Effects of Salicylic Acid on Physiological Characteristics of Eggplant Seedlings under Salt Stress

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Abstract: The salinized land area in Tianjin accounts for about 65.8% of the total land area in Tianjin. Eggplant is one of the main vegetable crops in Tianjin. The planting area and yield of eggplant affect the vegetable basket project in Tianjin. It is important to study the growth of eggplant in salinized soil. In order to utilize adequately salinized soil, the effect of salicylic acid on physiological characteristics of eggplant seedlings under salt stress was studied. The results showed that the growth of eggplant seedlings was significantly inhibited with the increase of salt concentration. The emergence rate of eggplant seeds were treated by salicylic acid was higher than that not treated by salicylic acid, the activity of superoxide dismutase, the content of proline and the content of soluble sugar by salicylic acid were significantly higher than that not treated by salicylic acid, and the content of malondialdehyde by salicylic acid was lower than that not treated by salicylic acid under salt stress. The content of superoxide dismutase, proline and soluble sugar in eggplant seedlings were accumulated by salicylic acid under salt stress, and the salt stress of eggplant seedlings was alleviated so as to improve its salt resistance. This study provided scientific basis for the rational use of salicylic acid to solve salt damage problem in eggplant cultivation.

1. Introduction

The normal growth and development of plants is affected by salt stress. Crop yield about (0.20-0.46) ×106 hm2 cultivated land area of the world were decreased by the harm of salinization every year[1]. As a result of growing climate change and overfertilization, soil salinization in the country is increasing. Rational utilization of existing large area of salinized land is one of the important measures at present. Eggplant is one of the common vegetables in China and even in the world today. It also occupies an important position in Tianjin vegetable market. Salicylic acid(SA) is a kind of small molecule phenolic substance, which widely exists in the plant kingdom[2]. Exogenous SA plays an important role in inducing stress resistance in plant[3]. As a signal molecule, Exogenous SA mediates seed germination, seedling growth, flowering, fruiting and fading[4].Soil salinization is one of the important adverse factors restricting plant growth and development. Excessive salinity in soil will cause certain damage to plants, which is most directly manifested as slow growth and development, reduced biological yield, and even serious failure to germinate seeds or death of plants[5]. The key stage from seed germination to seedling growth is often a period in which plants are most sensitive to salt stress in soil, and the most critical step in this period is to improve the stress resistance of plants[6]. In abiotic adversity, exogenous SA can improve the resistance of plants by reducing MDA content and increasing soluble sugar content, the application of exogenous SA under salt stress could enhance the stress resistance of plants[7].There are few studies on salt stress physiology of eggplant seedlings treated with exogenous SA. Therefore, the Ziyuanshuai hybrid first-generation eggplant seeds were selected as experimental materials to explore the effect of SA on the physiological characteristics of eggplant seedlings under salt stress. The theoretical foundation is laid for the improvement of salt tolerance of eggplant with exogenous SA.

2. Materials and methods

2.1 Test Materials

The eggplant variety is " Ziyuanshuai hybrid first-generation eggplant", which is purchased online by the Department of Seed Science and Engineering.

2.2 Experimental Method

Sand bed culture method: set experimental group(SA treatment) and control group(CK). In the control group, eggplant was cultured with nutrient solution with different concentration of NaCl, and the seeds and test process were treated without salicylic acid. In the experimental group, eggplant was cultured with the corresponding NaCl concentration nutrient solution, and the eggplant seeds were first soaked with 0.02 mmol /L salicylic acid for 10 s, and the seedlings were quantitatively sprayed with 0.02 mmol /L salicylic acid after growing to a certain extent. The content of proline, soluble sugar and malondialdehyde in the leaves of eggplant seedlings was determined on the 18th day after seedling emergence, and the activity of SOD was determined. Refer to the method of [8] for the salt concentration. 0, 60 and 120 mmol/L NaCl treatment was selected, which was repeated for 4 times.

2.3 Determine items and Measurement Methods

Early emergence rate = total number of emergence of 7 days/ number of seeds tested × 100% (1)

Total emergence rate = total number of emergence of 14 days/ number of seeds tested × 100%(2)

Content of MDA was determined by TBA method, content of soluble sugar was determined by anthrone colorimetric method, activity of SOD was determined by hydroxylamine method, and content of proline was determined by colorimetric method. (Kit: Nanjing Jiancheng Reagent Company)

2.4 Data Processing

Data processing and analysis were performed using Excel 2013 and SPSS 25 software.

