ACCUMULATION AND SUBCELLULAR DISTRIBUTION OF CADMIUM IN THE DIFFERENT ORGANS OF HYDROPONICALLY GROWN *IMPATIENS WALLERIANA*

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ABSTRACT

Impatiens (*Impatiens walleriana*) was validated as a potential Cd hyperaccumulator when growing in the contaminated soils. Rooted cuttings were hydroponically grown in the Cd solutions with different concentrations and the accumulation and subcellular distribution of Cd in the various organs were analyzed after growing for 25 days and 50 days. Experimental results show that the root, stem, and leaf accumulated approximately 120-1850, 60-1750, and 50-1450 mg/kg of Cd, respectively. Results of the subcellular distribution revealed that Cd was mainly compartmentalized in the soluble fraction in the roots. Nevertheless, most of the Cd was in the cell wall fraction in the leaves. Different growing periods changed the subcellular distribution in the stems and also the upward translocation of Cd.

Keywords: cadmium, impatiens, phytoremediation, subcellular distribution

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1. Introduction

Phytoremediation, an environmental friendly remediation technique, is the use of plants to remove pollutants from contaminated soils. Nevertheless, only few in situ experiments were conducted in the contaminated sites because it takes longer period in decontamination compared with other traditional remediation techniques. In Taiwan, many garden flowers were grown in the artificial Cd-contaminated soils and Cd-contaminated sites to test their phytoextraction potentials. Some of them were validated as Cd hyperaccumulators (Lai et al., 2010), which can accumulate more than 100 mg/kg of Cd in the shoots and have high bioconcentration factor (BCF = shoot conc. / soil conc.) and translocation factor (TF = shoot conc. / root conc.).

Impatiens (I. walleriana) is an herbaceous plant commonly found in Taiwan and with all the characteristics of a Cd hyperaccumulator. Experiment result of Lin et al. (2010) shows that the biomass of impatiens was not significantly affected when growing in the artificial Cd-contaminated soils with total concentration 9-18 mg/kg. The accumulated Cd concentrations in the shoots reached 48-100 mg/kg and their BCF and TF was in the levels of 5.0-5.7 and 1.0-1.7, respectively. Similar results were reported by Wei et al. (2012), who planted impatiens seedlings in the artificial Cd-contaminated soils with total concentrations of 20-80 mg/kg. The impatiens accumulated 280-1200 mg/kg of Cd in the shoots and their BCF and TF was in the levels of 9.1-14.8 and 1.7-2.6. However, the highest Cd treatment (80 mg/kg) significantly decreased the biomass compared with control.

The subcellular distribution has an important role in the tolerance and detoxification of heavy metals (Wang et al., 2008; He et al., 2013) which includes soluble fraction (Fs), organelle-containing fraction (Fco), and cell wall fraction (Fcw). Fu et al. (2011) used subcellular analysis to study the Cd compartmentalization in the different organs of Phytolacca Americana L. Experimental results show that the Cd in the roots and leaves were mainly in the Fs (53-69%) and followed by Fcw (23-30%). The vacuole and cell wall responded for the tolerance of Cd mostly. A hydroponic experiment was conducted in this study and the subcellular distribution was

analyzed. The objective is to understand how the impatiens can tolerate the Cd's toxicity and accumulate high concentration of Cd.

2. Materials and methods

The hydroponic experiment was conducted in the phytotron at MingDao University (day/night = 30oC /25oC; 12/12 h). The solutions were prepared according to Yoshida et al. (1976), artificially spiked with Cd (0, 2.5, 10, 20, and 40 □M), and adjusted to pH 5.5. Rooted impatiens cuttings (15-day-old) were planted in the experimental pots with three replicates and replaced the solutions every three days.

All plants were harvested after growing for 25 days (D25) and 50 days (D50) and then washed with tap water. After divided into three organs (root, stem, and leaf), the roots were further immersed in the 20 mM of Na2-EDTA solutions for 15 min to remove exchangeable Cd. The subcellular distribution was conducted according with Wang et al. (2008) with some modifications. Other plant organs were oven dried at 65°C for 72 h, weighed, and then ground with a grinder. After being digested with HNO3/HClO4 (v/v = 1/1), the Cd concentrations in the filtered solutions were measured with a flame atomic absorption spectrometer (PerkinElmer AAnalyst 200).

3. Results

For most of the treatments, the Cd concentrations in the various organs increased with the increasing Cd concentration in the solutions. The extension of growth period from D25 to D50 promoted the Cd accumulation (Figure 1). For D25, the highest Cd concentration was in the stems. Nevertheless and compared with other organs, higher Cd concentrations were in the roots in D50. Different Cd treatments did not affect the subcellular distribution of Cd in the carious organs. Regardless of growth period, the accumulated Cd in the roots was primarily compartmentalized in the Fs (48-70%), which has a high migration capacity (Figure 2). Nevertheless, the Cd was mainly compartmentalized in the Fcw and accounted for 46-81% of the total Cd (Figure 2). The Cd in the roots has a high migration capacity that can further translocate to stems and leaves. After been translocated to leaves, the Cd was compartmentalized in the cell wall as a detoxification mechanism. The subcellular distribution of Cd in the stems was quite different for two growth periods. The accumulated Cd in the stems and leaves was mainly in the Fs (61-77%) and Fcw (54-75%) for D25 and D50, respectively. The difference in the subcellular distribution may responses for the higher Cd concentration in D50 (Figure 1).

