Soaking Seeds with Exogenous Melatonin Improve Photosynthetic Characteristics of Radish under Aluminum Stress

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Abstract. A pot experiment was conducted to study the effects of exogenous melatonin (MT) on photosynthetic characteristics of radish under aluminum (Al) stress. Five treatments were used in the experiment: seeds were soaked with 0 (CK), 50, 100, 150 and 200 μmol·L^{-1} concentrations of melatonin solution. The results showed that melatonin enhanced net photosynthetic rate (Pn) and of radish significantly. Compared with CK, low concentration of MT enhanced transpiration rate (Tr) and stomatal conductance (Gs) of radish under Al stress. However when concentration of MT is too high, Tr and Gs of radish decreased. The result of light use efficiency (LUE) and water use efficiency (WUE) were the same as Pn. Soaking different concentrations of melatonin on radish under aluminum stress has not significant effect on CO_2 concentration of intercellular (Ci). Therefore, melatonin 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 100 μmol·L-1.

Introduction

In recent years, with the accelerated process of industrialization, frequently disturbed by human activity and the impact of a variety of other factors, soil acidification became prominent problem increasingly [1]. There are large areas of acid soils in South China, and aluminum toxicity is considered as major obstacle factor restricting crop production in acidic soils [2]. It was found that aluminum can hinder the synthesis of chlorophyll and inhibit growth of plant [3]. Studies have shown that exogenous organic acids can effectively relieve aluminum toxicity of rapeseed and soybean[4,5].

Melatonin (MT) is the strongest antioxidant scavenger of free radical, which can alleviate the damage caused by external environment [6].

In recent years, many studies have found that melatonin can alleviate abiotic stress harm to the plant, reduce the damage of low temperature and high temperature on plants, but also significantly increase the resistance of plants under sodium chloride stress [7-9]. Toxicity of aluminum chloride and sodium chloride to plants are similar, however, there is no study on whether melatonin can increase the resistance of plants under aluminum chloride stress.

Radish (*Raphanus sativus* L.) is rich in nutrients, has good food value and medicinal value, are widely cultivated throughout China[10].

In this study, we used different concentrations of melatonin to soak radish seeds for the purpose of screening the influence of melatonin 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. Melatonin was purchased from Sigma-Aldrich (St. Louis, MO, USA).

Experimental Design. Selected the same size and full of radish seeds, placed in five test tubes, soaked with 0 (CK), 50, 100, 150, 200 μmol·L^{-1} concentrations of melatonin solution for 24 h, added 50 mL melatonin 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, melatonin enhanced Pn of radish under Al stress significantly, and the Pn of radish was increased with the increasing of MT concentration (Fig. 1). When the concentration of MT were 50, 150 and 200 μmol·L^{-1}, these treatments enhanced Pn of radish by 21.75% ($p < 0.05$), 25.35% ($p < 0.05$) and 3.25% ($p > 0.05$) respectively, compared with CK. When the concentration of MT was 100 μmol·L^{-1}, Pn of radish reached the highest, and increased by 44.30 % ($p < 0.05$). In this study, it was illustrated that melatonin can alleviate the Al stress and improve photosynthetic capacity of radish seedlings.

Transpiration Rate (Tr). Melatonin increased the Tr of radish (Fig. 2). Compared with CK, When the concentration of MT were 50 and 150 μmol·L^{-1}, these treatments enhanced Tr of radish by 19.33% ($p > 0.05$) and 17.72% ($p > 0.05$) respectively. When the concentration of MT was 100 μmol·L^{-1}, Tr of radish reached the highest, and increased by 32.84 % ($p < 0.05$). However when concentration of MT is too high, Tr of radish decreased by 0.39 % ($p > 0.05$) compared with CK. It was showed that low concentration of melatonin can alleviate the Al stress of radish seedlings.

