Effects of Exogenous Abscisic Acid on Photosynthesis of Lettuce under NaCl Stress

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Keywords: Abscisic acid; NaCl stress; Lettuce; Photosynthesis

Abstract. Soil salinization has become a global problem. This test used the method of spraying different concentrations (1, 5, 10, 20 μmol·L^{-1}) of ABA to lettuce leaves respectively, with spraying water as control, to discuss the effects of exogenous abscisic acid (ABA) on photosynthesis of lettuce under NaCl stress. The results showed that after spraying ABA, net photosynthetic rate (Pn), stomatal conductance (Gs), water use efficiency (WUE), light use efficiency (LUE), transpiration rate (Tr) and CO_2 concentration of intercellular (Ci) of lettuce have improved in varying degrees, and when the ABA concentration was 5μmol·L^{-1}, enhanced by 33.67% (P <0.05), 24.38% (P <0.05), 7.47 % (P <0.05), 33.67% (P <0.05), 56.66% (P <0.05) and 12.57% (P <0.05), respectively compared with CK. Therefore, spraying ABA can significantly improve photosynthetic capacity of lettuce leaves under NaCl stress, and the best results appear in 5 μmol·L^{-1}.

Introduction

Soil salinization is a major environmental risk caused by natural or human-induced, worldwide there are about 831 million hm^2 subject to soil salinization threat [1]. Chinese soil salinization of about 36.9 million hm^2, accounted for 1/4 of the existing arable land [2]. Soil salt ions cause agglomeration plant physiological water, increasing soil salinity ions inhibit the absorption of other nutrients in plants, resulting in poor plant development leading to production cuts or death [3].

Lettuce (*Lactuca sativa* L.) is Asteraceae plants of the genus Lactuca genus. And it is common leafy vegetables in summer and autumn. Lettuce has the advantages of short production cycle, large market demand and rich in nutrients [4].

ABA is a kind of stress hormone, which can improve plant cold resistance [4], drought resistance [5] and aluminum resistance [6]. Studies had shown that exogenous ABA could improve photosynthesis, improve salt tolerance of sweet potato seedling under salt stress[7]. Currently, there are rarely reported about the effects of exogenous ABA on the photosynthesis of plants under NaCl stress. Therefore, this study investigated the effect of exogenous ABA on photosynthetic characteristics of lettuce under NaCl stress, in expectation to provide reference of lettuce grown under salt stress.

Materials and Methods

Materials. The experiments were conducted at Sichuan Agricultural University (30° 42′ N, 103° 51′ E), Wenjiang, China. The seeds of lettuce were harvested in 2015 and 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} NaCl 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, 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 1000 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). Spraying ABA can significantly improve thePn of lettuce leaves, and with the ABA concentration increased, Pn increased at first, at the concentration of 5 μmol·L^{-1} reached a peak, 33.67% (P <0.05) higher than the control, and then decreased slightly.When the ABA concentration of 10 and 20μmol·L^{-1}, Pn significantly higher than the control 24.09% (P <0.05) and 14.14% (P <0.05).

Transpiration Rate (Tr). As can be seen from Fig. 2, after spraying 1, 5, 10, 20 μmol·L^{-1} ABA, Tr of lettuce leaves were increased by 10.93% (P <0.05), 24.38% (P <0.05), 17.32% (P <0.05) and 12.08% (P <0.05), respectively, compared with CK.

Water Use Efficiency (WUE). It was clearly observed that WUE of lettuce leaves were increased, after spraying ABA. Spraying 5 and 10 μmol·L^{-1} were increased by 7.47% (P<0.05) and 5.77% (P<0.05), with a significant difference from the control;the difference of spraying 1 and 20 μmol·L^{-1} ABA with CK is not significant.

Light Use Efficiency (LUE). After spraying ABA, LUE of each treatment were significantly higher than the control, and it increased first and then decreased with the ABA concentration increased. Compared with CK ,when the ABA concentration were 1, 5, 10, 20 μmol·L^{-1}, LUE of lettuce leaves were increased by 13.13% (P <0.05), 33.67% (P <0.05), 24.09% (P <0.05), and 14.14% (P <0.05), respectively.

