Physiological response of *Solanum nigrum* to salt stress

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Abstract. The effects of salt stress (100, 200, 300 mmol/L) on physiological characteristics of *Solanum nigrum* seedlings were studied by pot experiment. The results showed that the contents of chlorophyll a, chlorophyll b, carotenoids and total chlorophyll in *S. nigrum* leaves showed a trend of first flattening and then increasing with the aggravation of salt stress. With the aggravation of salt stress, the net photosynthetic rate, stomatal conductance and intercellular CO2 concentration of *S. nigrum* decreased gradually, and reached the lowest value when the NaCl concentration was 300 mmol/L. With the increase of NaCl concentration, the SOD activity of *S. nigrum* leaves decreased gradually. When the concentration of NaCl was 300 mmol/L, the SOD activity of *S. nigrum* decreased by 53.39% ($P < 0.05$). The activities of POD, CAT and soluble protein in *S. nigrum* increased first and then decreased with the increase of NaCl concentration. When the concentration of NaCl was 100 mmol/L, the activities of POD, CAT and the content of soluble protein reached the maximum.

1 Introduction

With the rapid development of economy, there are many environmental problems, among which soil salinization is one of them. Soil salinization is also a worldwide environmental problem, which is one of the main causes of land desertification and soil degradation [1]. According to statistics, the area of saline soil in China is about 520million ha, of which, the salt soil is about 240 million ha [2]. Saline alkali land is not only huge in area, but also widely distributed in northwest, north, northeast and coastal areas of China [3]. Salinization can reduce soil porosity, make soil easy to board and permeability becomes poor. It can also reduce the content of soil organic matter, and the degree of carbon and nitrogen mineralization can decrease, which can lead to the decline of soil fertility [4]. In short, salinization of soil will have a negative effect on plant growth and development. The results showed that the chlorophyll content of three turfgrasses increased firstly and then decreased with the aggravation of salt stress [5]. Pn, Gs and Tr of the three blueberry seedlings decreased gradually with the increase of NaCl concentration, while intercellular CO_2 concentration increased gradually [6]. In addition, salt stress also causes the plant anti reverse reaction, and by improving the activity of antioxidant enzymes, it can resist the damage of reactive oxygen on cells [7]. The results showed that superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activities in tomato leaves increased with the increase of NaCl concentration [8].

Solanum nigrum is a plant of Solanaceae, which is distributed all over China. It grows on the edge of fields, roadsides, hillsides and grasslands [9]. As a Chinese herbal medicine, *S. nigrum* has many effects such as clearing away heat and detoxification, antiphlogistic and diuretic. In recent years, studies have found that *S. nigrum* also plays an important role in anti-cancer, and the alkaloids contained in its extract are a variety of effective anti-tumor components, which has attracted extensive attention of scholars at home and abroad [10]. Therefore, *S. nigrum* has important research value. In this experiment, *S. nigrum* was used as material to study the effect of salt stress on the physiological characteristics of *S. nigrum* seedlings by irrigating different concentrations of NaCl solution.

2 Materials and method

2.1 Materials

The *S. nigrum* seeds used in the experiment were collected from the farmland around the Yucheng District, Ya'an City, Sichuan Province, China.

2.2 Experimental design

In September 2020, *S. nigrum* was seeded in a 32-hole tray. Mix perlite, coconut brick and soil in the ratio of 1:1:1 and put them into 8cm × 10cm (height × diameter) plastic basin for use. When the seedlings grew to 3-4cm, the seedlings were transplanted into plastic pots with 3 plants in each basin. After that, the plastic pot was placed in a large tray and cultured with Hoagland nutrient solution. When the seedling grew to 15 cm (8 true leaves were expanded), salt stress treatment was carried out. Four NaCl concentration gradients [0 (CK), 100, 200 and 300 mmol/L] were set in the experiment, and each treatment was repeated 4 times. Prepare 1 L NaCl

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solution and pour it into the large tray, and replace it every 2 days. After 7 days of culture, the leaves were collected for determination of related indexes.

Photosynthetic rate was measured by Li-6400 portable photosynthesis instrument. The photosynthesis parameters of the photosynthesis instrument are manually controlled with a CO_2 concentration of 400 μmol/mol, a temperature of 30°C, and a light intensity of 1000 μmol/m^2/s.The photosynthetic parameters include net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), and intercellular CO_2 concentration (Ci). The contents of photosynthetic pigments (chlorophyll a, chlorophyll b, total chlorophyll and carotenoid) in mature leaves of *S. nigrum* were measured. The activity of antioxidant enzymes (SOD, POD, and CAT) and the content of soluble protein in *S. nigrum* were measured [11].

