

Study on Cadmium Accumulation Characteristics of Four Bidens Species

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Keywords: Bidens; Cadmium; Phytoremediation; Difference

Abstract: A pot experiment was carried out to study the difference of cadmium (Cd) accumulation characteristics of four Bidens species. The results showed that *Bidens biternata* had the highest biomass and Cd accumulation amount of whole plant than the other three species under Cd-contaminated soil. The root and shoot biomasses of four Bidens species were ranked as: *B. biternata* > *Bidens parviflora* > *Bidens pilosa* > *Bidens bipinnata*. The Cd contents in roots and shoots of *B. pilosa* were maximal among the four species, and the Cd accumulation amount of whole plant of those four species was: *Bidens biternata* > *Bidens pilosa* > *Bidens parviflora* > *Bidens bipinnata*. Therefore, *Bidens biternata* is the best material among the four Bidens species to remediate Cd-contaminated soil.

Introduction

With the development of social industrialization, the irrational exploitation and utilization of various resources, the soil heavy metal contamination have been serious increasingly, which has become a limiting factor affecting the development of regional agricultural [1]. Cadmium (Cd) is a toxic heavy metal and high concentration of Cd could seriously affect the normal growth, yield and quality of crops [1]. Phytoremediation is a technology by planting hyperaccumulator or accumulator into heavy metal-contaminated soil to remove toxic elements from the environment to plants and makes soil non-toxic [2]. The technology has important research value and application prospect in the field of heavy metal contaminated soil because of its advantages of low cost, non-destructive effects on soil structure and no secondary pollution [3-5]. As is well known, we should study and compare the absorption and accumulation abilities of heavy metals of different plants so that the appropriate plant could be selected for phytoremediation and the effect of phytoremediation technology can be applied greatly. The Bidens plants belong to Compositae, which distribute almost all over the country in China and most of them are one year or perennial wild weeds [6]. Some studies have shown that some Bidens species have accumulation ability of Cd, which could be used as a pioneer plant to remove Cd from the contaminated soil [7-9]. However, there is no comparative study on the Cd accumulation of different Bidens species. Therefore, in this study, a pot experiment was conducted to study the differences of Cd accumulation of four Bidens species, which aimed at selecting the best species to remediate Cd contaminated soil efficiently.

Materials and Methods

Materials. In May 2016, the seeds of four species of Bidens including *Bidens bipinnata*, *Bidens pilosa*, *Bidens parviflora* and *Bidens biternata* were collected from the surrounding farmland at the

Chengdu campus of Sichuan Agricultural University (30° 42' N, 103° 50' E). Then, the seeds were put in the climate chamber to germination and further cultivation and transplanting.

Experimental Design. The experiment was conducted in Chengdu campus of Sichuan Agricultural University from May to July 2016. Soil samples for the experiment were collected from the surrounding farmland at the Chengdu campus of Sichuan Agricultural University. The basic properties of soils were as follows: the pH was 7.09, the total nitrogen content was 1.50 g/kg, the total phosphorus content was 0.76 g/kg, the total potassium content was 18.02 g/kg, the total Cd content was 1.96 mg/kg, the alkali solution nitrogen content was 94.82 mg/kg, the available phosphorus content was 6.30 mg/kg, the available potassium content was 149.59 mg/kg and the available Cd content was approximately 0 mg/kg. The basic physicochemical properties and Cd content of soils were determined from the methods of the reference [10]. In May 2016, the soils were air-dried and passed through a 6.72-mm sieve. 3 kg air-dried soil was weighed into each plastic pot (21 cm high, 20 cm in diameter), soaking uniformly by 10 mg/kg Cd (in the form of CdCl₂•2.5H₂O) solution for 4 weeks. All pots were watered each day to keep the soil moisture about 80%, and dug aperiodically to make soil mixed fully. In June 2016, three seedlings of each four species of *Bidens* with similar growth were transplanted into each pot. For each treatment with three replicates and the pots placed completely random. The distance between pots was 15 cm, and the pot position exchanged aperiodically to weaken the impact of the marginal effects.

Plants were dug up and divided into three parts of roots, stems, leaves after transplanting 60 days, then washed with tap water firstly, followed by deionized water to remove surface dust and soil. After that, the tissues of all plants were dried at 80°C until constant weight, weighed, ground to < 0.149 mm, and sealed into plastic bags for analysis. The samples of plant tissues were digested by concentrated HNO₃ and HClO₄ with 4:1 (vol/vol), and the Cd content were determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS, iCAP 6300, Thermo Scientific, USA) [11].

Experimental Design. Statistical analyses were conducted using SPSS 13.0 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. The following calculated were used: shoot bioconcentration factor (BCF) = Cd content in shoots / Cd concentration in soil [12]; translocation factor (TF) = Cd content in shoots / Cd content in roots [11]; translocation accumulation factor (TAF) = (Cd content in shoots×biomass in shoots) / (Cd contents in roots×biomass in roots) [13].