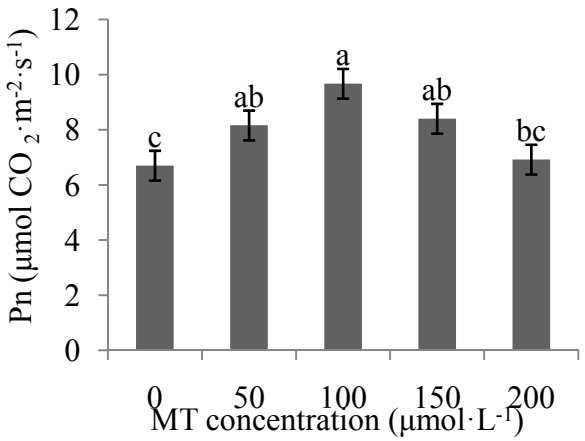

Fig. 1 Pn of MT soaked radish

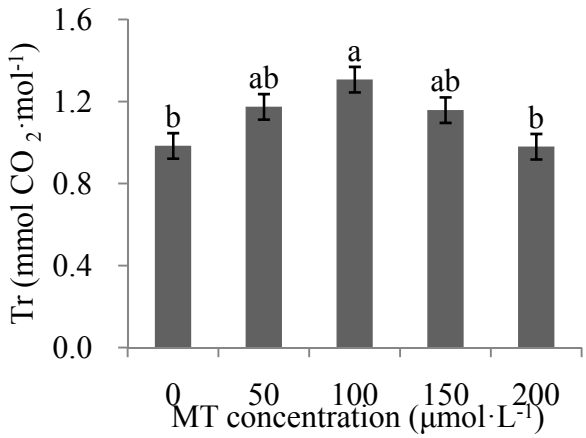

Fig. 2 Tr of MT soaked radish

Water Use Efficiency (WUE). Compared with CK, When the concentration of MT were 50,150 and 200 μmol·L^{-1}, these treatments enhanced WUE of radish by 2.02% ($p > 0.05$), 6.48% ($p > 0.05$)and 3.66% ($p > 0.05$) respectively. When the concentration of MT was 100 μmol·L^{-1}, WUE of radish reached the highest, and increased by 8.63 % ($p < 0.05$). It was showed that suitable concentration of melatonin can alleviate the Al stress.

Light Use Efficiency (LUE). Melatonin increased the LUE of radish with the increasing of MT concentration under Al stress (Fig. 4). When the concentration of MT were 50, 150 and 200 μmol·L^{-1}, these treatments enhanced LUE of radish by 21.75% ($p < 0.05$), 25.35% ($p < 0.05$) and 3.25% ($p > 0.05$) respectively, compared with CK. When the concentration of MT was 100 μmol·L^{-1}, LUE of radish reached the highest, and increased by 44.30% ($p < 0.05$). It was showed that melatonin can alleviate the Al stress of radish seedlings.

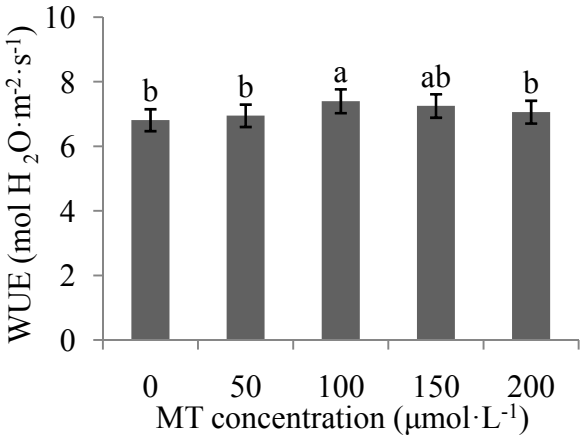

Fig. 3 WUE of MT soaked radish

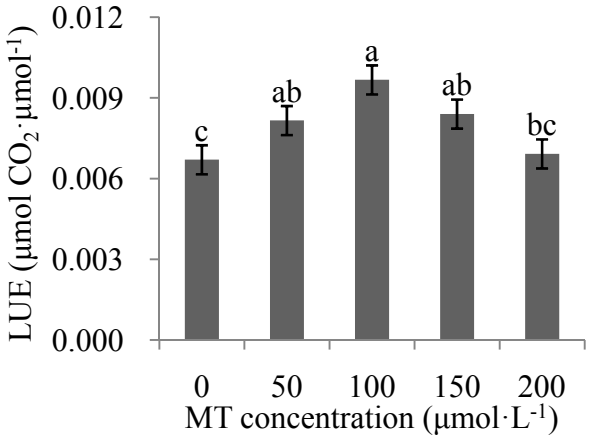

Fig. 4 LUE of MT soaked radish

Stomatal Conductance (Gs). After soaked with melatonin, Gs of radish increased (Fig. 5). Compared with CK, When the concentration of MT were 50,100 and 150 μmol·L^{-1}, these treatments enhanced Gs of radish by 6.23% ($p > 0.05$), 42.79% ($p > 0.05$) and 11.30% ($p > 0.05$) respectively. When concentration of MT is too high (200 μmol·L^{-1}), Gs of radish decreased by 21.50 % ($p > 0.05$) compared with CK. However, treatments of different concentrations of MT were not significant. It is illustrated that the effect of melatonin on Gs was not obvious.

