150 meq of NaCl, the root biomasse increased by 2% and 11% following the respective amendment of the growing medium by the exudates of crushed and cut roots (Fig. 4). The effects of the contributions of the root extracts are announced even more important at the level of the plants subjected to a salinity of level of 250 meq NaCl. Under these conditions, this contribution increase the dry root biomass with rates of 21% and 18% respectively following the application of exudates from the crushed and cut roots. The above-ground dry biomass was also significantly reduced by the application of salinity for the two concentrations of NaCl, 150 and 250 meq (Table 1). It is noted that the reduction rate reached approximately 8% in the batches subjected to salinity compared to the control (Fig. 5). The application of exudates from crushed and cut salicornia roots allowed only slight variations of aboveground biomass. Thus in plants subjected to a salinity of 250 meq, the increase in this biomass was of the order of 4%, indiscriminately for the two types of origin exudates, crushed and cut roots (Fig. 5). Secondary salinity damages mainly result in reduced vegetative growth, which was observed in this study. Indeed, the application of salinity was accompanied by a reduction in root volume and dry matter, especially under the concentration of 250meq. These results confirm those of Yasmeen et al., (2013), et Elhakem (2020), which show that an increase in salt stress considerably reduces root growth. However, the application of exudates obtained from crushed and cut roots of European glasswort contributed to the reduction of these effects. Thus, volume and dry matter of roots were higher in plants treated with root exudates of this species. The application of root exudates from both crushed and cut roots of European samphire have greatly contributed to the reduction of these effects. Thus, the root volume and dry matter were higher in plants treated with root exudates of this species. In the same context, Mutlu-Durak et al., (2021), showed that the application of plant extracts improves root growth in plants subjected to salinity. Also, Martini et al. (2021) et Mazepa et al., (2021) illustrated that biostimulants derived from algae represent a tool to stimulate root development. In addition, Dehkordi et al., (2021), posited that the algae extract appears to enhance root growth by concealed growth stimulants and increasing the water-holding capacity of the soil due to the structure of the resulting jelly. Results of the present study also show that the above-ground biomass is significantly reduced by salinity at 150 and 250 meq of NaCl. According to the works of Mahjoor et al., (2016), et Ghaderi et al., (2018), salinity causes a significant reduction in aerial biomass following an inhibition of growth which, according to Latif (2016), results from a hormonal imbalance. Application of exudates of crushed and cut roots of salicornia allowed a slight increase in the above-ground biomass of plants subjected to salinity. These results are proven by the work of Latif (2016) who demonstrated that this trend is justified by an increase in the content of phytohormones essential for vegetative growth following the application of Moringa leaf extracts on the bean plants submitted to the salt stress.

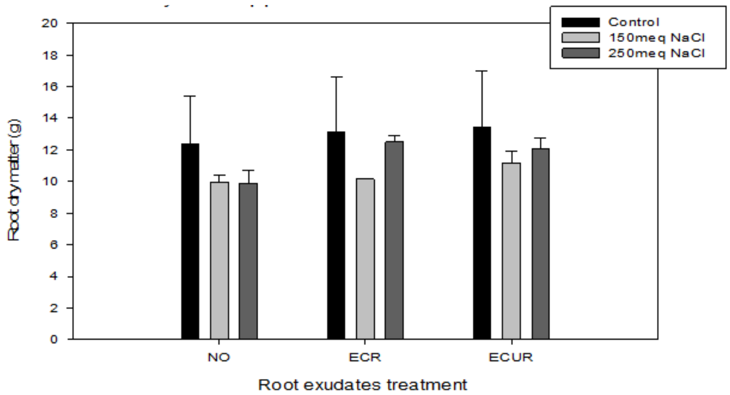

Fig. 4. Effect of root exudates supply on root dry matter of eggplants of plants sujected to different salinity levels by NaCl application.

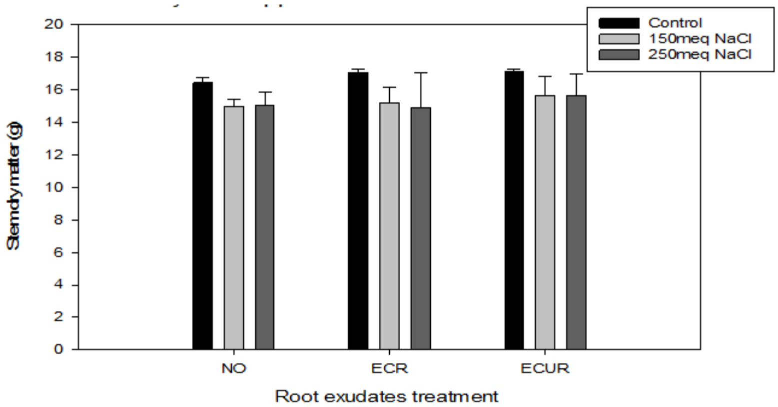

Fig. 5. Effect of root exudates supply on stem dry matter of eggplants of plants sujected to different salinity levels by NaCl application.

Conclusion

Root exudates in the cut and crushed forms of de S. europaeacan act as biostimulants under the effect of salinity by reducing the osmotic effect of NaCl by increasing the Relative Water Content of Leaf and which allow to improve the accumulation of soluble sugars and growth parameters such as root volume, root dry matter and aerial biomass of eggplant plants.

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