Effects of abscisic acid on soluble sugar content of *Perilla frutescens* seedlings under cadmium stress

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Abstract. The experiment aimed to study the effects of abscisic acid on soluble sugar content of *Perilla frutescens* seedlings under cadmium stress. The leaves of *P. frutescens* were foliage sprayed with different concentrations (0, 1, 5, 10, 20 μmol·L⁻¹) of ABA under cadmium stress (10 mg·kg⁻¹). The results showed that the soluble sugar content in root, stem and shoot increased with the ABA concentration increasing at first, and then decreased. The soluble sugar content in leaf decreased with the ABA concentration increasing. The soluble sugar content in root and stem peaked when the ABA concentration was 5 μmol·L⁻¹, which increased by 8.11% and 19.87% compared to the ABA concentration was 0 μmol·L⁻¹, respectively. And the soluble sugar content in leaf peaked when the ABA concentration was 1 μmol·L⁻¹, which increased by 1.04%. In conclusion, appropriate concentration of ABA could increase the soluble sugar content of *P. frutescens* under cadmium stress, and alleviated the stress of cadmium on *P. frutescens* seedlings to some extent.

1. Introduction

*Perilla frutescens* is a traditional Chinese medicine and oil crop, which distributed in more than 20 provinces across the country. It is one of the first 60 Chinese medicines that are prescribed by the Ministry of Health as both medicine and food [1]. It has received extensive attention at domestic and foreign in recent years because of the great development potential in the field of medicine and food [2-3]. In the background of rapid economic development, the safety of agricultural land is at stake. At present, the cultivated area contaminated by heavy metals in China has reached 2 × 10⁵ km², accounting for 1/6 of the total cultivated area, and cadmium is one of the most important sources of pollution [4]. Studies had shown that with the increase of cadmium concentration, the *P. frutescens* showed symptoms of poor growth, when the cadmium concentration was 10 mg·L⁻¹, the leaves of the *P. frutescens* appeared obviously chlorotic, and the lower leaves turned yellow and fallen off, the plants stopped growing [5].

Abscisic acid (ABA) is a kind of "stress hormone", which forms rapidly under adverse conditions and can induce plant resistance like drought resistance, heat resistance, cold resistance, disease resistance and salt tolerance [6]. Studies had shown that ABA played a role in the cadmium tolerance
of rice seedlings, and ABA pretreatment could reduce the accumulation of cadmium in the shoot of plants, and alleviated the toxic effects on rice seedlings to a certain degree [7-8]. Therefore, in the study, the soluble sugar content of different organs of *P. frutescens* was determined, to verify if ABA has effects on soluble sugar content of *P. frutescens* seedlings under cadmium stress.

2. Materials and methods

2.1. Materials

Seeds of *P. frutescens* were collected from uncontaminated soil on a farm at the Chengdu Campus of Sichuan Agricultural University (30°71ʹN, 103°87ʹE) in October 2017, air dried and stored at 4°C.

2.2. Experimental design

The experiment was conducted in the greenhouse of Chengdu Campus farm from March to July 2018. In March 2018, after the soil was air dried, crushed, mixed and sieved (6.72 mm), 3.0 kg soil was accurately weighed into each plastic pot (23 cm height × 30 cm diameter). A CdCl₂·2.5H₂O solution was added to the soil to achieve a final cadmium concentration of 10 mg·kg⁻¹ [9-10], and the soil moisture was maintained at 80% of field capacity for 8 weeks. After this period, the soil was crushed and mixed thoroughly. Four uniform *P. frutescens* seedlings (with three pairs of expanded true leaves) were transplanted into each pot in May 2018, then sprayed ABA solution that concentration was 0, 1, 5, 10 and 20 μmol·L⁻¹ onto the foliage of seedlings, respectively (25 mL per pot). Each treatment was repeated four times and watered every day to maintain the soil moisture at 80% of field capacity until the plants were harvested.

Two months after the plants were transplanted (July 2018), the young parts of the root, stem and leaf of *P. frutescens* were collected to determine the corresponding soluble sugar content [11].

2.3. Statistical analyses

Statistical analyses were conducted using statistical software of SPSS 17.0. Data were analyzed by one-way ANOVA with least significant difference at 5% confidence level.

