Effects of salt stress on the physiological characteristics of *Solanum photeinocarpum*

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Abstract. A pot experiment was used to study the effects of different concentrations of salt (100, 200, 300 mmol/L) stress on the photosynthetic physiology and antioxidant enzyme activities of *Solanum photeinocarpum*. The results showed that NaCl of 100 and 200 mmol/L could significantly improve the contents of chlorophyll *a*, chlorophyll *b* and carotenoid in *S. photeinocarpum*. However, under different concentrations of salt stress, there was no significant difference in the amount of total chlorophyll in *S. photeinocarpum*. Besides, as the salt stress increased, the net photosynthetic rate, stomatal conductance, CO_2 concentration of intercellular and transpiration rate of *S. photeinocarpum* gradually decreased, when the concentration of NaCl was 300 mmol/L, reached the lowest value. With the increase of salt stress, the POD activity, CAT activity and soluble sugar content of *S. photeinocarpum* increased first and then decreased, reaching the highest when the concentration of NaCl was 100 mmol/L. Therefore, *S. photeinocarpum* had a certain salt tolerance, low concentration of NaCl (≤ 200 mmol/L) stress could promote its growth, but high concentration (> 200 mmol/L) could inhibit its growth.

1 Introduction

Soil salinization is an important cause of land degradation and soil fertility decline [1], which not only causes serious waste of resources, but also has a serious impact on the ecological environment and social and economic development [2]. China's salinized soil area is about 34.6 million ha, and the salinized cultivated land is 7.6 million ha. About 20% of the cultivated land is salinized, which is mainly distributed in arid, semi-arid areas and coastal areas [3, 4]. Soil salinization will cause the osmotic pressure of the soil solution to increase, and the aeration of the soil will become poor, which affects the absorption of water by plants, which in turn affects the growth of plants [5]. Studies have found that with the increase of salt stress, the chlorophyll content of *Tamarix chinensis* increases first and then decreases [6]. When *Paspalum vaginatum* is treated with different concentrations of NaCl solution, the chlorophyll content and antioxidant enzyme activity shows a trend of increasing first and then decreasing with the increase of salt concentration [7]. For tomato, the low salt concentration (0%-0.2%) conditions have little effect on seed germination, seedling growth and root tip micronucleus rate; when the salt concentration is higher than 0.3%, the seed germination, seedling growth status, or root tip micronucleus are inhibited by salt [8].

Solanum photeinocarpum is an annual herb that grows in fields, roadsides and other places. Its tender stems can be used as edible wild vegetables. The taste is sweet, tender and delicious. At the same time, the roots, stems and leaves of *S. photeinocarpum* can be used as medicine [9, 10]. This experiment studied the effects of different concentrations of salt (100, 200, 300 mmol/L) stress on the growth and physiological characteristics of *S. photeinocarpum*, and explored the adaptive mechanism of *S. photeinocarpum* to salt stress.

2 Materials and method

2.1 Materials

The *S. photeinocarpum* seeds used in the experiment were collected from the farmland around the Yucheng District, Ya'an City, Sichuan Province, China. The substrate used in the experiment was coconut brick: perlite: soil=1:1:1.

2.2 Experimental design

In September 2020, sown the *S. photeinocarpum* seeds in 32-hole plug trays, and when the seedlings grow to 3-4 cm, transplant them into 8 cm × 10 cm (diameter × height) plastic pots, and three plants were planted in each pot. After transplanting, Hoagland solution was watered for nutrient solution culture. When the seedlings grow to about 15 cm (8 true leaves unfolded), salt stress was applied. A total of four NaCl concentration gradients were set, respectively, including 0 (CK), 100, 200, and 300 mmol/L. One pot was one repetition, and 4 repetitions. The plants were placed in large trays containing different salt solutions. The solutions in the

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trays were changed every 2 days for a total of 7 days. After 7 days, their physiological and biochemical indexes were measured.

