Effects of Abscisic Acid on Photosynthetic Characteristics of Radish 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 radish under aluminum (Al) stress. Five treatments were used in the experiment: seeds were soaked with 0 (CK), 1, 5, 10 and 20 μmol·L^{-1} concentrations of abscisic acid solution. The results showed that abscisic acid enhanced net photosynthetic rate (Pn) of radish significantly. With the increasing of abscisic acid concentration, Pn of radish was enhanced significantly, and when the concentration was 10 μmol·L-1, Pn of radish reached the highest. The result of transpiration rate (Tr), light use efficiency (LUE) and water use efficiency (WUE) were the same as Pn. However when concentration of abscisic acid is too high, Gs of radish decreased. Soaking different concentrations of abscisic acid on radish 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 radish, which would help to improve the adaptability of radish, and the best concentration of melatonin was 10 μmol·L-1.

Introduction

In recent years, with the rapid development of industry, problems of environmental pollution have become increasingly serious. Acidification of atmosphere, excessive use of pesticides and fertilizers causes soil acidification intensifies, and soluble aluminum content in soil increased significantly. Studies have shown that low concentrations of aluminum can promote the growth of plants, but the concentration of aluminum increased to a certain extent, it will be toxic to plants [1]. It was found that aluminum stress is the main limiting factor for crops in acid soils, can cause crop losses of 40% [2]. So the study of how to ease aluminum stress is very important.

Abscisic acid is a plant endogenous hormones related with plant growth and development[3]. It has effect on inhibiting seed germination, inhibiting of cell elongation and promoting aging [4]. As a stress signal, abscisic acid plays an important role in regulating balance of substances in the plant and inducing resistance of stress [5-7].

Radish (Raphanus sativus L.) is rich in nutrients, has good food value and medicinal value, are widely cultivated throughout China[8].

In this study, we used different concentrations of abscisic acid to soak radish seeds for the purpose of screening the influence of abscisic acid on photosynthetic characteristics of radish 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 radish named red skin radish were harvested in 2014 and purchased from Chengdu, China. All chemicals used in experiments were of analytical grade.

Experimental Design. Selected the same size and full of radish seeds, placed in five test tubes, soaked with 0 (CK), 1, 5, 10, 20 μmol·L^{-1} concentrations of abscisic acid solution for 24 h, added 50 mL abscisic acid solution in every test tubes, respectively. There were 20 seeds in each test tube.

After germination, seeds were planted in nutrition pot filled with vermiculite and perlite, the pot was ten centimeters in diameter and height. Each treatment consisted of 10 pots with one plant per pot.

When the cotyledons growed, seedlings were irrigated with 20 ml Hoagland nutrient solution containing 50 μmol·L^{-1} concentrations of aluminum chloride every three day, watering according to weather conditions, until the experiment finishing. Positions of the pots were randomly changed daily to minimize positional effects. 45 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.

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, abscisic acid enhanced Pn of radish under Al stress significantly, and the Pn of radish was increased with the increasing of abscisic acid concentration (Fig. 1). When the concentration of abscisic acid were 1, 5 and 20 μmol·L^{-1}, these treatments enhanced Pn of radish by 17.73% ($p < 0.05$), 31.77% ($p < 0.05$) and 6.86% ($p > 0.05$) respectively, compared with CK. When the concentration of abscisic acid was 10 μmol·L^{-1}, Pn of radish reached the highest, and increased by 68.98 % ($p < 0.05$). In this study, it was illustrated that abscisic acid can alleviate the Al stress and improve photosynthetic capacity of radish seedlings.

Transpiration Rate (Tr). Abscisic acid increased the Tr of radish (Fig. 2). The trend of Tr was consistent with Pn. Compared with CK, When the concentration of abscisic acid were 1, 5 and 20 μmol·L^{-1}, these treatments enhanced Tr of radish by 15.31% ($p < 0.05$), 26.91% ($p < 0.05$) and 1.31% ($p > 0.05$) respectively, compared with CK. When the concentration of abscisic acid was 10 μmol·L^{-1}, Tr of radish reached the highest, and increased by 56.24 % ($p < 0.05$). It was showed that abscisic acid can alleviate the Al stress of radish seedlings.

