Effects of Exogenous Absciscic Acid on Resistance of *Capsella bursa-pastoris* Under Salt Stress

Yumei Tan^{1,a}, Jianhua Li^{2,b}, Huan Yao^{1,c}, Zicheng Lu^{3,d}, Maolin Chen^{4,e},
Mei Qing^{1,f} and Lijin Lin^{5,g*}

¹College of Horticulture, Sichuan Agricultural University, Chengdu, Sichuan, China

²Sichuan Ya'an Municipal Product Quality Supervision & Inspection Institute, Ya'an, Sichuan, China

³College of Agronomy, Sichuan Agricultural University, Chengdu, Sichuan, China

⁴College of Economics, Sichuan Agricultural University, Chengdu, Sichuan, China

⁵Institute of Pomology and Olericulture, Sichuan Agricultural University, Chengdu, Sichuan, China

^a2229809882@qq.com, ^b710753781@qq.com, ^c272365026@qq.com, ^dlzcheng666@qq.com,

^e3208585092@qq.com, ^f1115435013@qq.com, ^glj800924@163.com

*Corresponding author. Yumei Tan and Jianhua Li contributed equally to this work.

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Abstract: A pot experiment was carried out to study the effects of exogenous absciscic acid (ABA) on the resistance of *Capsella bursa-pastoris* under salt stress. Spraying ABA increased the root, stem, leaf and shoot biomasses of *C. bursa-pastoris* under salt stress. ABA applications also enhanced the plant height of *C. bursa-pastoris*. With the increase in the ABA concentrations, the biomass and plant height of *C. bursa-pastoris* increased. ABA treatments enhanced the antioxidant enzyme (SOD, POD and CAT) activities of *C. bursa-pastoris*. With increasing ABA concentrations, the SOD, CAT and POD activities of *C. bursa-pastoris* were enhanced under salt stress and the soluble protein content of *C. bursa-pastoris* also showed an increasing trend. Therefore, ABA could enhance the resistance of *C. bursa-pastoris* to salt stress, and promote its growth.

Introduction

Capsella bursa-pastoris is a common wild vegetable with a strong nutritional value [1-2]. However, because of irrational fertilization, vegetable fields have become overly salinized, which has serious effects on *C. bursa-pastoris* production [2]. Therefore, to enhance the resistance of *C. bursa-pastoris* to salt stress, different concentrations of absciscic acid (ABA) were used to treat *C. bursa-pastoris* seedlings. The aim of this study was to determine the optimal ABA concentration for enhancing the resistance of *C. bursa-pastoris* to salt stress, and to provide a reference for improving salt resistance in vegetable species.

Materials and Methods

Materials. Seedlings of *C. bursa-pastoris* with five euphyllas were collected from the Chengdu Campus of Sichuan Agricultural University (30° 42' N, 103° 51' E) in October 2015. The culture medium in the experiment was a 1:1 mixture of perlite and vermiculite.

Experimental Design. The culture medium was placed into polyethylene pots (10 cm high, 10 cm in diameter), and three uniform seedlings of *C. bursa-pastoris* were transplanted into each pot. The plant seedlings were irrigated with 20 mL Hoagland nutrient solution (containing 50 mmol/L NaCl) [2] per pot every two days until the plants were harvested. When *C. bursa-pastoris* seedlings had grown for 15 days, five concentrations (0, 1, 5, 10 and 20 µmol/L) of ABA [3], with three replicates, were sprayed independently on the leaves of plants. The second and third ABA sprayings occurred at 18 days and 21 days after transplanting, respectively. At each spraying, 25 mL of ABA solution was used per pot, which just soaked the plants. 30 days after the last ABA spraying, the plant height of each *C. bursa-pastoris* was measured. Then, the whole plants were then harvested, and the roots,

stems and leaves were washed with tap water and dried with absorbent paper for weighing the fresh biomasses.

Statistical Analyses. Statistical analyses were performed using SPSS 13.0 statistical software (IBM, Chicago, IL, USA). Data were analyzed by a one-way analysis of variance with least significant difference at a 5% confidence level.

