Cadmium Accumulation Characteristics of *Cyphomandra betacea* Seedlings

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Abstract: A pot experiment was conducted to study the accumulation characteristics of cadmium (Cd) in *Cyphomandra betacea* Seedlings. The annual *C. betacea* seedlings were treated with Cd of different concentration gradients (0 - 20 mg/kg). The results showed that with the increase of soil Cd concentration, the root biomass, stem biomass, leaf biomass and shoot biomass of *C. betacea* seedlings tended to decrease, without showing obvious toxic symptoms. When the soil Cd concentration was less than 5 mg/kg, the distribution of Cd in *C. betacea* seedlings was as follows: root > stem > shoot > leaf, when the Cd concentration in soil was more than 5 mg/kg, the order of Cd content in the organs of *C. Betacea* seedlings was: root > leaf > shoot > stem. With the increase of soil Cd concentration, the Cd content in *C. betacea* seedlings increased evidently, when the soil Cd concentration reached 20 mg/kg, the Cd content in the roots was 168.86 mg/kg, and 8.08 mg/kg in the shoots respectively. For the translocation factor (TF), the results showed that the TF of *C. Betacea* seedlings decreased first and then increased, and the TF of different soil Cd concentration was less than 0.3. Therefore, with Cd accumulated mainly in the roots, *C. betacea* seedlings had a strong tolerance to Cd stress.

Introduction

Cadmium (Cd) is a natural element in the earth's crust, and is one of the most toxic heavy metals which can be a serious threat to human health [1]. With the development of industry and agriculture, the contaminated area of heavy metal in soil is increasing [2]. In response to Cd stress in plant seedlings, previous studies showed that low concentration of Cd might promote the growth, and as the concentration of Cd increased, the biomass, the content of chlorophyll, and the activity of antioxidant enzyme decreased, which were detrimental to plant growth [3,4]. The results of fluorescence quantitative PCR showed that plants could remove reactive oxygen from Cd stress by synergistic action of antioxidant enzymes and non-enzymatic substances in the body [5]. However,there are significant differences in the distrubution and tolerance of different plants to Cd tress and different plants have different detoxification mechanisms against Cd stress [6]. *Cyphomandra betacea* is a fruit tree belongs to the Solanaceae family, and is currently cultivated in the southwest part of China [7]. Other researchers have found that *C. betacea* had strong ability to resist insect pests and could grow normally under low concentration Cd pollution (10 mg/kg) [7,8]. To further understand the Cd accumulation characteristics of *C. betacea* seedlings, a pot experiment with Cd of different concentration gradients (0 - 20 mg/kg) was conducted. The objectives of this study were to provide guiding significance for its cultivation application and safe production in Cd contaminated orchard.

Materials and Methods

Materials. The seeds of *C. betacea* were collected from a perennial *C. betacea* of Chengdu Academy of Agriculture and Forestry (30° 42′ N, 103° 51′ E) in August, 2016, air-dried and stored at 4 °C respectively.

Experimental Design. The experiment was conducted at Chengdu Campus of Sichuan Agricultural University (30° 42′ N, 103° 51′ E) from May to August 2017. The soil samples were air-dried and passed through a 5-mm mesh in May 2017, and then 3.0 kg of soil was weighed into each polyethylene pot (15 cm tall, 18 cm diameter). Cd was added to make a final soil Cd concentration of 0, 1, 5, 10, 15 and 20 mg/kg. with a saturated heavy metal solution in the form of $CdCl_2 \cdot 2.5H_2O$. The soils were mixed aperiodically during the next 4 weeks, and the soil moisture was kept at 80%. The seeds of *C. betacea* were sown in the farmland of the Chengdu Campus in June 2017. Two weeks later, three seedlings of each treatment were transplanted into each pot, and each treatment was repeated five times with a 10-cm spacing between pots. In order to reduce the marginal effect, the position of the pots was completely randomly arranged and exchanged during the whole growth process. After 2 months of planting, the whole plant was harvested, washed with tap water and detached water for 3 times. The sample of tree tomato was divided into three parts: root, stem and leaf, each part was killed at 75 ℃ for 15 min.and dried at 110 ℃ for 15 min. Electronic balance was used to weigh the biomass of the samples. After boiling with nitroacid and hyperchloric acid (volume product ratio 4: 1), iCAP6300 type ICP spectrometer was used to determine the Cd content and translocation factor (TF), TF = Cd content in shoots/ Cd content in roots [9].

