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Uptake and Accumulation of Cd from Wastewater by Alternanthera Philoxeroides (Mart.) Griseb

KEYWORDS: Alternanthera philoxeroides, Cd, Bioaccumulation Factor (BCF), Translocation Factor (TF)

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ABSTRACT *The study investigates the potential of the wetland macrophyte Alternanthera philoxeroides (Martius) Griseb (Amaranthaceae) in uptake and accumulation of cadmium (Cd). A. philoxeroides was exposed in the laboratory to 3.0, 5.0, and 10.0 mg L-1 Cd, and Cd accumulation was estimated at the time intervals of 3, 24, 72, 240 and 720 hours. The accumulation of Cd as well as the bioaccumulation (BCF) and translocation factors (TF) were the highest in stem, followed by that in root, and the lowest in leaf. The large biomass of the stem of A. philoxeroides coupled with its high Cd concentration as well as BCF and TF values, are indicative of its potential use in Cd phytoremediation.*

Introduction

Heavy metal pollution has emerged as an important environmental problem worldwide, which is also affecting developing countries like India, Pakistan and Bangladesh, where small industrial units are pouring their untreated effluents into surface water (Lone *et al.*, 2008). Metal pollutants are particularly difficult to remediate from soil, water and air because toxic elements such as lead, mercury, cadmium, copper and zinc, have long residency time in the environment. Cadmium (Cd) is an important toxic metal in aquatic systems. Release of Cd from anthropogenic activities such as waste disposal, mining, fertilization, metal smelting and electroplating is many times higher than that from its natural sources (Dalcorso *et al.*, 2008).The problem with Cd is that it does not get easily removed from water by self-purification. Moreover, it is readily taken up by plants, and translocate into different areas of the plant body. Thus, it could seriously threaten human health if it accumulates through the food chain (Wang *et al.*, 2009).

Phytoremediation technology has started to gain great importance for the removal of elemental pollutants from soil and water. Many aquatic macrophytes can take up and accumulate high concentrations of heavy metals in their tissues, especially roots (Abbasi & Ramasami, 1999; Meagher & Heaton, 2005; Khumanleima Chanu & Gupta, 2014). Various species show different patterns of metal accumulation in their roots, stems and/or leaves. Therefore, it is useful to identify the plant organ that absorbs the greatest amount of trace elements (St. Cyr & Campbell, 1994; Baldantoni *et al.*, 2004). The alligator weed *Alternanthera philoxeroides* possesses strong reproductive abilities so that even small fragments are able to readily establish themselves and spread in novel environments (Martin, 1972). Considering the high propagation potential and wide distribution of *A. philoxeroides*, the present study aims to investigate the pattern of Cd accumulation in the different tissues of the plant and its possible implication in Cd phytoremediation.

Materials and Methods

Collection and acclimatization of test plant

A. philoxeroides was collected from a community pond in Silchar (24 °49′ N; 92°48′ E), Cachar district, Assam. The plants were acclimatized in the laboratory for one week in plastic tubs containing filtered pond water.

Experimental set up and procedure

Stock solution of 100 mg L^{-1} cadmium was prepared by dissolving the appropriate amount of $CdCl_2$, H_2O, in triple distilled deionized water. Exposure concentrations of 3, 5 and 10 mg L^{-1} Cd was prepared by serial dilution of the stock solution with filtered pond water. *A. philoxeroides* segments (25 - 30 cm) having well-developed roots and leaves were incised with a stainless steel razor from the same mother plant and placed in circular plastic tubs containing the different Cd concentrations. A control with the same water without any added metals was similarly prepared. Both exposed and control plants were harvested after 3, 24, 72, 240 and 720 hour (h) for further analysis.

Heavy Metal Analysis

The collected plants were carefully washed with distilled water and sorted into above ground (leaves and stem) and belowground (roots) parts. To measure dry weight, plants were oven dried at 120 °C for 24 h until constant weight (APHA, 1998).The samples were ground to a fine powder using mortar and pestle, and digested in concentrated, reagent grade HNO_3.The residue was dissolved in distilled water and Cd content in the samples was determined in an atomic absorption spectrophotometer (Perkin Elmer 3110) using the flame method (Gupta, 1996). The detection limits were 0.01 µg L^{-1} for Cd.

