Effects of Exogenous Abscisic Acid on the Growth and Physiological Properties of Chinese Cabbage Seedlings under $AlCl_3$ Stress

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Abstract. A pot experiment was conducted to study the effects of photosynthesis of Chinese cabbage under $AlCl_3$ stress, and different concentrations of abscisic acid (ABA) solution about 1, 5, 10 and 20 μmol·L^{-1} were sprayed, control was sprayed water on leaves. The results showed that sprayed ABA could improve the plant height and leaf area, dry weight and fresh weight of Chinese cabbage seedlings under $AlCl_3$ stress, and with the rising of ABA concentration, which was raised first and then reduced. Compared with control, when the ABA concentration was 10μmol·L^{-1}, the height, leaf area, dry weight and fresh weight of cabbage seedling was increased by 15.69% ($p < 0.05$), 31.86% ($p < 0.05$), 40.11% ($p < 0.05$) and 38.46% ($p < 0.05$) respectively; total chlorophyll content, carotenoid content increased 37.01% ($p < 0.05$) and 29.78% ($p < 0.05$) respectively; the SOD activity and CAT activity increased 11.24% ($p < 0.05$) and 74.02% ($p < 0.05$) respectively. Thus, exogenous ABA could improve the biomass, photosynthetic pigment content , antioxidant enzyme activity and reduce MDA content of Chinese cabbage seedling, and the optimal concentration of ABA was 10 μmol·L^{-1}.

Introduction

Aluminium (A1) is one of the most abundant metal elements in the crust, the average content accounts for about 8% of the earth's crust [1]. Aluminum in the soil is usually in the form of the silicate or aluminum oxide, which had no toxic to plants. When the soil pH is less than 5, the slightly solubility aluminum may turn into solubility (mainly Al^{3+}). Along with industrial development and human activities, soil acidification increasingly serious. According to statistics, the world acidic soil was about 35 percent of total land area, accounting for 50% of the total cultivated area [2]. Because of Al^{3+} of soil cation exchange accounted for 20% to 80% of the total, resulting in soil cation other easy leaching, resulting in lack of fixed and phosphorus, potassium, calcium, magnesium, boron and other nutrients can lead to crop production 40 % [3].

ABA is a plant stress inducing factor, can improve plant cold resistance [4], drought resistance [5] and salt resistance [6]. Studies have shown that, under Al stress, ABA can alleviate stress inhibited aluminum on soybean root elongation, promote soybean absorbing moisture and nutrients [7]. Currently, seed soaking on ABA on photosynthesis of plants under aluminum stress on studies rarely reported, so this test Chinese cabbage seedlings as materials, aluminum explore forced under ABA pretreatment on photosynthesis Chinese cabbage seedlings to soil contaminated Chinese cabbage cultivation acidic aluminum for reference.

Materials and Methods

Materials. The experiments were conducted at Sichuan Agricultural University (30° 42′ N, 103° 51′ E), Wenjiang, China. The seeds of Chinese cabbage named quick 35 were harvested in 2015and purchased from Chengdu, China. All chemicals used in experiments were of analytical grade. ABA was purchased from Sigma-Aldrich (St. Louis, MO, USA).

Experimental Design. Seeds were sterilized in 10% sodium phosphate solution for 30 minutes, flushed five times in distilled water, and then placed on 9-cm-diameter Petri dishes with three layers of filter paper moistened with distilled water and germinated at 25℃ in darkness. Seeds were considered germinated when the seed coat was broken and a radicle was visible. After germination, seeds were planted in nutrition pot filled with vermiculite and perlite, the pot was ten centimeters in diameter and height.

Seedlings were irrigated with 20 mL Hoagland nutrient solution containing 50 μmol·L^{-1} $AlCl_3$ every other day, until the experiment finished.

When the third leaf expanded, their leaves were sprayed with 0 (control), 1, 5, 10, 20 μmol·L^{-1} concentrations of ABA solution until foliage and dorsal dripping. Seedlings were sprayed with ABA solution every other day, and three times in total. Each treatment consisted of 10 pots with one plant per pot. Positions of the pots were randomly changed daily to minimize positional effects. 30 days after treatment, measure growth index (plant height, leaf area, fresh weight, dry weight and water content) , photosynthetic pigment content (chlorophyll a and chlorophyll b, total chlorophyll content and carotenoids content), antioxides enzyme activity(activity of SOD, CAT, POD) and MDA content.

