Effects of Exogenous Melatonin on Photosynthetic Characteristics of Lettuce Seedlings under NaCl Stress

Zesheng Yan[1,a],Mi Li[1,b] andYi Tang[2,c*]

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

[2]Institute of Pomology and Olericulture, Sichuan Agricultural University, Chengdu, Sichuan, China

[a]379049591@qq.com, [b]1696552752@qq.com,[c]tangyisunguochao@sina.com

*Corresponding author

Keywords: Melatonin;NaCl stress; Lettuce; Photosynthetic characteristics

Abstract.A pot experiment was conducted to study the effects of spraying melatonin(MT) on photosynthesis of lettuce seedlings under NaCl stress. The results showed that net photosynthetic rate(Pn), stomatal conductance(Gs), light use efficiency (LUE)and transpiration rate (Tr) were improved, especially when the concentration of melatonin was 100μmol·L^{-1}, increased by 31.85% (P<0.05), 55.82% (P<0.05), 31.85% (P<0.05) and 48.64% (P<0.05) compared withcontrol,respectively.Therefore, exogenous MT could efficiently increase resistance oflettuce seedlings toNaCl stress, and theMT concentration of 100 μmol·L^{-1} was the best.

Introduction

Amenities soil secondary salinization problem has become one of the major constraints to sustainable development of agricultural facilities, particularly in the solar greenhouse and plastic greenhouses.[1]. Na^+, Mg^{2+}, Ca^{2+} and CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} contentin soil solutionas the main features of saline soil, especially Na^+ and Cl^- content [2]. With the adjustment of industrial structure in rural areas, the area of facility vegetable cultivation was 5300 hm^2 from 1978 to 2011, the development of more than 4 million hm^2[3]. Butprotected cultivation presented continuous cropping,excessive fertilization, soil erosion lack of rain, wastewater irrigation, which widespread salt accumulation and secondary salinization, resulting in reduced yield and quality of vegetables [4,5].

Melatonin (melatonin, MT) was first discovered in the animal's pineal gland, is a strong antioxidant endogenous free radical scavenger [6]. Studies have shown that, MT can effectively alleviate the high temperature [7], chilling [8], UV radiation [9] and heavy metal contamination [10] and other non-biological factors on plant damage. At the same time, plant increased levels of endogenous MT [11], to prevent the degradation of chlorophyll, maintaining cell membrane integrity. Zhang et al. have shown that melatonin helps improve antioxidant enzyme activity, reduce the damage of salt stress on pennisetum.

In recent years, more and more studies of plant stress physiology of melatonin, but the research on salt stress on photosynthesis of plants is still rare. Thus, this experiment was studied the influence of different concentrations of melatonin on photosynthesis of lettuce under saltstress,and hope to provide a reference for salted lettuce cultivation.

Materials and Methods

Materials. The experiments were conducted at Sichuan Agricultural University (30° 42′ N, 103° 51′ E), Wenjiang,China.The seeds of lettucewere harvested in 2015and 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. 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 wasten centimeters in diameter and height.

Seedlings were irrigated with20mLHoagland nutrient solution containing 50μmol·L^{-1} concentrations ofNaClevery other day, until the experiment finishing.

When the third leaf expanded, their leaves were sprayed with 0 (CK), 50,100, 200,400 μmol·L^{-1} concentrations of melatonin solution until foliage and dorsal dripping. Seedlings were sprayed with melatonin 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[11].

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 5% confidence level.

Results and Discussion

Net PhotosyntheticRate (Pn). After spraying melatonin, Pnof lettuce leaves were significantly higher than controls. ThePn of lettuce was increased with the increasing of MT concentration from 0 μmol·L^{-1} up to 100 μmol·L^{-1}. When the concentration of MT was 100μmol·L^{-1}, the Pn of lettucewas the highest, 31.85%(p<0.05) higher than CK.After spraying MT of 200 and 400μmol·L^{-1}, Pndecreased 18.03% (p<0.05)and 14.38% (p<0.05)respectively,compared with CK.

Transpiration Rate (Tr). With melatonin concentration increased, theTr of lettuce leaves were firstly increased and then decreased.When the melatonin concentration was 100μmol·L^{-1}, Trreached a peak, enhanced by 48.64% (P <0.05) compared with CK, and had a significant difference with other treatments. After sprayed melatonin of 400μmol·L^{-1},there were not significant difference onTrcompared with CK.

