Effects of ABA on Photosynthetic Characteristics of Chinese Cabbage under Aluminum Stress

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Abstract. A pot experiment was conducted to study the effects of exogenous abscisic acid (ABA) on photosynthetic characteristics of Chinese cabbage under aluminum (Al) stress. Five treatments were used in the experiment: leaves were sprayed with 0 (CK), 1, 5, 10 and 20 $\mu mol \cdot L^{-1}$ concentrations of abscisic acid solution. The results showed that low concentration of abscisic acid enhanced net photosynthetic rate (Pn) of Chinese cabbage under Al stress. However when concentration of abscisic acid is too high, Pn of Chinese cabbage decreased. The result of transpiration rate (Tr), light use efficiency (LUE) and stomatal conductance (Gs) were the same as Pn. Different concentration of abscisic acid enhanced water use efficiency (WUE) of Chinese cabbage of a different degree under Al stress. Spraying different concentrations of abscisic acid on Chinese cabbage under aluminum stress has not significant effect on CO_2 concentration of intercellular (Ci). Therefore, abscisic acid could use to enhance the photosynthetic ability of Chinese cabbage, and the best concentration of abscisic acid was 5 $\mu mol \cdot L^{-1}$.

Introduction

Aluminum is the highest content of metallic element in the soil, but not the necessary nutrients for plant growth and development[1]. Typically, aluminum exists in the soil solid phase as silicate or oxide form, and is not toxic to plants. However, in acidic soils, aluminum exists as cation form, which raises a number of direct or indirect physical harm after being absorbed by plants[2,3].

Abscisic acid is an important hormones regulating plant growth and development[4], which is now widely recognized that has associated with the promotion of seed maturation, induction and maintenance of seed dormancy and inhibition of seed germination [5]. Abscisic acid as a stress signal, plays an important role in regulating balance of substances in the plant and inducing resistance of stress [6-8].

Chinese cabbage (*Brassica rapa* ssp. *pekinensis*) is an important vegetable. In China, cultivation area and consumption of Chinese cabbage rank first in all kinds of vegetables. It has important value in food and economic.

In this research, we used different concentrations of abscisic acid to spray Chinese cabbage seedlings, to screen the influence of abscisic acid on photosynthetic characteristics of Chinese cabbage under aluminum stress.

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 2014 and purchased from Chengdu, China. All chemicals used in experiments were of analytical grade.

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} concentrations of aluminum every other day, until the experiment finishing.

When the third leaf expanded, their leaves were sprayed with 0 (CK), 1, 5, 10, 20 μmol·L^{-1} concentrations of abscisic acid solution until foliage and dorsal dripping. Seedlings were sprayed with abscisic acid 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, the photosynthesis of each plant was determined by using LI-6400 portable photosynthesis meter (LI-COR Inc., USA). The photosynthetic parameters of the photosynthesis meter were manual control CO_2 concentration 400 μmol·CO_2 mol^{-1}, temperature 25℃, light intensity 1200 μmol m^{-2}·s^{-1}. The determination of photosynthetic parameters were net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs) and CO_2 concentration of intercellular (Ci), and each treatment was repeated three times. Water use efficiency (WUE) = net photosynthetic rate (Pn) / transpiration rate (Tr), Light use efficiency (LUE) = net photosynthetic rate (Pn) / light intensity[9].

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

Net Photosynthetic Rate (Pn). Compared with CK, low concentration of abscisic acid enhanced Pn of Chinese cabbage under Al stress, and the Pn of Chinese cabbage was increased. However when concentration of abscisic acid is too high, Pn of Chinese cabbage decreased by 5.98 % ($p > 0.05$). When the concentration of abscisic acid were 1 and 10 μmol·L^{-1}, Pn of Chinese cabbage increased by 13.32% ($p > 0.05$) and 7.21% ($p > 0.05$) respectively, compared with CK. When the concentration of abscisic acid was 5 μmol·L^{-1}, Pn of Chinese cabbage reached the highest, and increased by 35.28 % ($p < 0.05$). In this study, it was illustrated that suitable concentration of abscisic acid can alleviate the Al stress and improve photosynthetic capacity of Chinese cabbage seedlings.