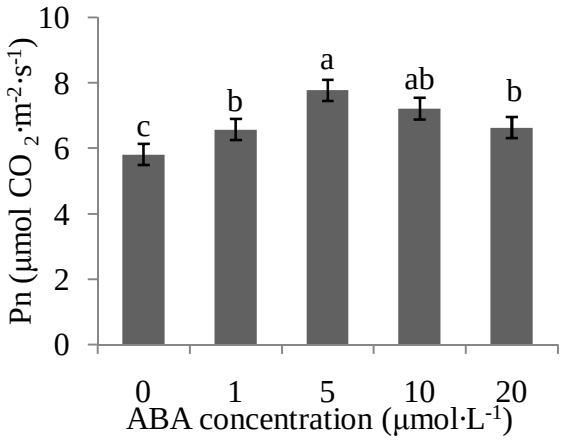

Fig. 1 Pn of ABA sprayed lettuce

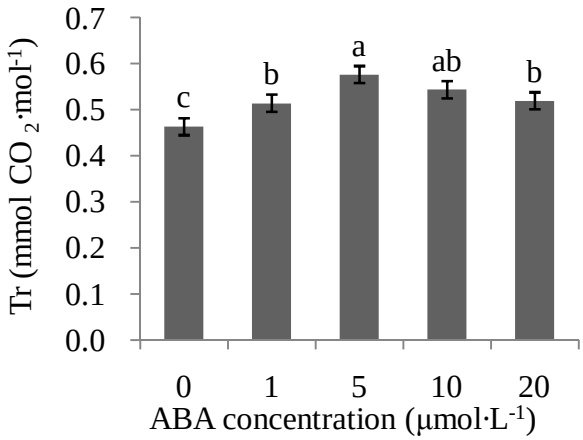

Fig. 2 Tr of ABA sprayed lettuce

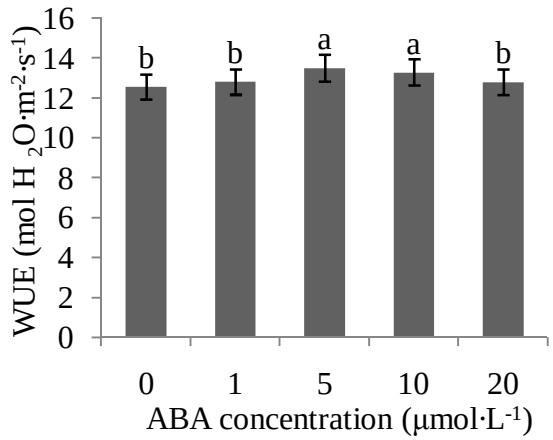

Fig. 3 WUE of ABA sprayed lettuce

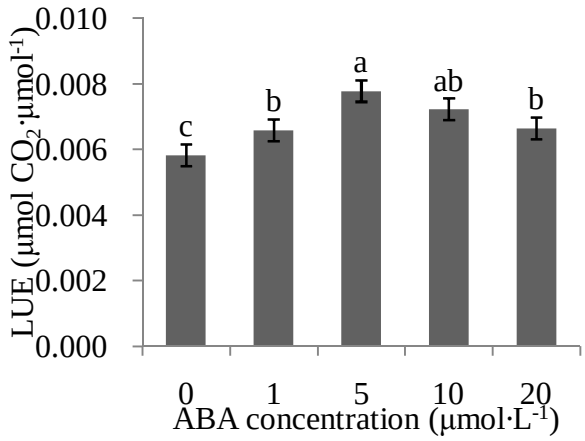

Fig. 4 LUE of ABA sprayed lettuce

Stomatal Conductance (Gs). The same as the trend of Pn and Tr, when the ABA concentration is less than 5 μmol·L^{-1}, Gs of lettuce incersed with the concentration of ABA increased, and the Gs maximum for the CK of 156.66% (P<0.05), when ABA concentration is 5 μmol·L^{-1}. And then with the ABA concentration increased, Gs decreased, but significantly higher than the control.

CO_2 Concentration of Intercellular (Ci). As shown in Fig. 6, after sprayed ABA of 1, 5, 10

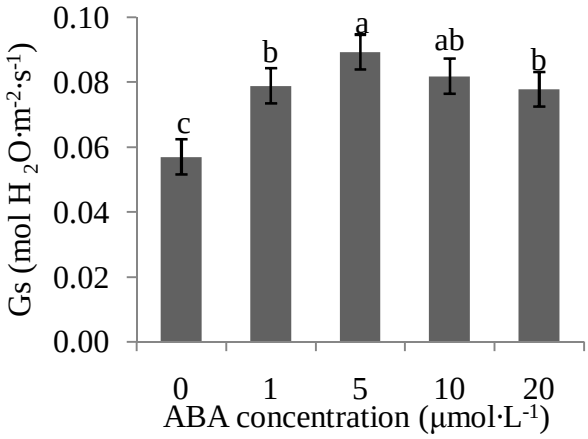

Fig. 5 Gs of ABA sprayed lettuce

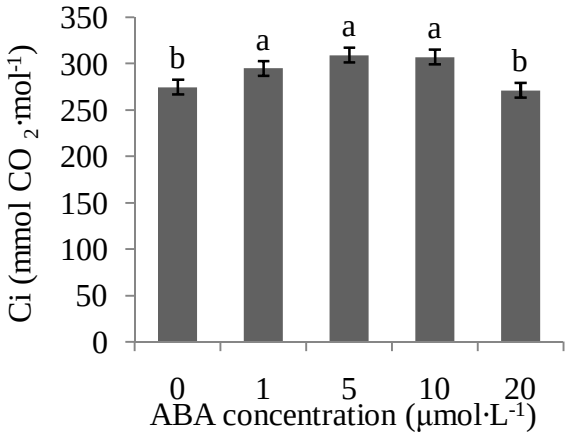

Fig. 6 Ci of ABA sprayed lettuce

μmol·L^{-1}, Ci of lettuce under NaCl stress significantly incresed 7.37% (P<0.05), 12.57% (P<0.05) and 11.72% (P<0.05), respectively, Compared with CK.

Conclusions

Studies have shown that the plant metabolic disorders, Chlorophyll-related activity increased to accelerate the decomposition of chlorophyll under salt stress [10]. At the same time, the salt stress leaded to stomatal closure [11]. These factors eventually lead to plants photosynthesis reduced. ABA as a stress hormone plays an important role in plants against salt stress [12]. Photosynthetic parameters were precise, fast, non-destructive to evaluate the salt tolerance of plants [13]. In this paper ,results showed that after spraying ABA, lettuce leaves of Pn, Gs, Ci, Tr, WUE and LUE were increased, and the best results appeared at the ABA concentration of 5 μmol·L^{-1},

Acknowledgements

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

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