Water Use Efficiency (WUE). As shown in Fig. 3, the WUE of lettuce was decreased with the increasing of MT concentration from 0 μmol·L-1 up to 100μmol·L-1. When the concentration of MT was 100μmol·L-1, the WUE of lettuce reached the lowest point.After sprayde the concentration

of 50 and 200 μmol·L-1, WUEthough decreasedby 3.16% (P **>** 0.05), 2.83% (P **>** 0.05)compared with CK, not significant .

Light UseEfficiency (LUE).MT promotedLUE of lettuce under NaCl stress, The same as Pn,spraying concentration of MT was100μmol·L^{-1},the treatmentenhanced LUE by 31.85% (p<0.05), compared with CK.

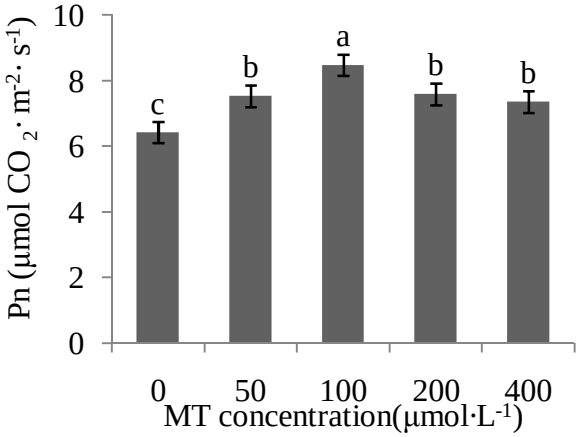

Fig. 1 Pn of MT sprayedlettuce

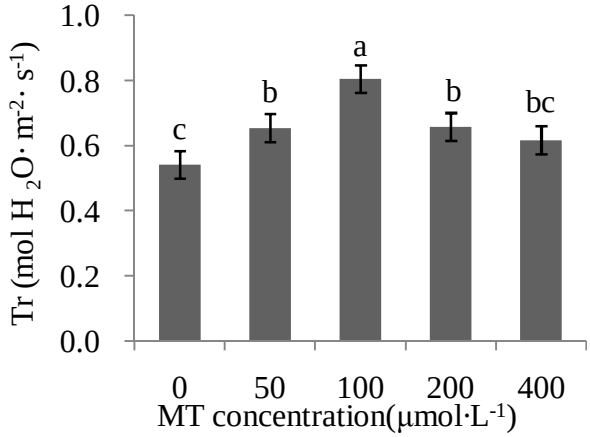

Fig. 2 Tr of MT sprayedlettuce

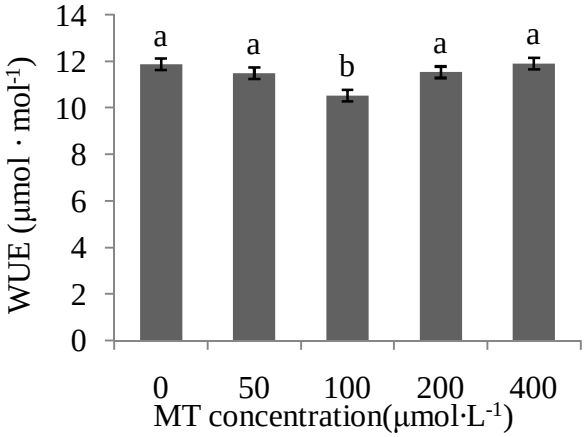

Fig. 3 WUE of MT sprayedlettuce

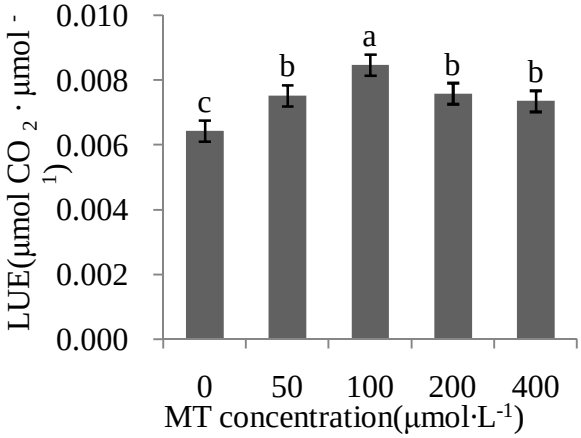

Fig. 4 LUE of MT sprayedLettuce

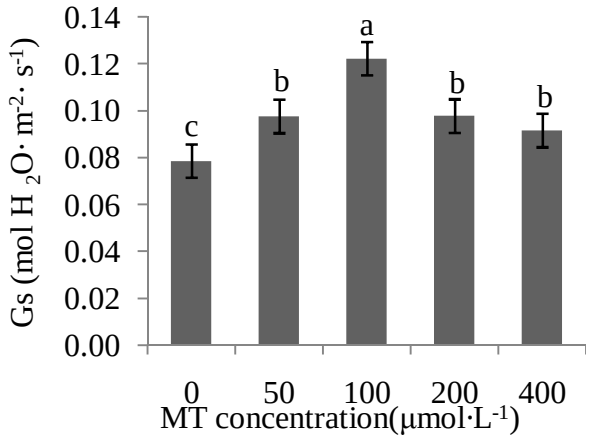

Fig. 5Gs of MT sprayedlettuce

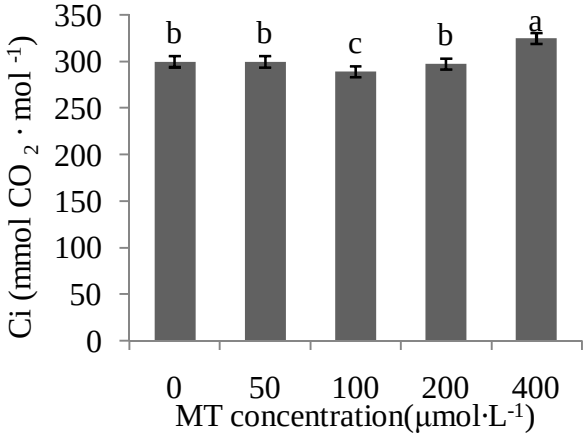

Fig. 6Ci of MT sprayedlettuce

StomatalConductance (Gs). It can be clearly seen from Fig.5, compared with CK, after spraying melatonin, Gsof lettuce leaves are significantly increased. When melatonin concentrations of 50, 100 and 400μmol·L^{-1}, these treatments enhanced Gs oflettuce by 24.33% (p<0.05), 55.82% (p<0.05), 24.62% (p<0.05) and 16.68% (p<0.05), respectively.

CO_2Concentration of Intercellular (Ci). Sprayed 50 and 200μmol·L^{-1} melatonin, Ci of lettuce under NaCl stress had no significant difference with the control, when the concentration of melatonin was 100μmol·L^{-1}, Ci was reduced by 3.57%(p<0.05). When the concentration of melatonin was 400μmol·L^{-1}, Ci was higher than the control, significantly.

Conclusions

