# Cadmium Tolerance and Phytoextraction Efficiency of Arum (Colocasia antiqourum) Grown in Spiked Cd Contaminated Soil

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***Abstract*- A pot experiment was conducted to investigate the cadmium tolerance and phytoextraction efficiency of arum (*Colocasia antiqourum*) grown in soil spiked with cadmium (Cd) levels of 0, 5, 10, 25, 50, and 100 mg kg$^{-1}$. Arum plants were grown for 105 days in the Cd contaminated soil. After harvest, the plants were separated into leaves, stems, bulbs and roots and dry mass of those were recorded. Dry matter yield was not affected by the application of Cd but Cd concentration in plant parts increased linearly with Cd application rates in soil. Without growth retardation, Cd concentrations in arum increased from 8.3 to 75 mg kg$^{-1}$ in the leaves, 40 to 262 mg kg$^{-1}$ in the stems, 4.3 to 55 mg kg$^{-1}$ in the bulbs and 166 to 912 mg kg$^{-1}$ in the roots, when Cd levels increased from 5 to 100 mg kg$^{-1}$ in the soil. In the shoots (leaves and stems) of arum, Cd concentration was 137 and 168 mg kg$^{-1}$ at the 50 and 100 mg kg$^{-1}$ Cd supply levels in soils respectively. Those values were above the accepted threshold level of Cd hyper accumulator plants. Similar to Cd concentration, Cd accumulation (concentration × dry weight of plant) increased in different parts of arum with Cd application rates in the soil. Cadmium accumulation in the whole plant increased from 2.2 to 16.2 mg plant$^{-1}$ when Cd levels in the soil increased from 5 to 100 mg kg$^{-1}$. Cadmium accumulation in different parts of arum decreased in the order: root > stems > bulbs > leaves. Cadmium translocation from root to shoot was about 50% of the total Cd, showing a moderate mobility of Cd in arum, however, this plant is easy to harvest with roots. The outcomes of this study confirm that this plant is a suitable candidate for the phytoremediation of Cd contaminated soil.**

***Keywords- Cadmium; Hyperaccumulator; Contaminated Soil; Phytoremediation***

## I. INTRODUCTION

Mining, manufacturing, intensive agriculture and other industrial activities have greatly increased the heavy metal contamination of soils over the past century [1]. Cadmium contamination in soils has become a major environmental issue worldwide because Cd is easily transferred to the food chain and threatens to human health. It is therefore, important to develop methods to cleanup Cd in contaminated soils. Most traditional remediation techniques are physical or chemical that involves high cost and have low public acceptance [2]. Therefore, phytoremediation where hyperaccumulators or accumulators are used to take up large quantities of pollutants has become a promising soil remediation technique [3]. Phytoremediation takes advantage of the natural processes of plants to remove, transfer or stabilize contaminants in soil, sediment and water [4]. About 400 species of hyperaccumulators have been identified in the world, but only few of them have been considered as Cd hyperaccumulators [5], and most of them have not been widely used because of low biomass production, difficulty in cultivation and slow growth rates [6]. Cadmium concentrations in some soils of Japan are found to range from as low as 0.03 to as high as 19.7 mg kg$^{-1}$ [7]. Thus, it is very important to identify new hyperaccumulators to cleanup Cd-contaminated soils. In this investigation, we selected a common and locally popular plant species arum (*Colocasia antiqourum*). It has deep roots and long shoots. It possesses the characteristics of high biomass, easy cultivation, extensive competitive ability, wide geographic distribution and strong resistance to environmental stresses. In our previous study, it was shown that this plant had strong tolerance to Cd in the nutrient solution and strong accumulation capability of Cd in its body [8]. Hydroponics provides potential to examine metal tolerance and magnitude of metal accumulation in plant species with greater precision than soil studies. Therefore, metal accumulators should be selected under standard and repeatable conditions using both hydroponics and soil cultures [9]. The aim of this study was to investigate the cadmium tolerance and phytoextraction efficiency of arum grown in a spiked Cd contaminated soil.