Results and Discussion

Biomass of *C. bursa-pastoris*. Spraying ABA increased the root, stem, leaf and shoot biomasses of *C. bursa-pastoris* (Table 1). When the doses of ABA were 1 and 5 $\mu\text{mol/L}$, there were no significant differences in the root biomasses compared with that of the control. ABA at 10 and 20 $\mu\text{mol/L}$ increased the root biomass of *C. bursa-pastoris* by 5.48% ($p < 0.05$) and 6.30% ($p < 0.05$), respectively, compared with the control. When the ABA concentrations were 1, 5, 10 and 20 $\mu\text{mol/L}$, the shoot biomass of *C. bursa-pastoris* increased by 6.13% ($p < 0.05$), 12.51% ($p < 0.05$), 20.97% ($p < 0.05$) and 8.40% ($p < 0.05$), respectively, compared with the control. ABA applications also enhanced the plant height of *C. bursa-pastoris*, which increased by 4.54% ($p > 0.05$), 6.47% ($p > 0.05$), 8.40% ($p < 0.05$) and 10.42% ($p < 0.05$). Thus, ABA can promote the growth of *C. bursa-pastoris* under salt stress.

When plants are under stress conditions, their bodies rapidly synthesize a large amount of ABA to enhance their resistance to the environmental stress [4]. The application of exogenous ABA can promote the rapid synthesis of ABA, and enhance the plant's salt resistance [5]. Under salt stress, the exogenous ABA promotes the growth of maize seedlings and increases their biomass [6]. In this experiment, the exogenous ABA increased the root, stem, leaf and shoot biomasses of *C. bursa-pastoris*. ABA applications also enhanced the plant height of *C. bursa-pastoris*. With the increase in the ABA concentrations, the biomass and plant height of *C. bursa-pastoris* increased. These results were consistent with those of other studies [6-7]. Therefore, exogenous ABA could promote the growth of *C. bursa-pastoris* by increasing the biomass and enhancing the plant height under salt stress, with the optimal ABA dose of ABA being 20 $\mu\text{mol/L}$ in this experiment.

Table 1 Biomass of *Capsella bursa-pastoris*

ABA concentrations ($\mu\text{mol/L}$)	Root biomass (g/plant)	Stem biomass (g/plant)	Leaf biomass (g/plant)	Shoot biomass (g/plant)	Plant height (cm)
0	0.492 $\pm$ 0.012b	1.155 $\pm$ 0.012b	1.634 $\pm$ 0.008e	2.789 $\pm$ 0.020e	20.72 $\pm$ 1.15b
1	0.507 $\pm$ 0.010ab	1.167 $\pm$ 0.015b	1.793 $\pm$ 0.038d	2.960 $\pm$ 0.053d	21.66 $\pm$ 0.87ab
5	0.512 $\pm$ 0.008ab	1.203 $\pm$ 0.014a	1.935 $\pm$ 0.021c	3.138 $\pm$ 0.035c	22.06 $\pm$ 1.33ab
10	0.519 $\pm$ 0.006a	1.213 $\pm$ 0.010a	2.161 $\pm$ 0.027b	3.374 $\pm$ 0.037b	22.46 $\pm$ 1.21a
20	0.523 $\pm$ 0.013a	1.224 $\pm$ 0.016a	2.321 $\pm$ 0.041a	3.545 $\pm$ 0.057a	22.88 $\pm$ 0.95a

Values are means ($\pm$ SE) of three replicate pots. Different lowercase letters within a column indicate significant differences based on a one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$).

Antioxidant enzyme activities and the soluble protein content of *C. bursa-pastoris*. ABA treatments enhanced the antioxidant enzyme (SOD, POD and CAT) activities of *C. bursa-pastoris* (Table 2). The activities of SOD, POD and CAT increased with increasing ABA concentrations. When the ABA concentrations were 1, 5, 10 and 20 $\mu\text{mol/L}$, the SOD activities were enhanced by 18.42% ($p < 0.05$), 29.50% ($p < 0.05$), 44.25% ($p < 0.05$) and 51.54% ($p < 0.05$), respectively, the POD activities were enhanced by 0.60% ($p > 0.05$), 33.01% ($p < 0.05$), 39.36% ($p < 0.05$) and 51.22% ($p < 0.05$), respectively, and the CAT activities were enhanced by 20.58% ($p < 0.05$), 75.83% ($p < 0.05$), 136.15% ($p < 0.05$) and 188.65% ($p < 0.05$), respectively, compared with those of the control. The ABA applications also increased *C. bursa-pastoris*' soluble protein content, which increased with increasing ABA concentrations (Table 2). When the ABA concentrations were 1, 5, 10 and 20