Salt stress lead to photosynthesisimpaired [12]. The studyfound that the Pn,Tr, LUE and Gsof lettucewere promotedby low concentration of MT and inhibited by high concentration, which may be a high concentration of MT has toxic effects on the photosynthetic apparatus. To sum up, spraying low concentrations of MT can improve photosynthesis of lettuce under NaCl stress, in addition,the best concentration of MT was 100μmol·L^{-1}.

Acknowledgements

This work was financially supported by the Sichuan Agricultural University “Shuang-Zhi Plan”Foundation, Sichuan Provincial Department of Education Foundation (15ZA0011).

References

[1] M. Y. Nong, N. M. Zhang and J. Shi: Soil and Fertilizer Sciences in China Vol.6(2013), p. 6-10 (In Chinese).
[2] D. L. Liu and Q. J. Wang:Chinese Journal of Soil ScienceVol.33(2002), p. 449-455 (In Chinese).
[3] S. R. Guo, J. Sun and S. Suo: China Vegetables Vol.18 (2012), p. 1-14 (In Chinese).
[4] L. L. Tang, Z. J. Chen and J. B. Zhou: Agricultural Research in the Arid AreasVol.24(2006), p.70-74 (In Chinese).
[5] C. Q. Zhao: Shaanxi Agricultural Sciences Vol.2(2005), p.82-83 (In Chinese).
[6] R. J. Reiter: Progress in NeurobiologyVol.56 (1998), p.359-384 (In Chinese).
[7] T. Iskender,K. Huseyin: Journal of Pineal Research Vol.52 (2012), p.332-339.
[8] X. Y. Lei,R. Y. Zhu and G. Y. Zhang :Journal of Pineal Research, Vol.36(2004), p.126-131.

[9] L. J. Zhang, J. F. Jia and K. Mei: Journal of Nuclear Agricultural Sciences, Vol.5 (2015), p. 830-835 (In Chinese).
[10] M. Posmyk Małgorzata, H. Kuran and K. Marciniak: Journal of Pineal ResearchVol.45 (2008), p.24-31.
[11] M. B. Arnao and J.Hernández-Ruiz: Food Chemistry Vol.138 (2013), p.1212–1214.
[12] L. Sun, Y. F. Zhou and F. X. Zhou: Scientia Agricultura Sinica Vol. 45 (2012), p. 3265-3272 (In Chinese).