## II. MATERIALS AND METHODS

A surface (0-20 cm) clay loam soil was collected from the experimental station of Iwate University, Morioka, Japan to use in this experiment. The soil is Volcanic ash soil, (Andisol). This soil had 44% sand, 42% silt and 14% clay. The collected soil in moist stage was ground and passed through a 4 mm sieve for using in this green house experiment. For laboratory analysis, a sub sample was air dried and passed through a 2 mm sieve and stored. Soil pH (6.9) was measured in a 1:2 soil/water

suspension. Soil organic carbon (OC) of 8.3% was determined by wet oxidation method [10]. Cation exchange capacity (CEC) of 45.6 cmol $kg^{-1}$ was determined by extraction with 1 M $NH_4OAc$ (pH 7.0) [11]. The hydrometer method was used for the particle size distribution [12].

The experiment was conducted under natural light condition in a green house in the Laboratory of Plant Physiology and Nutrition at the Iwate University, Japan. Moist soil equivalent to 5 kg dry mass was placed in plastic pot (30 cm height and 25 cm diameter) after mixing with Cd at levels of 0, 5, 10, 25, 50, and 100 mg $kg^{-1}$. The source of Cd was ($CdSO_4$). Each pot received 5 g of N-P-K (10-10-10) mineral fertilizer (equivalent to 100 mg $kg^{-1}$ soil of N, P and K). Three replications of each treatment were set out in a complete randomized block design. Two healthy and uniform sizes of arum bulbs were sown in each pot. After one month, one seedling was left in each pot. From 40 days of growth, water was added daily as required during the growth period. After 105 days of growth, plants were harvested and separated into leaves, stems, bulbs and roots. Harvested plant parts were washed with distilled water to remove soils, and oven dried at 65°C for 72 h, and dry weight was recorded. Plant samples were ground in a stainless steel grinder. The plant tissues were digested with $HNO_3$-$HClO_4$ (3:1) acid mixture and Cd in the digest was measured using atomic absorption spectrophotometer (170-30 Hitachi, Tokyo, Japan. Reagent blanks were processed to ensure Cd was not added during sample preparation. All results are presented on dry weight (DW) basis. The results obtained were subjected to one way analysis of variance using Minitab program [13]. The significant difference was set among the treatments at $p<0.05$.

## III. RESULTS

### A. *Effects of Cd on Plant Growth*

Cadmium application rates (0 and 100 mg $kg^{-1}$) did not affect the total dry matter yield of leaves, stems, bulbs, roots of arum plants. There were no visual symptoms of toxicity caused by high Cd application in any plants parts. The dry matter yield of arum in control pots were of 18, 26, 33 and 8 g for the leaves, stems, bulbs and roots, respectively, while in the pots treated with 100 mg $kg^{-1}$ the corresponding values were of 14, 19, 36 and 9 g (Fig. 1).