Transpiration Rate (Tr). Compared with CK, low concentration of abscisic acid increased the Tr of Chinese cabbage (Fig. 2). The trend of Tr was consistent with Pn. Compared with CK, when the concentration of abscisic acid was 5 μmol·L^{-1}, Tr of Chinese cabbage reached the highest, and increased by 21.87 % ($p < 0.05$). However when concentration of abscisic acid were 10 and 20 μmol·L^{-1}, Tr of Chinese cabbage decreased by 2.55 % ($p > 0.05$) and 9.50 % ($p > 0.05$). It was showed that suitable concentration of abscisic acid can alleviate the Al stress of Chinese cabbage seedlings.

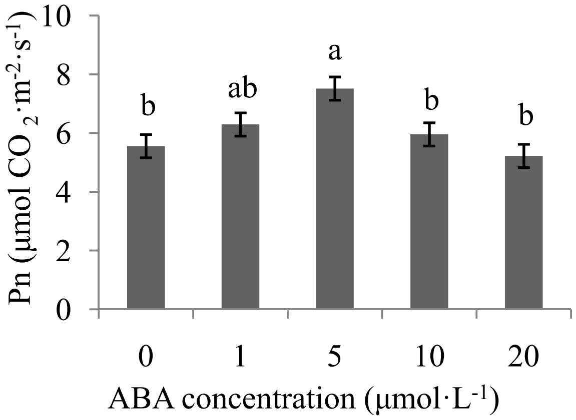

Fig. 1 Pn of ABA sprayed Chinese cabbage

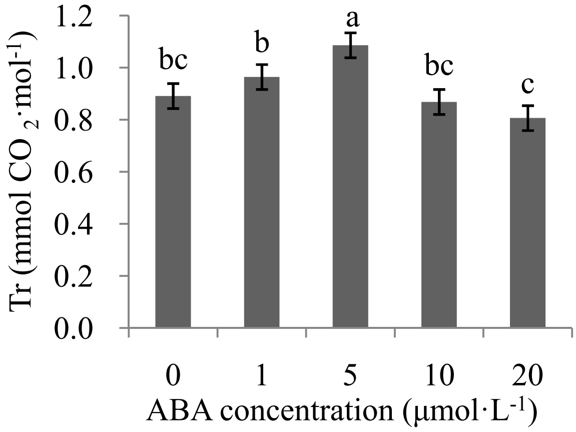

Fig. 2 Tr of ABA sprayed Chinese cabbage

Water Use Efficiency (WUE). The Fig. 3 shows that WUE of Chinese cabbage increased by abscisic acid treatment under Al stress. Compared with CK, when the concentration of abscisic acid were 1, 5, 10 and 20 μmol·L^{-1}, these treatments increased WUE of Chinese cabbage by 4.72% ($p > 0.05$), 11.01% ($p < 0.05$), 10.01% ($p < 0.05$) and 3.88% ($p > 0.05$), respectively.
Light Use Efficiency (LUE). Abscisic acid increased the LUE of Chinese cabbage (Fig. 4). When the concentration of abscisic acid were 1, 5 and 10 μmol·L^{-1}, these treatments enhanced LUE of Chinese cabbage by 13.32% ($p > 0.05$), 35.28% ($p < 0.05$) and 7.21% ($p > 0.05$) respectively, compared with CK. However when concentration of abscisic acid is too high, the LUE of Chinese cabbage decreased by 5.98 % ($p > 0.05$). It was showed that low concentration of abscisic acid can alleviate the Al stress of Chinese cabbage seedlings.