3. Results and Analysis

3.1 Effect of Salicylic Acid on Emergence Rate of Eggplant Seeds under Salt Stress

The early emergence rate and the total emergence rate of Ziyuanshuai hybrid first-generation eggplant were analyzed under different concentrations of salt stress, and the results were shown in Table 1.

Table 1. Emergence rate of Ziyuanshuai hybrid first-generation eggplant seeds under different treatments

Treatment	Early emergence rate(%)	Total emergence rate(%)
0 mmol/L	48 b	86 b
60 mmol/L	53 b	85 b
120 mmol/L	0 c	4 d
0 mmol/L+SA	57 a	93 a
60 mmol/L+SA	60 a	90 a
120 mmol/L+SA	31 b	41 c

Note: The letters in the table represent the analysis of variance of different treatments for a trait in the same column, and lowercase letters represents the level of 0.05

As can be seen from Table 1, the early emergence rate and total emergence rate of eggplant seeds under salt stress were improved or significantly improved by SA treatment than those without

SA treatment. The high emergence rate of eggplant seeds indicates that the seeds have strong vitality, which can measure the quality of the seeds. Under the 60 mmol/L of salt concentration, early emergence rate was 7% higher by exogenous SA than non-exogenous SA. total emergence rate increased by 5%. At the 120 mmol/L of salt concentration, the early emergence rate without exogenous SA treatment was 0, and the total emergence rate was only 4%, while the early emergence rate and the total emergence rate with exogenous SA treatment reached more than 30%. This indicated that SA could alleviate the effect of salt stress on the early seedling emergence rate and the total seedling emergence rate of eggplant seeds, and appropriate SA treatment could promote the emergence rate of eggplant seeds under salt stress.

3.2 Effect of SA on Proline Content in Eggplant Seedling under Salt Stress

Proline(PRO) is one of the molecular components of plant protein and can distribute widely in plants in a free state.The osmotic potential of eggplant seedlings can be reduced by accumulating PRO under salt stress, so as to enhance their salt tolerance. It can be seen from Figure 1 that PRO content in eggplant seedlings increased with the increase of salt stress concentration under the two treatments. The PRO content in eggplant seedlings treated with exogenous SA increased by 36.05% compared with those not treated with exogenous SA under the salt-free treatment. The PRO content in eggplant seedlings treated with exogenous SA increased by 35.98% compared with those not treated with exogenous SA under the 60 mmol/L of salt concentration. Because the eggplant seedlings no SA was used grew badly under 120 mmol/L of salt concentration and their physiological characteristics could not be sampled to measure. Therefore, no data was obtained for PRO content under this treatment, and no data were obtained for other physiological indexes under the same treatment conditions. At the same salt concentration, the PRO content of eggplant seedlings treated by exogenous SA was always higher than those not treated by SA, indicating that eggplant seedlings treated by SA had stronger adaptability to salt stress.