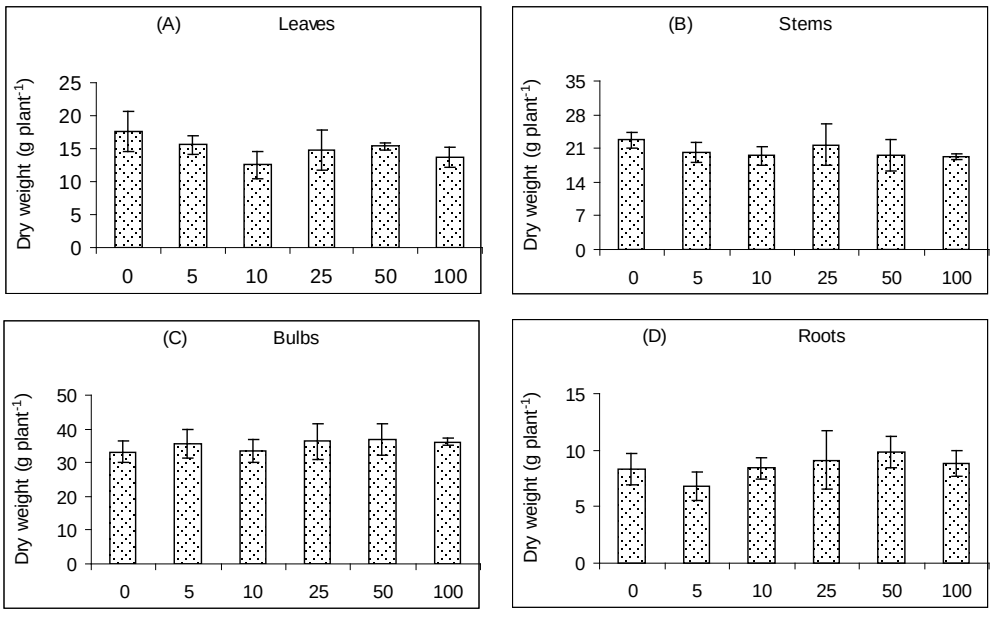


Fig. 1 Dry matter yield of arum plant parts (A) Leaves, (B) Stems, (C) Bulbs and (D) Roots. Vertical bars indicate standard deviation and they are not significant at p <0.5.

### B. *Cadmium Concentration, Accumulation and Distribution*

Cadmium concentrations in different parts of plant increased significantly ($p<0.05$) with increasing Cd levels in the growth media. Cadmium concentrations in arum increased from 8.3 to 75 mg $kg^{-1}$ in the leaves, 40 to 262 mg $kg^{-1}$ in the stems, 4.3 to 55 mg $kg^{-1}$ in the bulbs and 166 to 912 mg $kg^{-1}$ in the roots, when Cd levels in soils increased from 5 to 100 mg $kg^{-1}$ (Fig. 2). In the shoots (leaves plus stems) of arum, Cd concentrations were 137 and 168 mg $kg^{-1}$ at the 50 and 100 mg $kg^{-1}$ Cd supply levels, respectively. The values are more than 100 mg $kg^{-1}$ dry tissue weight, which is considered to be the accepted threshold value for Cd hyper accumulator [14, 15]. Without any growth retardation, Cd concentration in the whole plant of arum was of 55, 124, 223, 270 and 326 mg $kg^{-1}$, respectively at soil Cd levels of 5, 10, 25, 50 and 100 mg $kg^{-1}$.