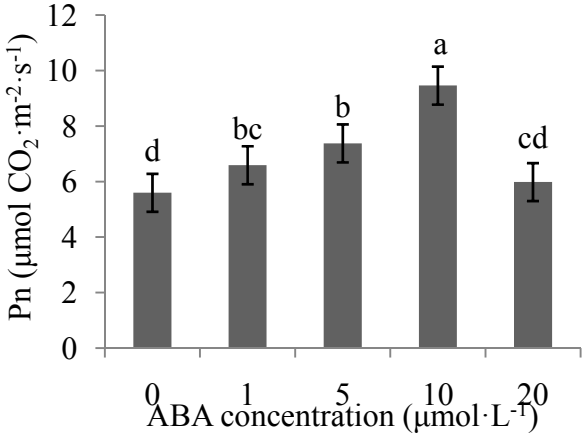

Fig. 1 Pn of ABA soaked radish

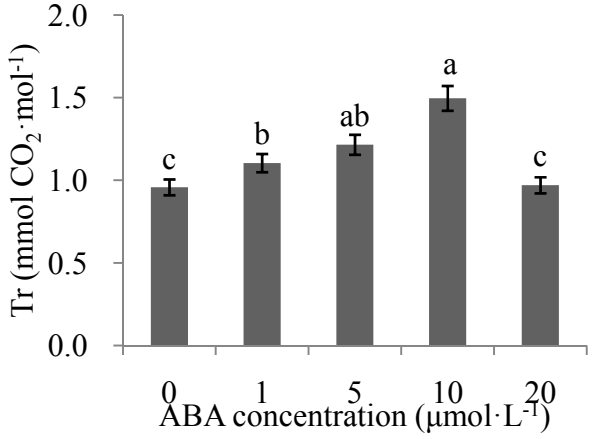

Fig. 2 Tr of ABA soaked radish

Water Use Efficiency (WUE). Compared with CK, When the concentration of abscisic acid were 1,5 and 20 μmol·L^{-1}, these treatments enhanced WUE of radish by 2.11% ($p > 0.05$), 3.83% ($p > 0.05$)and 5.48% ($p > 0.05$) respectively. When the concentration of abscisic acid was 10 μmol·L^{-1}, WUE of radish reached the highest, and increased by 8.15 % ($p < 0.05$). It was showed that suitable concentration of abscisic acid can alleviate the Al stress.

Light Use Efficiency (LUE). Abscisic acid increased the LUE of radish with the increasing of abscisic acid concentration under Al stress (Fig. 4). When the concentration of abscisic acid were 1, 5 and 20 μmol·L^{-1}, these treatments enhanced LUE of radish by 17.73% ($p < 0.05$), 31.77% ($p < 0.05$) and 6.86% ($p > 0.05$) respectively, compared with CK. When the concentration of abscisic acid was 10 μmol·L^{-1}, LUE of radish reached the highest, and increased by 68.98% ($p < 0.05$). It was showed that abscisic acid can alleviate the Al stress of radish seedlings.