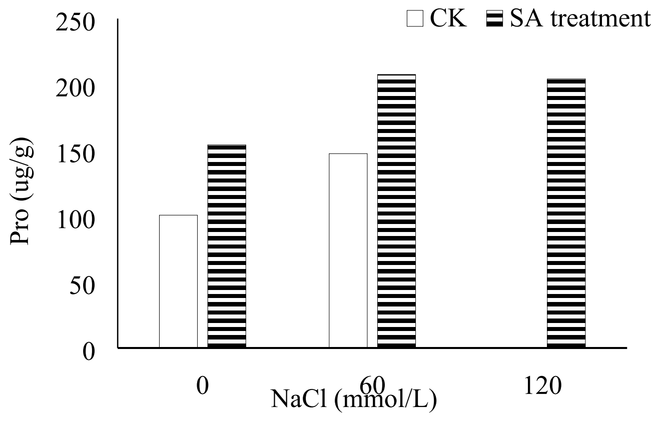

Figure 1. The proline content in eggplant seedling under different treatments

3.3 Effect of SA on Superoxide Dismutase Activity in Eggplant Seedling under Salt Stress

Superoxide dismutase(SOD) is one of the most important enzyme of scavenging free radical in plants. When SOD activity is high, superoxide free radicals can be properly scavenged, which can increase plant tolerance[9].As can be seen from Figure 2, SOD activity of eggplant seedlings under both treatment conditions increased with the increase of salt concentration between 0 mmol/L and 120 mmol/L, and SOD activity value of exogenous SA treatment was higher than that of non-SA treatment. Under the condition, SA increased the activity of SOD by 3.94% compared with the untreated one under 60 mmol/L of salt concentration. The maximum value of SOD activity was the activity of SOD under the 60 mmol/L of salt concentration. The activity of SOD is the decrease under the 120 mmol /L of salt concentration, which may be due to the destruction of the mechanism in plants with the increase of salt stress. It could be seen that SA can alleviate the stress of high concentration salt to some extent.

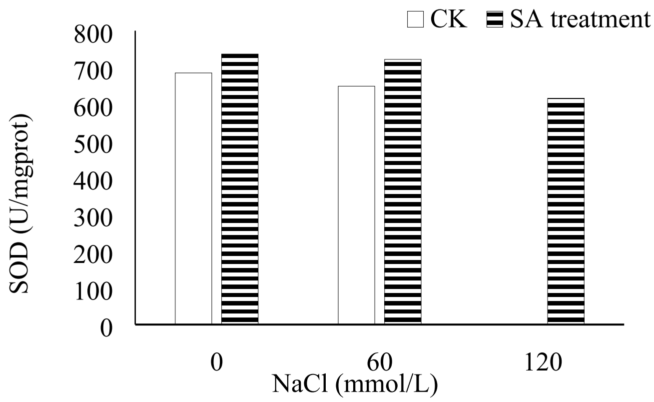

Figure 2. The superoxide dismutase activity in eggplant seedling under different treatments

3.4 Effect of SA on soluble sugar and malondialdehyde content in eggplant seedling under salt stress

Soluble sugar in plants is not only an important regulator of plant growth and development, but also anosmotic regulator, which can be used as a source of carbon shelf and energy [10].

It can be seen from Figure 3 that the soluble sugar content of eggplant increased with the increase of salt stress in both of treatment. The soluble sugar content of eggplant by SA treatment was significantly higher than that without SA treatment under the 60mmol/L and 120mmol/L of salt concentration. The soluble sugar content treated with exogenous SA increased by 53.70% compared with that not treated with exogenous SA at the 0mmol/L of salt concentration, and the soluble sugar content of exogenous SA increased by 40.47% compared with that of non-exogenous SA at 60mmol/L of salt concentration. SA treatment could improve the soluble sugar content of eggplant seedlings under salt stress, and could alleviate salt stress to some extent.

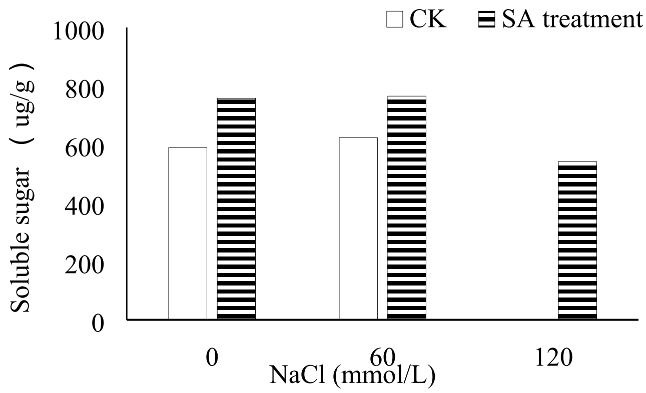

Figure 3. The soluble sugar content in eggplant seedling under different treatments

Malondialdehyde(MDA) is an indicator reflecting the lipid peroxidation of plant cell membranes. The higher the content of MDA, the more severe the lipid peroxidation damage of membrane will be, thus resulting in the destruction of membrane system [11]. As can be seen from Fig. 4, MDA content increased with the increase of salt stress under the both of treatment, indicating that the effect of salt stress on eggplant seedlings increased with the increase of salt concentration. MDA content of eggplant seedlings treated with exogenous SA was reduced by 5.88% compared with those treated without SA Under the 0mmol/L of salt concentration. MDA content in eggplant seedlings treated with exogenous SA was 38.38% lower than that treated without exogenous SA at 60mmol/L salt concentration. According to the change of MDA content, SA plays an important role in improving salt resistance of eggplant seedlings.