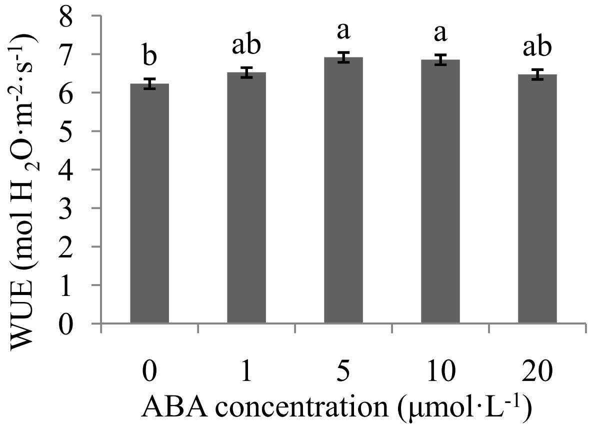

Fig. 3 WUE of ABA sprayed Chinese cabbage

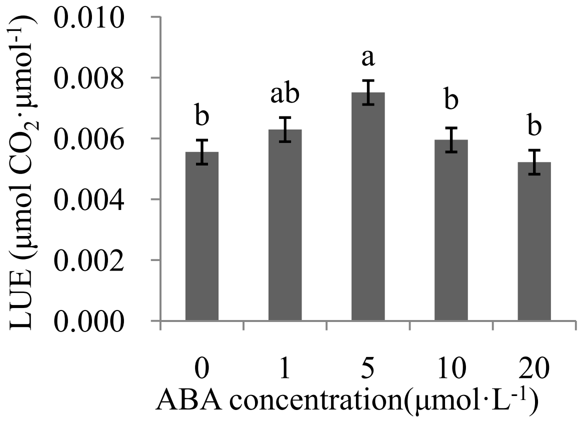

Fig. 4 LUE of ABA sprayed Chinese cabbage

Stomatal Conductance (Gs). After spraying abscisic acid, Gs of Chinese cabbage increased with the increasing of indoleacetic acid concentration from 0 μmol·L^{-1} up to5 μmol·L^{-1} (Fig. 5). Gs of Chinese cabbage reached the highest, and increased by 47.36 % ($p < 0.05$). When concentration of abscisic acid were 10 and 20 μmol·L^{-1}, Gs of Chinese cabbage decreased by 5.05 % ($p > 0.05$) and 13.48 % ($p > 0.05$).
CO_2 Concentration of Intercellular (Ci). Treatments of different concentrations of abscisic acid were not significant. Compared with CK, the difference between all treatments didn't appear obviously, which illustrate that the impact of abscisic acid on Ci was not obvious.

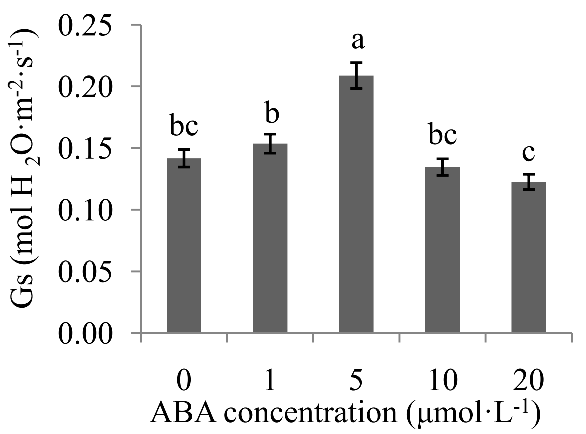

Fig. 5 Gs of ABA sprayed Chinese cabbage

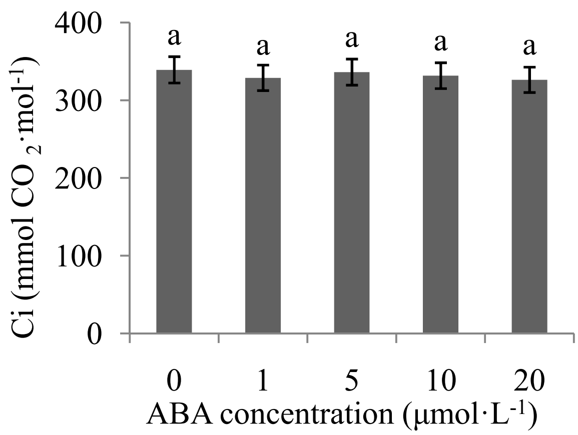

Fig. 6 Ci of ABA sprayed Chinese cabbage

Conclusions

Abscisic acid can improve photosynthetic capacity of Chinese cabbage seedlings under the Al stress. Compared with CK, low concentration of abscisic acid enhanced Pn of Chinese cabbage under Al stress. However when concentration of abscisic acid is too high, Pn of Chinese cabbage decreased. The result of Tr, LUE and Gs were the same as Pn. Different concentration of abscisic acid enhanced WUE of Chinese cabbage of a different degree under Al stress. Spraying different concentrations of abscisic acid on Chinese cabbage under aluminum stress has not significant effect on Ci. Therefore, abscisic acid could use to enhance the photosynthetic ability of Chinese cabbage, and the best concentration of abscisic acid was 5 $\mu mol \cdot L^{-1}$.

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