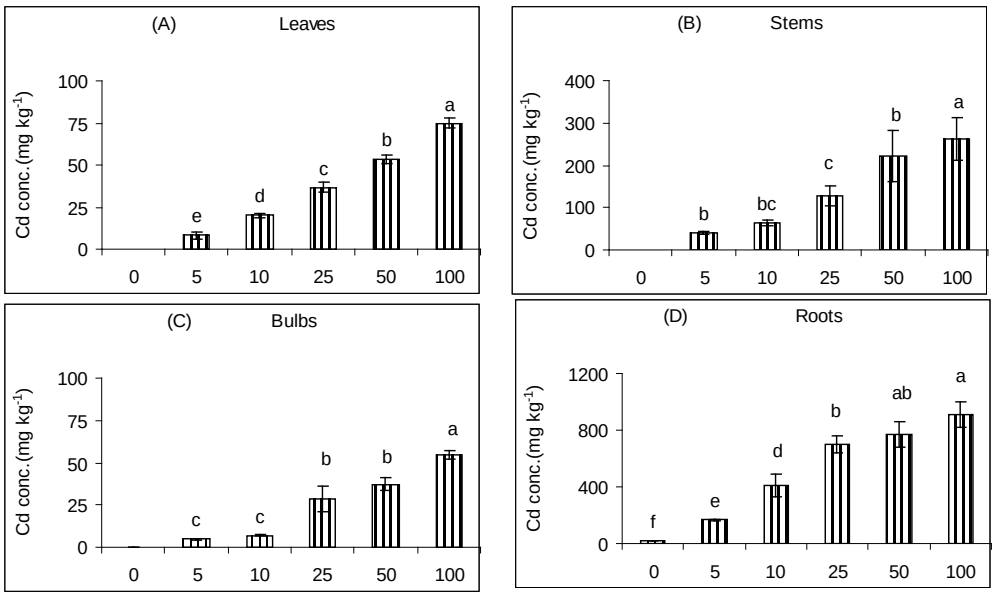


Fig. 2 Cadmium concentration in arum plant parts (A) Leaves, (B) Stems, (C) Bulbs and (D) Roots. Vertical bars indicate standard deviation.

Similar to Cd concentration, the accumulation (concentration × dry weight of plant) of Cd increased in different parts of arum with the Cd application rates applied in the soil. At the lowest rate (5 mg Cd $kg^{-1}$) of Cd application, Cd accumulation was of 0.13, 0.8, 0.17 and 1.13 mg $plant^{-1}$ in the leaves, stems, bulbs and in the roots, respectively and the corresponding values at the highest Cd (100 mg Cd $kg^{-1}$) application rate was of 1.03 mg $plant^{-1}$ in the leaves, 5.06 mg $plant^{-1}$ in the stems, 1.97 mg $plant^{-1}$ in the bulbs and 8.11 mg $plant^{-1}$ in the roots. Cadmium accumulations in the whole plant were of 2.2, 5.2, 10.6, 14.0 and 16.2 mg $plant^{-1}$ when Cd levels in the soil were of 5, 10, 25, 50 and 100 mg $kg^{-1}$, respectively. Cadmium accumulation in different parts of arum decreased in the order: root > stems > bulbs > leaves (Fig. 3).

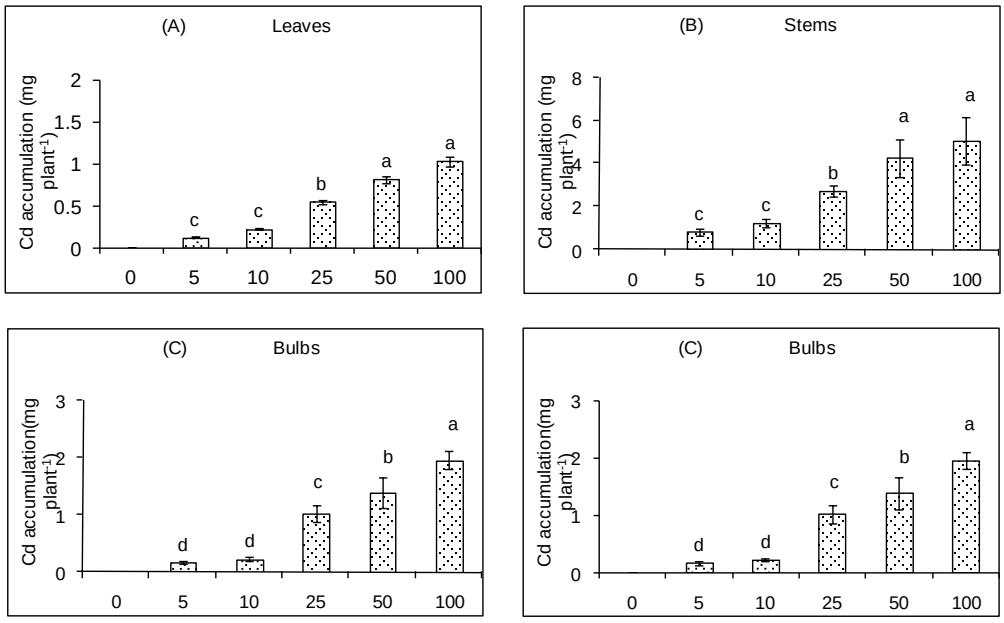


Fig. 3 Cadmium accumulation in arum plant parts (A) Leaves, (B) Stems, (C) Bulbs and (D) Roots. Vertical bars indicate standard deviation.