In October 2020, the LI-6400 portable photosynthesis meter was used to determine the photosynthesis of *S. photeinocarpum*. 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). After that, selected the upper mature leaves of *S. photeinocarpum* to determine the content of photosynthetic pigments (chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoids) content, and selected the young leaves of *S. photeinocarpum* to determine antioxidant enzymes [superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT)] activity and soluble protein content. A 0.200 g leaf sample was cut into pieces and soaked in 20 mL of a 1:1 v/v mixture of ethanol and acetone in the dark for 24 h, then the absorbances at 663, 645, 652, and 470 nm (for chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoids, respectively) were measured according to the methods of Hao et al. [11]. A 1.0 g aliquot of fresh leaf tissue was added to 6 mL extraction buffer (0.05 M potassium phosphate buffer containing 1 mM EDTA at pH 7.0) at 4 °C, and the mixture was homogenized and then centrifuged at 11000 *g* for 20 min. The activities of SOD, POD, and CAT were measured by the nitroblue tetrazolium reduction method, guaiacol method, and potassium permanganate titration method, respectively, and the soluble protein content was measured by the Coomassie brilliant blue method [11].

2.3 Statistical analyses

Statistical analyses were conducted using SPSS 20.0 (IBM, Chicago, IL, USA). Data were subjected to one-way analysis of variance, followed by least significant difference test (5% confidence level).

3 Results and discussion

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

With the increase of salt stress, the contents of chlorophyll *a*, chlorophyll *b*, carotenoid and total chlorophyll contents in *S. photeinocarpum* increased first and then decreased (Table 1). When the NaCl concentration was 200 mmol/L, the contents of chlorophyll *a* and chlorophyll *b* of *S. photeinocarpum* reached the maximum. Compared with the control, 100, 200, and 300 mmol/L NaCl concentrations increased the chlorophyll *a* content in *S. photeinocarpum* by 26.35% ($p < 0.05$), 27.35% ($p < 0.05$), and 8.40% ($p < 0.05$), respectively, increased the chlorophyll *b* content in *S. photeinocarpum* by 31.91% ($p < 0.05$), 32.34% ($p < 0.05$), and 11.91% ($p > 0.05$), respectively, and increased the total chlorophyll content in *S. photeinocarpum* by 27.72% ($p < 0.05$), 28.46% ($p < 0.05$), and 9.17% ($p > 0.05$), respectively. When the NaCl concentration was 100 mmol/L, the carotenoid content of *S. photeinocarpum* reached the maximum. Compared with the control, 100, 200, and 300 mmol/L NaCl concentrations increased the carotenoid content in *S. photeinocarpum* by 26.92% ($p < 0.05$), 20.00% ($p < 0.05$), and 16.92% ($p < 0.05$), respectively.

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

NaCl (mmol/L)	Chlorophyll *a* (mg/g)	Chlorophyll *b* (mg/g)	Carotenoid (mg/g)	Total chlorophyll (mg/g)
0	0.702±0.006c	0.235±0.004b	0.130±0.002b	0.938±0.010b
100	0.887±0.020a	0.310±0.012a	0.165±0.007a	1.198±0.032a
200	0.894±0.029a	0.311±0.012a	0.156±0.012a	1.205±0.041a
300	0.761±0.011b	0.263±0.017b	0.152±0.010ab	1.024±0.029b

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. photeinocarpum*

With the increase of the salt stress, the Pn, Gs, Ci and Tr of *S. photeinocarpum* gradually decreased (Table 2). When the NaCl concentration was 300 mmol/L, the Pn, Gs, Ci and Tr of *S. photeinocarpum* reached the lowest level. Compared with the control, 100, 200, and 300 mmol/L NaCl concentrations reduced the Pn of *S. photeinocarpum* by 18.28% ($p < 0.05$), 42.90% ($p < 0.05$), and 64.90% ($p < 0.05$), respectively, reduced the Gs of *S. photeinocarpum* by 16.21% ($p < 0.05$), 48.38% ($p < 0.05$), and 72.32% ($p < 0.05$), respectively, reduced the Ci of *S. photeinocarpum* by 15.04% ($p < 0.05$), 33.29% ($p < 0.05$), and 42.98% ($p < 0.05$), respectively, and reduced the Tr of *S. photeinocarpum* by 19.79% ($p <$