$\mu\text{mol/L}$, the soluble protein contents increased by 4.58% ($p > 0.05$), 18.81% ($p < 0.05$), 21.62% ($p < 0.05$) and 33.28% ($p < 0.05$), respectively, compared with the control. Thus, ABA could enhance the resistance of *C. bursa-pastoris* to salt stress.

In the normal physiological state, the active oxygen in the plant body is relatively stable, and the antioxidant enzyme system is inhibited when the plant is injured [8]. Under salt stress conditions, the reactive oxygen species accumulated in the plant will accumulate and eventually destroy the membrane structure, causing metabolic disorders [9]. SOD, CAT and POD are three important antioxidant enzymes in the plant body that can effectively scavenge free radicals and maintain the free radical metabolic balance to ensure normal growth and can regulate the metabolisms of membrane systems to enhance the plant resistance [8-10]. Under adverse conditions, plants produce a series of physiological and biochemical changes to induce a number of specific gene expressions, which produce proteins, and thus play a protective role [11]. ABA, as a stress signal substance, is directly involved in the expression of many stress response genes [12]. Under salt stress, exogenous ABA significantly enhances the SOD, CAT and POD activities of cucumber seedlings [13] and increases the soluble protein content of maize seedlings [6]. Thus, exogenous ABA can enhance the resistance of plants to salt stress. In this experiment, with increasing ABA concentrations, the SOD, CAT and POD activities of *C. bursa-pastoris* were enhanced under salt stress and the soluble protein content of *C. bursa-pastoris* also showed an increasing trend. These results indicate that ABA could enhance the resistance of *C. bursa-pastoris* to salt stress, which ensures its normal growth.

Table 2 Antioxidant enzyme activities and the soluble protein content of *Capsella bursa-pastoris*

ABA concentrations ($\mu\text{mol/L}$)	SOD activity (U/g)	POD activity (U/g)	CAT activity (U/g)	Soluble protein content (mg/g)
0	157.18 $\pm$ 3.99c	3293.7 $\pm$ 66.89d	18.95 $\pm$ 0.14e	12.44 $\pm$ 0.04c
1	186.14 $\pm$ 6.77b	3313.4 $\pm$ 56.46d	22.85 $\pm$ 1.27d	13.01 $\pm$ 1.00c
5	203.55 $\pm$ 5.28b	4381.0 $\pm$ 26.94c	33.32 $\pm$ 1.71c	14.78 $\pm$ 0.10b
10	226.73 $\pm$ 7.91a	4590.1 $\pm$ 21.00b	44.75 $\pm$ 1.26b	15.13 $\pm$ 0.37ab
20	238.19 $\pm$ 10.56a	4980.8 $\pm$ 85.98a	54.70 $\pm$ 0.99a	16.58 $\pm$ 0.98a

Values are means ($\pm$ SE) of three replicate pots. Different lowercase letters within a column indicate significant differences based on a one-way analysis of variance in SPSS 13.0 followed by the least significant difference test ($p < 0.05$).

Conclusions

Under salt stress, spraying ABA increased the root, stem, leaf and shoot biomasses of *C. bursa-pastoris*. ABA applications also enhanced the plant height of *C. bursa-pastoris*. With the increase in the ABA concentrations, the biomass and plant height of *C. bursa-pastoris* increased. ABA treatments enhanced the antioxidant enzyme (SOD, POD and CAT) activities of *C. bursa-pastoris*. With increasing ABA concentrations, the SOD, CAT and POD activities of *C. bursa-pastoris* were enhanced under salt stress and the soluble protein content of *C. bursa-pastoris* also showed an increasing trend. Therefore, ABA could enhance the resistance of *C. bursa-pastoris* to salt stress, and promote its growth.

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