Statistical Analyses. Statistical analyses were conducted using SPSS 17.0 statistical software (IBM, Chicago, IL, USA). Data were analyzed by one-way analysis of variance with least significant difference (LSD) at the $p = 0.05$ confidence level.

Results and Discussion

Biomass of *C. betacea* seedlings. The order of organ biomass of *C. betacea* seedlings was: leaf > root > stem, and the shoot biomass was 4 times bigger than the root biomass (Table 1). The biomass of *C. betacea* seedlings under soil Cd concentration of 1 mg/kg was the same as that of the control, but with the increase of soil Cd concentration, the root biomass, the stem biomass and the leave biomass tended to decrease. Under soil Cd concentration of 1, 5, 10, 15 and 20 mg/kg , the root biomass decreased by 4.04% ($P > 0.05$), 5.56% ($P > 0.05$), 8.59% ($P < 0.05$), 10.10% ($P < 0.05$) and 27.27% ($P < 0.05$) respectively, compared with the control. With the increase of soil Cd concentration, the trends of stem, leaf and shoot biomasses were the same as the root biomass. Under soil Cd concentration of 1, 5, 10, 15 and 20 mg/kg , the stem biomass decreased by 6.43% ($P > 0.05$), 24.29% ($P < 0.05$), 24.29% ($P < 0.05$), 23.57% ($P < 0.05$) and 33.57% ($P < 0.05$) respectively, compared with the control, the leave biomass decreased by -3.17% ($P > 0.05$), 6.20% ($P < 0.05$), 15.80% ($P < 0.05$), 22.48% ($P < 0.05$) and 36.89% ($P < 0.05$) respectively, and the shoot biomass decreased by -1.68% ($P > 0.05$), 9.12% ($P < 0.05$), 17.17% ($P < 0.05$), 22.57% ($P < 0.05$) and 36.25% ($P < 0.05$) respectively, compared with the control. Thus, Cd stress could reduce the biomass of *C. betacea* seedlings and inhibit the growth, and with the increase of Cd concentration, the inhibition increased.

Table 1 The biomass of *C. betacea* seedlings

Cd concentration (mg/kg)	Roots (g/plant)	Stems (g/plant)	leaves (g/plant)	Shoots (g/plant)
0	0.198±0.001a	0.140±0.005a	0.694±0.001a	0.833±0.007a
1	0.190±0.007a	0.131±0.007a	0.716±0.021a	0.847±0.028a
5	0.187±0.006ab	0.106±0.007b	0.651±0.023b	0.757±0.015b
10	0.181±0.009b	0.106±0.006b	0.584±0.010c	0.690±0.004c
15	0.178±0.001b	0.107±0.009b	0.538±0.006d	0.645±0.014d
20	0.144±0.001c	0.093±0.007b	0.438±0.007e	0.531±0.013e

Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($P < 0.05$).