Results and Discussion

Biomass. The difference of biomass of four species of *Bidens* at the soil Cd concentration of 10 mg/kg was showed in Table 1. The root biomass of four species of *Bidens* was ranked as: *Bidens biternata* > *Bidens parviflora* > *Bidens pilosa* > *Bidens bipinnata*. Similarly, the shoot biomass of those four species was ranked as: *Bidens biternata* > *Bidens parviflora* > *Bidens pilosa* > *Bidens bipinnata*. For the root/shoot ratio of those four species, there was almost no difference among them except *Bidens biternata*, and the order was *Bidens biternata* > *Bidens bipinnata* > *Bidens pilosa* > *Bidens parviflora*. The results indicated that *Bidens biternata* could growth better and has higher tolerance to Cd than the other three species under Cd-contaminated soil.

Table 1 Biomass of four *Bidens* species

Plant species	Roots (g/plant)	Stems (g/plant)	Leaves (g/plant)	Shoots (g/plant)	Total biomass (g/plant)	Root/shoot ratio
<i>Bidens bipinnata</i>	1.29±0.06c	4.03±0.07d	2.79±0.06d	6.82±0.13d	8.11±0.19d	0.189
<i>Bidens pilosa</i>	1.74±0.04b	6.37±0.09c	3.38±0.09c	9.75±0.19c	11.49±0.23c	0.178
<i>Bidens parviflora</i>	1.78±0.05b	6.57±0.08b	4.23±0.10b	10.8±0.18b	12.58±0.23b	0.165
<i>Bidens biternata</i>	4.63±0.08a	8.69±0.10a	4.47±0.11a	13.16±0.21a	17.79±0.13a	0.352

Cadmium Content. As shown in Table 2, the Cd contents in roots and shoots of *Bidens pilosa* were maximal among the four species of *Bidens*. The Cd contents in roots of the four species were: *Bidens pilosa* > *Bidens bipinnata* > *Bidens parviflora* > *Bidens biternata*. The Cd contents in shoots of the four species were: *Bidens pilosa* > *Bidens parviflora* > *Bidens biternata* > *Bidens bipinnata*. For the BCFs in shoots and TFs of the four species of *Bidens*, all the factors exceeded 1, which indicated that those four species have relatively high accumulation and transportation abilities of Cd.

Table 2 Cadmium content in four *Bidens* species

Plant species	Roots (mg/kg)	Stems (mg/kg)	Leaves (mg/kg)	Shoots (mg/kg)	Shoot BCF	TF
<i>Bidens bipinnata</i>	8.24±0.29ab	9.67±0.34c	11.37±0.48c	10.37±0.01c	1.04	1.26
<i>Bidens pilosa</i>	8.87±0.36a	12.34±0.64a	23.38±1.64a	16.17±1.02a	1.62	1.82
<i>Bidens parviflora</i>	7.86±0.41b	11.03±0.53b	19.44±0.96b	14.32±0.73b	1.43	1.83
<i>Bidens biternata</i>	6.46±0.34c	10.15±0.23c	13.52±1.51c	11.29±0.68c	1.13	1.76

Cadmium Accumulation. It illustrated the difference of Cd accumulation amount in four species of *Bidens* in Table 3. The Cd accumulation amount in roots of the four species was: *Bidens biternata* > *Bidens pilosa* > *Bidens parviflora* > *Bidens bipinnata*. The Cd accumulation amount in shoots was: *Bidens pilosa* > *Bidens parviflora* > *Bidens biternata* > *Bidens bipinnata*. On the whole, the Cd accumulation amount of whole plant about those four species was: *Bidens biternata* > *Bidens pilosa* > *Bidens parviflora* > *Bidens bipinnata*, which turned out that *Bidens biternata* has higher accumulation ability of Cd than the others. Moreover, the TAFs of the four species were high, indicating all of them could accumulate Cd preferably.

Table 3 Cadmium accumulation amount of four *Bidens* species

Plant species	Roots (µg/plant)	Stems (µg/plant)	Leaves (µg/plant)	Shoots (µg/plant)	Whole plant (µg/plant)	TAF
<i>Bidens bipinnata</i>	10.64±0.87c	38.99±2.05c	31.70±0.66c	70.69±1.39b	81.33±2.26b	6.66
<i>Bidens pilosa</i>	15.44±0.97b	78.65±5.19b	79.13±7.76a	157.77±12.95a	173.22±13.92a	10.21
<i>Bidens parviflora</i>	13.98±0.34b	72.50±4.36b	82.29±6.01a	154.79±10.37a	168.77±10.03a	11.09
<i>Bidens biternata</i>	29.93±2.09a	88.22±3.02a	60.54±8.24b	148.76±11.26a	178.69±9.17a	5.00

Conclusions

Among four species of *Bidens*, *Bidens biternata* has highest biomass and Cd accumulation amount of whole plant than the other three species in the same concentration of Cd-contaminated soil. The root and shoot biomasses of four *Bidens* species were ranked as: *B. biternata* > *Bidens parviflora* > *Bidens pilosa* > *Bidens bipinnata*. The Cd contents in roots and shoots of *B. pilosa* were maximal among the four species, and the Cd accumulation amount of whole plant of those four species was: *Bidens biternata* > *Bidens pilosa* > *Bidens parviflora* > *Bidens bipinnata*. Therefore, *Bidens biternata* is the best material among the four *Bidens* species to remediate Cd-contaminated soil.

Acknowledgements

This work was financially supported by the Application Infrastructure Project of Science and Technology Department of Sichuan Province (2016JY0258).

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