0.05), 34.29% ($p < 0.05$), and 43.33% ($p < 0.05$), respectively. Salt stress of different concentrations significantly reduced the Pn, Gs, Ci and Tr of *S. photeinocarpum*, and the differences between the treatments were significant.

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

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	9.268±0.312a	0.401±0.001a	338.5±1.93a	4.083±0.174a
100	7.574±0.127b	0.336±0.013b	287.6±7.29b	3.275± 0.101b
200	5.292±0.110c	0.207±0.009c	225.8±5.71c	2.683±0.069c
300	3.253±0.093d	0.111±0.007d	193.0±7.45d	2.318±0.020d

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. photeinocarpum*

With the concentration of NaCl increase, the SOD activity of *S. photeinocarpum* gradually decreased (Table 3). When the NaCl concentration was 300 mmol/L, the SOD activity of *S. photeinocarpum* reached the minimum value. Compared with the control, 100, 200, and 300 mmol/L NaCl concentrations reduced the SOD activity of *S. photeinocarpum* by 18.57% ($p < 0.05$), 29.07% ($p < 0.05$), and 35.23% ($p < 0.05$), respectively. The POD activity, CAT activity and soluble protein content of *S. photeinocarpum* showed a trend of first increasing and then decreasing. When NaCl concentration was 100 mmol/L, the POD activity, CAT activity and soluble protein content of *S. photeinocarpum* reached the maximum value. Compared with the control, 100, 200, and 300 mmol/L NaCl concentrations enhanced the POD activity of *S. photeinocarpum* by 58.07% ($p < 0.05$), 49.00% ($p < 0.05$), and 10.95% ($p < 0.05$), respectively, and increased the soluble protein content of *S. photeinocarpum* by 35.26% ($p < 0.05$), 17.75% ($p < 0.05$), and 11.49% ($p < 0.05$), respectively. The concentration of 100 mmol/L NaCl enhanced the CAT activity of *S. photeinocarpum* by 8.74% ($p < 0.05$) compared with the control. However, the concentrations of 200 and 300 mmol/L NaCl reduced the CAT activity of *S. photeinocarpum* by 9.76% ($p < 0.05$) and 22.15% ($p < 0.05$), respectively, compared with the control.

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

NaCl (mmol/L)	SOD activity (U/g)	POD activity (U/g/min)	CAT activity (mg/g/min)	Soluble protein content (mg/g)
0	214.3±10.53a	849±24.88c	4.92±0.21b	30.46±0.49c
100	174.5±9.14b	1342±29.85a	5.35±0.11a	41.20±1.71a
200	152.0±6.47c	1265±16.79a	4.44±0.01c	35.87±0.37b
300	138.8±4.13c	942±38.84b	3.83±0.10d	33.96±0.52b

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

4 Conclusions

In this experiment, low concentration of salt stress could promote the increase of chlorophyll *a*, chlorophyll *b* and carotenoid content of *S. photeinocarpum*. But all the salt stress had no significant effect on the total chlorophyll of *S. photeinocarpum*. With the increase of the salt stress, the Pn, Gs, Ci and Tr of *S. photeinocarpum* gradually decreased, and the differences between treatments were significant. Compared with the control, the SOD activity of *S. photeinocarpum* decreased, and the POD activity, CAT activity and soluble protein content increased first and then decreased. Therefore, under the condition of salt stress, *S. photeinocarpum* could increase photosynthetic pigment content, and improve the photosynthetic characteristics and antioxidant enzyme activity to improve resistance to salt stress.

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