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

Results and Discussion

Growth and biomass. As can be seen from Table 1, with ABA concentration from 0 to 10 μmol·L^{-1}, plant height, leaf area, dry weight and fresh weight of Chinese cabbage seedlings were increased with ABA concentration rose, when ABA concentration was 10 μmol·L^{-1} reached the maximum, enhanced by 15.69% ($p < 0.05$), 31.86% ($p < 0.05$), 40.11% ($p < 0.05$) and 38.46% ($p < 0.05$), respectively, compared with CK. When the concentration of ABA was 20μmol·L^{-1}, plant height and dry weight of Chinese cabbage was no significant difference between CK, but the leaf area and fresh weight was significantly higher than CK, enhanced by 12.42% ($p< 0.05$) and 32.62% ($p< 0.05$) respectively. Water content of Chinese cabbage seedling when ABA concentration of 5μmol·L^{-1} was the lowest, when ABA concentration of 20μmol·L^{-1} was the highest.

Table 1 Effects of ABA on the growth and biomass of Chinese cabbage under $AlCl_3$ stress

ABA concentration /(μmol·L^{-1})	Plant height /(cm)	Leaf area /(cm^2)	Plant fresh mass /(g)	Plant dry mass /(g)	Water Content /(%)
0	7.14±0.38 b	73.01±1.02 c	1.87±0.17 c	0.26±0.01 b	86.09%
1	7.33±0.47 b	81.26±1.46 b	2.19±0.11 b	0.28±0.01 b	87.21%
5	7.70±0.36 ab	92.57±0.88 a	2.22±0.08 b	0.33±0.02 ab	85.13%
10	8.26±0.42 a	96.27±0.73 a	2.62±0.14 a	0.36±0.01 a	86.25%
20	7.53±0.28 b	82.08±0.61 b	2.48±0.08 ab	0.29±0.01 b	88.31%

Note：Data followed different letters within column indicate significant difference of 0.05 level.

Photosynthetic pigment content. Photosynthetic pigment content could intuitive performance photosynthetic capacity of plant. As can be seen from table 2, after sprayed ABA, Chinese cabbage seedlings chlorophyll a, chlorophyll b, chlorophyll a + b and carotenoids content were increased and then reduced with the concentration of ABA increased, and reached the peak, when ABA concentration of 10 μmol·L^{-1}, compared with CK, enhanced by 35.13% ($p < 0.05$), 45.79% ($p < 0.05$), 37.01% ($p < 0.05$) and 29.78% ($p < 0.05$), respectively. After sprayed ABA of 5, 10, 20 μmol·L^{-1}, the treatment of photosynthetic pigment content were no significant difference with each other.

Table 2 Effects of ABA on the contents of photosynthetic pigments of Chinese cabbage under $AlCl_3$ stress

ABA concentration /(μmol·L^{-1})	Chlorophyll a /(mg·g^{-1})	Chlorophyll b /(mg·g^{-1})	Chlorophyll a+b /(mg·g^{-1})	Carotenoids /(mg·g^{-1})
0	0.501±0.01 c	0.107±0.01 b	0.608±0.01 c	0.178±0.06 b
1	0.567±0.01 b	0.115±0.01 b	0.682±0.01 b	0.195±0.02 b
5	0.599±0.04 ab	0.130±0.01 ab	0.729±0.04 ab	0.212±0.02 ab
10	0.677±0.06 a	0.156±0.03 a	0.833±0.03 a	0.231±0.04 a
20	0.597±0.05 ab	0.129±0.02 ab	0.726±0.05 ab	0.208±0.02 ab

The enzymatic antioxidant system. Spraying ABA increased SOD and CAT activity of Chinese cabbage seedling under $AlCl_3$ stress, significantly, both reached the maximum when ABA concentration was 10 μmol·L^{-1}, higher than CK by 11.24% ($p < 0.05$) and 74.02% ($p < 0.05$), respectively, but no significant difference between the treatment of splaying ABA concentration of 20 μmol·L^{-1} (Table 3). Changing trend of CAT was the same as SOD and POD, when ABA concentration was 10μmol·L^{-1}, it come to the maximum, 24.09% ($p < 0.05$) higher than CK, and other treatments were no significant differences, compared with the control.