Besides concentration, the BCF and TF are two important indices in identifying the capacities of accumulation and translocation. Both of them should more than unity for a potential hyperaccumulator (Sun et al., 2009). Experimental results of this study show that the BCF of most of the treatments increased with the increasing Cd concentration in the solutions. In agreement with Lai et al. (2010), the D50 also had higher BCF values compared with D25. Besides, D50 also had higher TF compared with D25. The TFshoot/root of most treatments in D25 was in the levels of 0.3-0.7, however, the TFshoot/root increased to 0.6-1.0 in D50. In the stems, the prolongation of growth period from D25 to D50 decreased the Cd in Fs from 61-77% to 17-41%. The Cd in Fcw, with a less migration capacity, also increased from 19-32% to 54-75% (Figure 2). Forgoing results revealed that the impatiens grown for D50 had developed a better detoxification mechanism compared with D25.

4. Conclusions

The impatiens shows the characteristics of a potential Cd hyperaccumulator and the Cd compartmentalization in the different organs had an important role in the tolerance and detoxification of Cd. Nevertheless, most of the TF values were less than unity possibly because cuttings were used in the study. The leaves of impatiens were not developed completely compared with marketable seedlings even growing for D25 or D50. Further study is needed to investigate the effect of extending growth period on the TF.

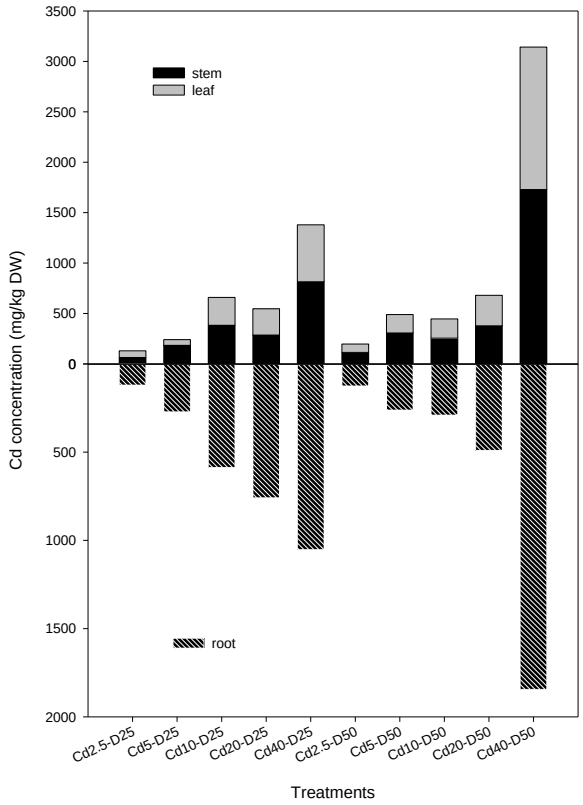

Figure 1. Cd accumulation in the various organs of impatiens.

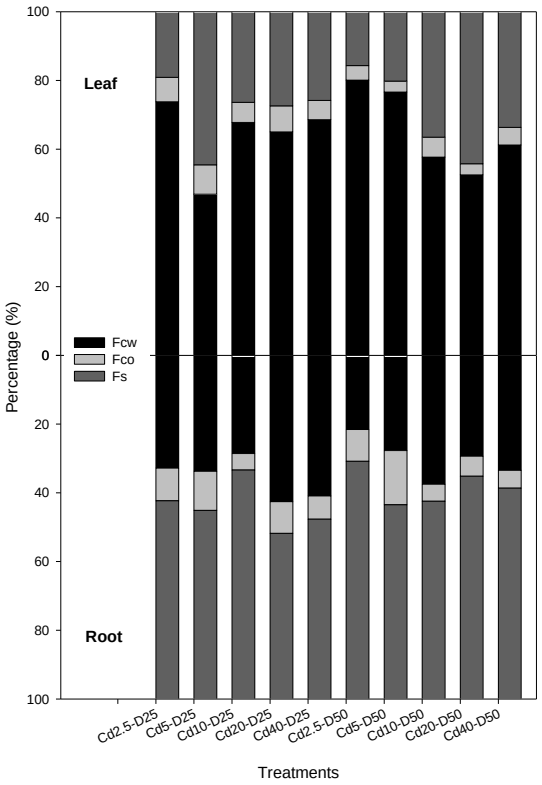

Figure 2. Subcellular distribution of Cd in the various organs of impatiens.

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