Cadmium distribution (percent of the total uptake) of arum did not very significantly in the plant parts with Cd application rates except in the bulbs, where it increased from 5% to 12% when the Cd application rates increased from 10 to 100 mg Cd $kg^{-1}$ soil. At the highest rate of Cd application (100 mg Cd $kg^{-1}$), Cd distributions were of 6, 31, 12 and 50% in the leaves, stems, bulbs and in the roots, respectively (Fig. 4). This distribution indicates that 50% of the total Cd was translocated into the shoots, irrespective of Cd application rates.

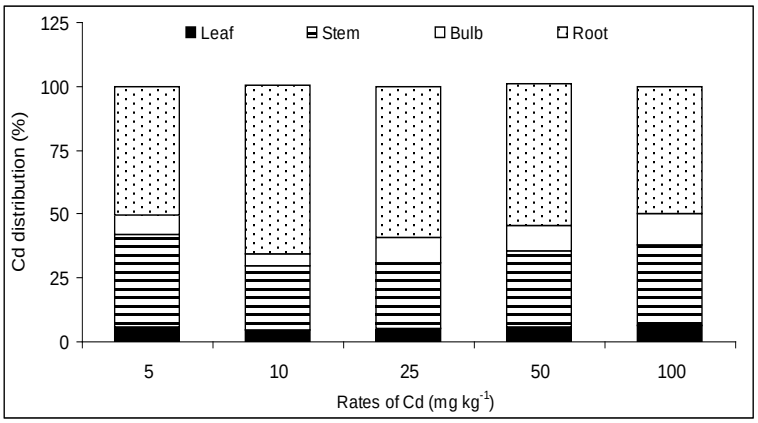


Fig. 4 Distribution of Cd in different plant parts of arum at different Cd application rates

## IV. DISCUSSION

Cadmium is a non essential and toxic element for plants. Growth inhibition is known as a result of Cd toxicity. In the present study, there were no visible symptoms and growth retardation of arum. Among the plant parts, 50% of total Cd was accumulated in the roots and 50% in shoots (Leaves plus stems) of arum, irrespective of Cd application. This indicated that both shoots and roots are the major sinks of Cd. Among the plant parts, maximum accumulation of Cd in the roots may be due to immobilization of Cd through precipitation and /or adsorption on the root surface and within the symplasm of root cells as well as due to sequestration of Cd by phytochelatins in the vacuole of root cells [16]. Researchers are always trying to find new plants for the purpose of phytoremediation. Most accumulator plants are small in size. *Arabidopsis halleri gemmifera* is a new Cd and Zn accumulator plant that was found in Japan [17]. Kashem et al. [17] measured Cd concentrations as high as 820, 590 and 400 mg $kg^{-1}$ in leaves, stems and roots of *Arabidopsis halleri gemmifera*, respectively at 10 µM Cd in the nutrient solution but with a total accumulation of 2.8 mg Cd $plant^{-1}$. In this study, Cd concentration and accumulation in arum were of 326 mg $kg^{-1}$ and 16.2 mg $plant^{-1}$ at the highest rate (100 mg $kg^{-1}$) of Cd application without any growth retardation. This accumulation value is six fold higher than *Arabidopsis halleri gemmifera* because of vigorous growth of arum plant. In another study, Kashem et al. [8], investigated the phytoextration efficiency of arum (*Colocasia antiqourum*), radish (*Raphanus sativus* L.) and water spinach (*Ipomoea aquatica*) grown in hydroponics at 10 µM Cd where they found that arum could accumulate 25 mg Cd $plant^{-1}$ while Cd concentration was 166 mg $kg^{-1}$ in the entire arum plant without growth retardation. Arum with many roots can accumulate substantial amounts of Cd and is possible to harvest the entire plant including roots. It is a fast growing, easily propagated, easy to manage and capable to grow both in dry and marsh conditions. In this study, arum plants appear to posses the potential to provide a novel technique for the removal of Cd from industrially contaminated waters and soil.