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

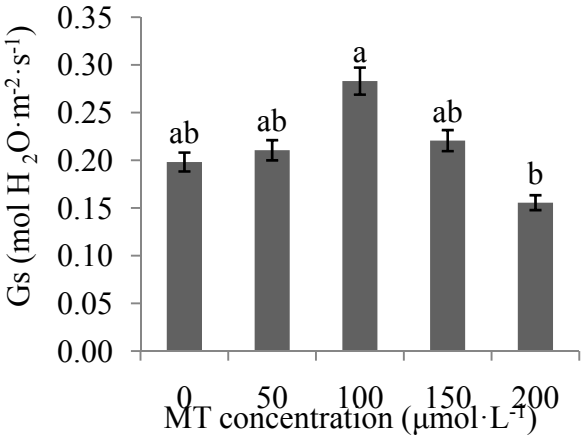

Fig. 5 Gs of MT soaked radish

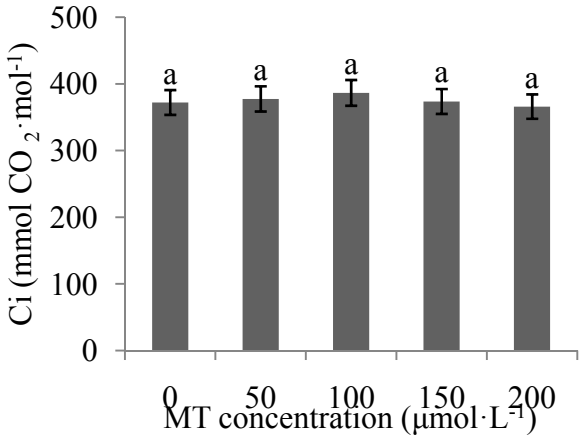

Fig. 6 Ci of MT soaked radish

Conclusions

Melatonin can alleviate the Al stress on photosynthetic organ damage and improve photosynthetic capacity of radish seedlings. With the increasing of MT concentration, Pn of radish were enhanced significantly. Compared with CK, low concentration of MT enhanced Tr and Gs of radish under Al stress. However when concentration of MT is too high, Tr and Gs of radish decreased. The result of LUE and WUE were the same as Pn. Soaking different concentrations of melatonin on radish under aluminum stress has not significant effect on Ci. Therefore, melatonin 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] Z.G. Yuan and J.Yang: Journal of Agriculture Vol. 5 (2015), p.51-55 (In Chinese).

[2] J.H. Weng, L.F. Huang and X.R. Liu: China Environmental Science Vol. 20 (2000), p.501-505 (In Chinese).

[3] Y.X. Zheng, S.T. Jia and Y.P. Zhao: Acta Agriculturae Boreali-Sinica Vol. 30(2015), p.150-156 (In Chinese).

[4] S.Y. Yan and Y. P. Wang: Guangdong Journal of Agricultural Sciences Vol. 40 (2013), p.16-20 (In Chinese).

[5] T.T. Jin and P. Liu: Chinese Journal of Oil Crop Sciences Vol. 28 (2006), p.302-308 (In Chinese).

[6] N. Zhang, H.J. Zhang and R.C. Yang: Chinese Agricultural Science Bulletin Vol. 28 (2012), p.16-20 (In Chinese).

[7] H.Y. Pan, X.Q. Zhang and J. Li: Journal of Northwest University (Natural Sciences Edition) Vol.43 (2013), p.238-242 (In Chinese).

[8] X.D. Xu, Y. Sun and X.Q. Guo: Chinese Journal of Applied Ecology Vol. 21 (2010), p.2580-2586 (In Chinese).

[9] N. Zhang, Q. Jiang and D.B. Li: Journal of China Agricultural University Vol. 19 (2014), p.54-60 (In Chinese).

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