Statistical Analysis

The data were subjected to one-sample Kolmogorov-Smirnov test to determine whether these were normally distributed. All normally distributed datasets were statistically compared using one way ANOVA, and post-hoc Tukey test using SPSS 20 software. Differences at $p \leq 0.05$ were considered significant.

Translocation factor (TF)

The plant's ability to translocate metals from root to the aerial parts (stem and leaf) was estimated using the translocation factor (TF), which was calculated as follows:

TF = Metal concentration in aerial part (leaf and stem) / Metal concentration in roots (Yoon *et al.*, 2006; Ho *et al.*, 2008).

Bioaccumulation Factor (BCF)

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The bioaccumulation factor (BCF) is defined as the metal concentration in plant tissue (μg g^{-1}) divided by metal concentration in water (μg ml^{-1}) (Wang *et al*, 1997).

BCF = Metal concentration in plant tissue (μg g^{-1}) / Metal concentration in water (μg ml^{-1})_

Results and Discussion

The Cd uptake and accumulation by leaf, stem and root of *Alternanthera philoxeroides* exposed to different Cd concentrations (3, 5, and 10 mg L^{-1}) are shown in Table 1. The highest Cd accumulation was observed in the stem at all exposure concentrations. Cd was not detected in water in which the plant was grown at the end of the experiment, indicating its complete removal at all the concentrations. *Alternanthera philoxeroides* was found to be an efficient Cd accumulator at 0.5 and 1.0 mg L^{-1} (Liu *et al.*, 2014). The present study reveals that this plant could effectively remove Cd from water even at a much higher concentration of 10.0 mg L^{-1}, although beyond 3.0 mg L^{-1}, major accumulation was found to occur in the stem. This observation is supported by the translocation factor (TF) values obtained (Table 2). TF reflects the ratio of metals in leaves and stems to that in roots, thereby giving a measure of internal metal transportation. As shown in Table 2, TF values increase from Cd exposure of 3 - 10 mg L^{-1}, thus revealing that as the Cd concentration in the medium increases, more Cd translocate to stem. The bio concentration factor (BCF) is also the highest in stem, showing it to be the major site of Cd accumulation.

Table 1. Comparisons among Cd concentrations in different tissues of *A. philoxeroides* in control and on exposure to graded Cd concentrations for 30 days

Cd concentrations	Cd μg g^{-1} dry weight (mean ± SE)		
	Leaf	Stem	Root
Control	BDL^{ad}	BDL^{ad}	BDL^{ad}
3 μg L^{-1}	9.56 ± 1.49^{bd}	49.32 ± 15.65^{be}	40.71 ± 12.09^{bde}
5 μg L^{-1}	10.62 ± 1.83^{bd}	34.58 ± 8.09^{abe}	17.93 ± 8.49^{abde}
10 μg L^{-1}	19.46 ± 3.03^{cd}	71.78 ± 18.24^{be}	13.35 ± 3.02^{abd}

Values in the same column but different rows with different superscripts (a-c) have significant differences among one another at $p \leq 0.05$; values in the same row but different columns with different superscripts (d-e) have significant differences among one another at $p \leq 0.05$

Table 2: Mean bioaccumulation factor (BCF) and translocation factor (TF) of Cd in different tissues of *A. philoxeroides*

Cd concentration	Mean Bioaccumulation Factor			Mean Translocation Factor(TF)
	Leaf	Stem	Root	
Control	0.00	0.00	0.00	0.00
3 μg L^{-1}	3.19	16.44	13.57	1.45
5 μg L^{-1}	2.12	6.92	3.59	2.52
10 μg L^{-1}	1.95	7.18	1.34	6.83

Conclusion

The results of this study shows that *Alternanthera philoxeroides* has the potential to be explored as an accumulator of Cd, with possibility for use in Cd phytoremediation. Since this species grows abundantly in diverse aquatic ecosystems like floodplain wetlands, ponds, ditches, sluggish streams, and others, covering almost the entire water surface. Its ability to absorb Cd, especially in its large stem biomass could be exploited for Cd removal from wastewater.

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