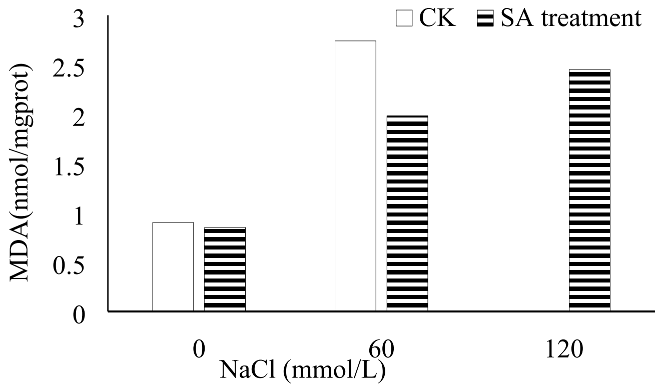

Figure 4. The malondialdehyde content in eggplant seedling under different treatments

4. Discussion

Seed germination is the beginning of plant life and the earliest moment when plants can respond to external conditions. Its germination is directly related to the growth and quality of crops [12]. Studies have shown that plants have different salt tolerance at different developmental stages, but it is generally considered that plants have the worst salt tolerance at germination and seedling stage [13]. Therefore, salt tolerance should be done in the germination and seedling stage of plants. This study showed that higher salt concentration had a great influence on the early emergence rate and the total emergence rate of eggplant seeds. Exogenous SA could improve the early emergence rate and total emergence rate of eggplant seeds, indicating that exogenous SA could enhance the salt tolerance of eggplant seedling and promote the emergence rate of eggplant under salt stress. PRO is considered be the most widely distributed osmotic protective substance among the numerous osmotic regulatory substances in plant cells [14]. Eggplant seedlings under salt stress can reduce osmotic potential by accumulating PRO, so that water can flow to various tissues of plants and enhance their salt tolerance. This study showed that eggplant seedlings treated with exogenous SA could alleviate the toxic effects brought by salt stress and enhance their adaptability to salt stress. When eggplant seedlings were exposed to salt stress, they could adapt to the stress by increasing their SOD activity. SOD activity of eggplant seedlings treated with exogenous SA was higher than that of control at the same salt concentration. SA treatment significantly increased the soluble sugar content in eggplant leaves under salt stress, indicating that exogenous SA can increase the soluble sugar content and thus promote the growth of eggplant seedlings, which was consistent with the results of wheat seedlings and saponaria japonica and so on [15]. Salt stress can induce the accumulation of reactive oxygen species(ROS) in plants, and excessive ROS will initiate the lipid peroxidation of cell membranes [16]. MDA is the main product of membrane peroxidation, and its accumulation can destroy membrane and many biological functional molecules in cells. SOD is an important protective enzyme of the membrane peroxidase defense system in plants. This enzyme, in cooperation with other antioxidant enzymes, can effectively eliminate ROS accumulated in plants, prevent membrane peroxidation, and make the cell membrane less hurt [17].

The reason for the improvement of salt-tolerance of eggplant under SA treatment may be that SA induces the increase of enzyme activity of cell protective enzymes such as SOD in eggplant leaves, inhibits the accumulation of MDA in eggplant leaves, reduces the level of membrane peroxide caused by salt stress, and improves the salt-tolerance of eggplant.

5. Conclusion

In the absence of salt stress, SA significantly increase proline content, soluble sugar content and SOD activity in eggplant seedling. Under salt stress, SA can not only significantly increase the content of proline and soluble sugar and the activity of SOD, but also significantly reduce the content of MAD in eggplant seedling. The seeds and seedlings were treated by SA could increase the content of permeable substances in eggplant seedlings, improve the activity of antioxidant enzymes in the seedlings, and enhance the salt resistance of eggplant. SA treatment can be used as one of the effective methods to improve germination ability of eggplant seeds and seedling growth under salt stress.

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