MDA content. MDA content is a sign of membrane lipid peroxidation, and the higher of MDA content, the higher level of membrane lipid peroxidation. In this experiment, the MDA content decreased first and then slightly increased with the concentration of ABA increased. When ABA concentration was 10 μmol·L^{-1}, MDA content decreased the lowest, 20.70% ($p < 0.05$) lower than CK (Table 3). After Sprayed ABA of 1, 5, 20 μmol·L^{-1}, there were no significant differences between the MDA content of Chinese cabbage seedling under $AlCl_3$ stress, but all significantly lower than CK. Therefore, Spraying ABA may reduce the MDA content of Chinese cabbage seedling under $AlCl_3$ stress.

Table 3 Effects of ABA on the enzymatic antioxidant system of Chinese cabbage under $AlCl_3$ stress

ABA concentration /(μmol·L^{-1})	SOD activity /(U·g^{-1})	POD activity /(U·g^{-1})	CAT activity /(U·g^{-1})	MDA content /(nmol·g^{-1})
0	139.60±7.79 c	2200±96.68 b	18.63±0.79 d	7.44±0.38 a
1	157.28±4.16 b	2322±74.36 b	23.46±0.68 c	7.02±0.57 b
5	166.21±4.52ab	2388±53.74 b	26.73±0.27 b	6.96±0.14 b
10	174.96±7.38 a	2730±50.37 a	32.42±0.84 a	5.90±0.39 c
20	166.22±6.17 ab	2398±41.28 b	31.87±1.03 a	6.84±0.04 b

Conclusions

Immobilized aluminum is easy to be activated to form soluble state and cause harm to the plant under the condition of Acidic soil. Researches have showed that Al^{3+} inhibited the growth of plant roots, reduced the plant root activity, which affected plant growth and development. The test results

showed that sprayed suitable concentration of ABA could improve the plant height and leaf area, dry weight and fresh weight of Chinese cabbage seedlings under $AlCl_3$ stress. At the same time, after spraying ABA, the photosynthetic pigment content and activities of antioxidant enzymes of cabbage seedling increased, but MDA content decreased, which showed that spraying ABA could improve the resistance Chinese cabbage seedling to salt stress, and the best concentration of ABA was 10 $\mu mol \cdot L^{-1}$

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References

[1] W. W. Chen：the Earth Vol. 5 (2007), p. 275－284 (In Chinese).
[2] P. R. Rya and E. Delhaize: Functional Plant Biology Vol. 37 (2010), p. 275－284.
[3] P. R. Rya, S. D. Tyerman and T. Sasaki: Journal of Experimental Botany Vol. 62 (2011), p. 9-20.
[4] L. R. Wang, Y. Z. Xue and M. H. Chang: Journal of Nuclear Agricultural Sciences Vol. 30 (2016), p. 396-403 (In Chinese).
[5] T. C. D. Souza, P. C. Magalhães and E. M. D. Castro: Acta Physiologiae Plantarum，Vol. 35 (2013), p. 515–527.
[6] Q. Xiao, G. Wang and Y. J. Yi: Journal of Plant Nutrition and Fertilizer Vol.22 (2016), p. 201-208 (In Chinese).
[7] J. F. Yu, N. N. Hou and M. Y. Xu: Journal of Plant Nutrition and Fertilizer Vol.16 (2010), p. 899-905 (In Chinese).
[8] G. R. Rout, S. Samantary and P. Das: Agronomie Vol.21 (2001), p. 2-21.
[9] P. Liu, Y. S. Yang and G. T. Xu: Chinese Journal of Oil Crop Sciences Vol.26 (2004), p. 49-54 (In Chinese).