2.3 Statistical analyses

Spss22.0 was used to analyze the data and Duncan's new complex range method was used for multiple comparisons (significance level was 5%).

3 Results and discussion

3.1 Effect of salt stress on the photosynthetic pigment content of *S. nigrum*

Compared with the control, the contents of chlorophylla, carotenoid and total chlorophyll in *S. nigrum* leaves were significantly increased by 200 and 300 mmol/L NaCl solution, and chlorophyll b content in *S. nigrum* leaves was significantly increased by 300 mmol/L NaCl solution, but there was no significant difference between the treatment of 100 mmol/L NaCl solution and the control.

Table 1. The photosynthetic pigment content of *S. nigrum.*

NaCl (mmol/L)	Chlorophyll *a* (mg/g)	Chlorophyll *b* (mg/g)	Carotenoid (mg/g)	Total chlorophyll (mg/g)
0	0.703±0.004b	0.240±0.004b	0.126±0.002b	0.943±0.008b
100	0.710±0.003b	0.243±0.005ab	0.126±0.004b	0.953±0.008b
200	0.774±0.025a	0.255±0.005ab	0.144±0.000a	1.030±0.030a
300	0.773±0.011a	0.262±0.011a	0.145±0.009a	1.036±0.023a

Value are means ± standard errors. Means with the same letter within each column are not significantly different at $p< 0.05$.

3.2 Effect of salt stress on photosynthetic characteristics of *S. nigrum*

With the aggravation of salt stress, Pn, Gs and Ci of *S. nigrum* leaves gradually decreased, and the differences were significant among treatments. When the concentration of NaCl was 300 mmol/L, the Pn, Gs and Ci decreased by 67.16% ($P < 0.05$), 66.72% ($P < 0.05$) and 39.34% ($P < 0.05$) respectively. Compared with the control, the treatment of salt stress significantly reduced the Tr of leaves, among which 200 mmol/L NaCl solution decreased the most significantly, which was 28.95% lower than the control ($P < 0.05$).

Table 2. Photosynthetic characteristics of *S. nigrum.*

NaCl (mmol/L)	Pn (μmol CO_2/m^2/s)	Gs (mol H_2O/m^2/s)	Ci (μmol CO_2/mol)	Tr (mmol H_2O/m^2/s)
0	9.125±0.252a	0.640±0.024a	354.6±4.33a	4.601±0.118a
100	6.722±0.263b	0.426±0.017b	328.5±2.69b	3.752±0.106b
200	4.468±0.285c	0.316±0.007c	270.1±5.43c	3.269±0.010c
300	2.997±0.082d	0.213±0.014d	215.1±6.33d	3.543±0.003b

Value are means ± standard errors. Means with the same letter within each column are not significantly different at $p < 0.05$.

3.3 Effect of salt stress on antioxidant enzyme activity of *S. nigrum*

With the aggravation of salt stress, the SOD activity of *S. nigrum* decreased gradually. When the concentration of NaCl was 300 mmol/L, the SOD activity of *S. nigrum*decreased by 53.39% ($P < 0.05$). The activities of POD, CAT and soluble protein in *S. nigrum* leaves increased first and then decreased with the aggravation of salt stress. When the concentration of NaCl was 100 mmol/L, the activities of POD, CAT and soluble protein decreased by 50.94% ($P < 0.05$), 15.68% ($P < 0.05$) and 54.76% ($P < 0.05$) respectively.

Table 3. Antioxidant enzyme activity of *S. nigrum.*

NaCl (mmol/L)	SOD activity (U/g)	POD activity (U/g/min)	CAT activity (mg/g/min)	Soluble protein content (mg/g)
0	333.2±21.16a	758±6.48c	5.23±0.17c	25.86±0.69c
100	233.0±8.08b	1545±49.47a	6.05±0.16a	40.02±1.22a
200	218.3±13.21b	1254±59.95b	5.71±0.16ab	32.08±2.82b
300	155.3±3.38c	829±19.00c	5.30±0.17bc	29.84±1.63bc

Value are means ± standard errors. Means with the same letter within each column are not significantly different at $p< 0.05$.

4 Conclusions

With the aggravation of salt stress, the contents of chlorophyll a, chlorophyll b, carotenoids and total chlorophyll in *S. nigrum* leaves showed a trend of first flattening and then increasing, while Pn, Gs and Ci of leaves gradually decreased, and the differences were significant among treatments. In addition, in the aspect of antioxidant enzyme activity, the increase of NaCl concentration decreased the activity of SOD, while the activities of POD, CAT and soluble protein increased first and then decreased with the increase of NaCl concentration. Therefore, under salt stress, *S. nigrum* increased the content of photosynthetic pigment, improved the photosynthetic characteristics and antioxidant enzyme activity, and showed certain salt tolerance.

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