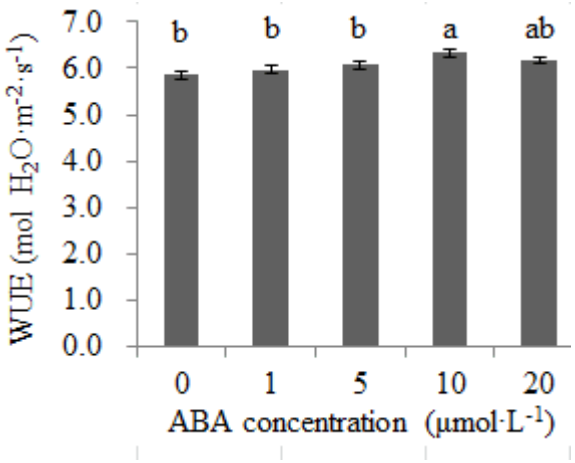

Fig. 3 WUE of ABA soaked radish

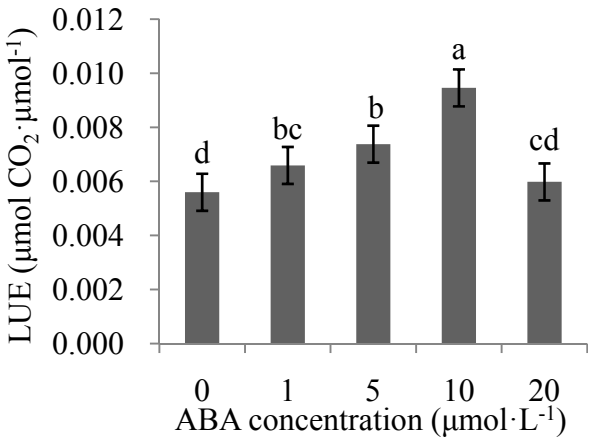

Fig. 4 LUE of ABA soaked radish

Stomatal Conductance (Gs). After soaked with abscisic acid, Gs of radish increased (Fig. 5). Compared with CK, When the concentration of abscisic acid were 1,5 and 10 μmol·L^{-1}, these treatments enhanced Gs of radish by 28.41% ($p > 0.05$), 80.12% ($p < 0.05$) and 108.37% ($p < 0.05$) respectively. When concentration of abscisic acid is too high (20 μmol·L^{-1}), Gs of radish decreased by 17.23 % ($p > 0.05$) compared with CK.

CO_2 Concentration of Intercellular (Ci). Difference between soaked with different concentrations of abscisic acid were not significant. It is illustrated that the effect on Ci of abscisic acid was not obvious.

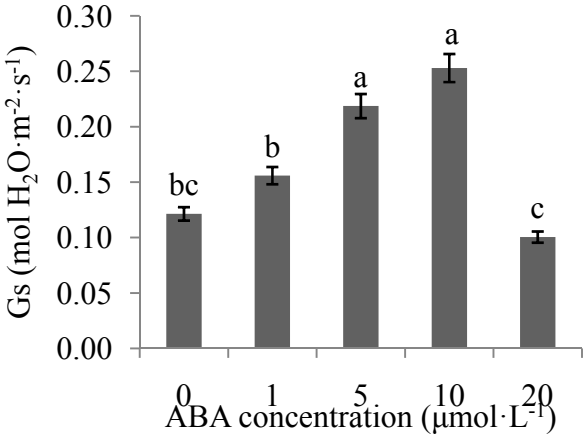

Fig. 5 Gs of ABA soaked radish

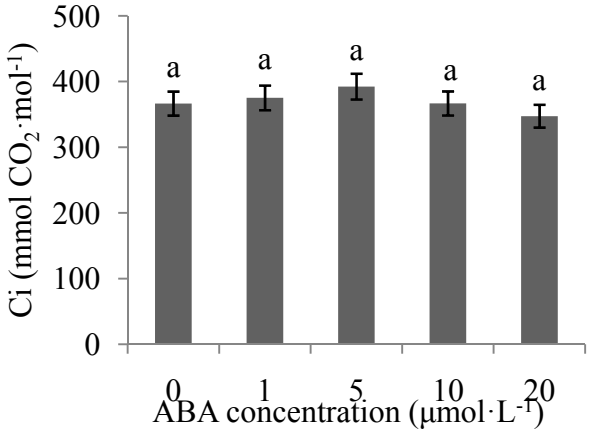

Fig. 6 Ci of ABA soaked radish

Conclusions

Abscisic acid can alleviate the Al stress on photosynthetic organ damage and improve photosynthetic capacity of radish seedlings. With the increasing of abscisic acid concentration, Pn of radish was enhanced significantly, and when the concentration was 10 μmol·L^{-1}, Pn of radish reached the highest. The result of Tr, LUE and WUE were the same as Pn. However when concentration of abscisic acid is too high, Gs of radish decreased. Soaking different concentrations of abscisic acid on radish under aluminum stress has not significant effect on Ci. Therefore, abscisic acid could use to enhance the photosynthetic ability of radish, which would help to improve the adaptability of radish.

Acknowledgements

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References

[1] X.L. Zheng and H.L. Ye: Chinese Journal of Applied Ecology Vol. 21 (2010), p.1998-2003 (In Chinese).

[2] J.F. Ma and P.R. Ryan: Functional Plant Biology Vol. 37 (2010), p.3-6 .

[3] J. Leung and J. Giraudal: Annual Review of Plant Physiology and Plant Molecular Biology Vol. 49(1998), p.199-222.

[4] M. J. Holdsworth and S. Finch: Trends in Plant Science Vol. 13 (2008), p.7-13

[5] M. Perras and F. Sarhan: Plant Physiology Vol. 89 (1989), p.577-585

[6] Y. Fujita and K. Shinozaki: Journal of Plant Research Vol. 124(2011), p.509-525

[7] A.S. Raghavendra and V.K. Gonugunta: Trends in Plant Science Vol. 15 (2010), p.395-401

[8] J.S. Li, R. Yang and X.L. Sui: Acta Agriculturae Boreali-Sinica Vol. 23(2008), p.77-80 (In Chinese).