3. Results and discussion

3.1. Soluble sugar content in root of *P. frutescens*

With the concentration of ABA increasing, the soluble sugar content in root of *P. frutescens* increased, peaked when the ABA concentration was 5 μmol·L⁻¹ and then decreased (Figure 1). The content of soluble sugar in root when the ABA concentration was 5 μmol·L⁻¹ was significant higher than which when the ABA concentration was 0 μmol·L⁻¹, which was 8.11% (<0.05) higher than that. And the difference in soluble sugar content between ABA concentration 5 μmol·L⁻¹ and 10 μmol·L⁻¹ was not significant (>0.05). The soluble sugar content in root for all the ABA treatments were higher than that for the ABA concentration was 0 μmol·L⁻¹, showed that ABA treatment could promote the accumulation of soluble sugar in *P. frutescens*.

3.2. Soluble sugar content in stem of *P. frutescens*

The change in soluble sugar content in stem of *P. frutescens* showed a pattern similar to that in root. The content of soluble sugar in stem increased firstly, and then decreased (Figure 2). When the ABA concentration was 5 μmol·L⁻¹, the soluble sugar content in stem reached the peak, which was 19.87% (<0.05) higher than that when the ABA concentration was 0 μmol·L⁻¹. Similarly, the difference in soluble sugar content in stem between ABA concentration 5 μmol·L⁻¹ and 10 μmol·L⁻¹ was not significant (>0.05).
3.3. Soluble sugar content in leaf of *P. frutescens*

With the concentration of ABA increasing, the soluble sugar content in leaf of *P. frutescens* decreased (Figure 3). The soluble sugar content in leaf was the highest when the ABA concentration was 0 μmol·L⁻¹, and the soluble sugar content in leaf at the ABA concentration of 1, 5, 10 and 20 μmol·L⁻¹ was 1.33% (*p* > 0.05), 15.20% (*p* < 0.05), 21.63% (*p* < 0.05) and 21.63% (*p* < 0.05) lower than that at ABA concentration of 0 μmol·L⁻¹, respectively. The results showed that ABA treatment decreased soluble sugar content in leaf of *P. frutescens*.

3.4. Soluble sugar content in shoot of *P. frutescens*

The change in soluble sugar content in shoot of *P. frutescens* was similar to that in root and stem, also increased firstly and then decreased (Figure 4). The content of soluble sugar in shoot reached peak at the ABA concentration of 1 μmol·L⁻¹, and the difference among ABA concentration 0, 1 and 5 μmol·L⁻¹ was not significant (*p* > 0.05). The soluble sugar content when the ABA concentration was 1 μmol·L⁻¹ was 1.04% (*p* > 0.05) higher than that when the ABA concentration was 0 μmol·L⁻¹.
4. Conclusions

Under heavy metal stress, carbohydrate metabolism in plants has been disturbance. The change of soluble sugar content in plants depends on cadmium concentration and plant species. Low concentration of cadmium treatment increases the soluble sugar content in plants, while the soluble sugar content in plants treated with high concentration of cadmium decreases [12]. In the experiment, the results were consisting with the above. All the soluble sugar content were increased firstly and then decreased with ABA concentration increasing except the soluble content in leaf. The soluble sugar content in root and stem was maximum when the ABA concentration was 5 μmol·L⁻¹, and increased by 8.11% and 19.87% compared to the ABA concentration was 0 μmol·L⁻¹, respectively. The soluble sugar content in shoot reached peak when the ABA concentration was 1 μmol·L⁻¹, and increased by 1.04% compared to the ABA concentration was 0 μmol·L⁻¹. The soluble sugar content in root and stem later peak appeared when the ABA concentration was 5 μmol·L⁻¹, while the soluble sugar content in leaf when the ABA concentration was 0 μmol·L⁻¹. It may because that ABA was in direct contact with the leaves, while it needs to be transported over long distances to reach the stem and root, which requires a higher concentration of ABA for signal transmission. In conclusion, ABA could increase the soluble sugar content of *P. frutescens* under cadmium stress, and alleviated the stress of cadmium on *P. frutescens* seedlings to some extent.

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