Cd content in *C. betacea* seedlings. Table 2 shows that with the increase of soil Cd concentration, the content of Cd in the roots, stems, leaves and shoots of *C. Betacea* seedlings increased, and the difference between each treatment was significant ($P < 0.05$). The distribution of Cd in *C. Betacea* seedlings was different under different soil Cd concentration. When the soil Cd concentration in soil was 0, 1 and 5 mg/kg, the order of Cd content in *C. betacea* seedlings was: root > stem > shoot > leaf, when the Cd concentration in soil was 10, 15 and 20mg/kg , the order of Cd content in the organs of *C. Betacea* seedlings changede as: root > leaf > shoot > stem. Under soil Cd concentration of 1, 5, 10, 15 and 20 mg/kg, the Cd content in the roots was 1.91 times ($P < 0.05$), 20.26 times ($P < 0.05$), 21.21 times ($P < 0.05$), 24.98 times ($P < 0.05$) and 29.27 times ($P < 0.05$) respectively as much as that in the control, and the Cd content in the shoots was 1.90 times ($P < 0.05$), 3.81 times ($P < 0.05$), 6.13 times ($P < 0.05$), 8.89 times ($P < 0.05$) and 11.22 times ($P < 0.05$) respectively as high as that in the control group. When the soil Cd concentration reached 20 mg/kg, the Cd content was 168.86 mg/kg in the roots, 7.57 mg/kg in the stems, 8.59 mg/kg in the leaves and 8.08 mg/kg in the shoots. With the increase of soil Cd concentration, the TF of *C. Betacea* seedlings decreased first and then increased, and the TF of different soil Cd concentration treatments was less than 0.3. Those results indicated that the Cd was mainly accumulated in the roots of *C. Betacea* seedlings, which could reduce the effect of Cd on the shoots of *C. Betacea* seedlings and was very beneficial to their growth.

Table 2 The Cd content in *C. Betacea* seedlings

Cd concentration (mg/kg)	Roots (mg/kg)	Stems (mg/kg)	leaves (mg/kg)	Shoots (mg/kg)	TF
0	5.77±0.10f	1.26±0.05f	0.18±0.01f	0.72±0.02f	0.25
1	11.05±0.27e	2.12±0.15e	0.62±0.02e	1.37±0.09e	0.25
5	116.90±2.37d	3.05±0.10d	2.42±0.04d	2.74±0.07d	0.05
10	122.40±2.74c	3.64±0.12c	5.17±0.03c	4.41±0.08c	0.07
15	144.15±0.24b	5.72±0.07b	7.08±0.09b	6.40±0.01b	0.09
20	168.86±3.39a	7.57±0.06a	8.59±0.07a	8.08±0.00a	0.10

Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($P < 0.05$).

Conclusions

C. Betacea seedlings did not show obvious toxic symptoms under the soil Cd concentration of 1 - 20 mg/kg. With the increase of soil Cd concentration, the root biomass, stem biomass, leaf biomass and shoot biomass of *C. Betacea* seedlings decreased gradually, the Cd content in the roots, stems, leaves and shoots increased significantly compared with the control. Moreover, the distribution of Cd in the stems and leaves of *C. Betacea* seedlings was different when they were under different soil Cd concentration. When the soil Cd concentration in soil was 0, 1 and 5 mg/kg, the order of Cd content in *C. betacea* seedlings was: root > stem > shoot > leaf, when the Cd concentration in soil was 10, 15 and 20mg/kg , the order of Cd content in the organs of *C. Betacea* seedlings was: root > leaf > shoot > stem. When the soil Cd concentration reached 20 mg/kg, the Cd concentration of the roots was 168.86 mg/kg, 29.27 times as much as that in control. As for the transport coefficient, the results showed that with the increase of soil Cd concentration, the TF of *C. Betacea* seedlings decreased first and then increased, and the TF of different soil Cd concentration was less than 0.3. These results showed that *C. Betacea* seedlings had low amplitude of biomass and strong absorption ability to Cd under the condition of low soil Cd concentration(1 - 20 mg/kg), and the Cd was mainly accumulated in the roots of *C. Betacea* seedlings, which could reduce the effect of Cd on the shoot of *C. Betacea* seedlings and is very beneficial to its growth. Therefore, *C. Betacea* seedlings had a strong tolerance to Cd stress.

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