## V. CONCLUSION

The results of this study show that the growth of arum is unaffected by Cd application levels up to 100 mg Cd $kg^{-1}$ soil. The Cd concentration found in shoot tissue indicated that arum has an excellent potential for Cd phytoextraction. This implies that arum is a potential candidate for the reclamation of Cd contaminated soil and water.

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## REFERENCES

[1] U. Krämer, “Phytoremediation: novel approaches to cleaning up polluted soils”, Curr Opin Biotechnol., Vol. 16, pp.133-141, 2005.

[2] K. P. Prabha, Y. L. Loretta, “Phytoremediation technology: hyperaccumulation metals in plants”, Water Air Soil Pollut., Vol.184, pp. 105–126, 2007.

[3] Y. L. Han, H. Y. Yuan, S. Z. Huang, Z. Guo, B. Xia, J. G. Gu, , “Cadmium tolerance and accumulation by two species of Iris”,Ecotoxico., Vol. 16, pp. 557–563,2007.

[4] X. Z. Yu, J. D. Gu, “Hexavalent chromium induced stress and metabolic responses in hybrid willows”, Ecotoxico., Vol. 16, pp. 299–309, 2007.

[5] S. H. Wei, Q. X. Zhou, X. Wang, “Cadmium-hyperaccumulator Solanum nigrum L. and its accumulating characteristics”, Environ Sci., Vol. 26, pp.167–171, 2005.

[6] Y. Q. Zhou, S. Z. Huang, , S. L. Yu, , J. G. Gu, J. Z. Zhao, Y. L. Han,, J. J. Fu, “The physiological response and sub-cellular localization of lead and cadmium in Iris pseudacorus L”, Ecotoxico., Vol.19, pp. 69–76, 2010.

[7] Geochemmap, “http://www.aist.go.jp/RIODB/geochemmap/zenkoku/zenkoku.htm”, 2004.

[8] M. A. Kashem, B. R. Singh, S. Imamul Huq, S. Kawai, "Cadmium phytoextraction efficiency of arum (Colocasia antiqourum), radish ((Raphanus sativus l.) and water spinach (Ipomoea aquatica) grown in hydroponics", Water Air Soil Poll., Vol. 192, pp. 273-279, 2008.

[9] V. M. J. Grispen, H. J. M. Nelissen, J. A. C. Verkleij, "Phytoextraction with Brassica napus L.; A tool for sustainable management of heavy metal contaminated soils", Environmental Pollut., Vol. 144, pp.77-83, 2006.

[10] A. Walkley, I. A. Black, "An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method", Soil Sci., Vol. 37, pp. 29-38, 1934.

[11] Soil Survey Laboratory Staff,."Soil Survey Laboratory methods manual", Soils Surv. Invest. Resps., 42. USDA- SCS, Washington, D C., 1992.

[12] G. J. Bouyoucos, "Hydrometer method improved for making particle size analysis of soils. Agron. J., Vol. 54, pp. 464-465, 1962.

[13] Minitab Inc. "Minitab Handbook, Second Edition", 1992.

[14] A. J. M. Baker, R. R. Brooks, "Terrestrial higher plants which hyperaccumulate metallic elements-a review of their distribution, ecology and phytochemistry", Biorecover., Vol. 1, pp. 81-126, 1989.

[15] Y. B. Sun, Q. X. Zhou, C. Y. Diao, "Effects of cadmium and arsenic on growth and metal accumulation of Cd-hyperaccumulator Solanum nigrum L", Bioresour Technol., Vol. 99, pp.1103–1110, 2008.

[16] T. Shute, S. M. Macfie, "Cadmium and zinc accumulation in soybean: A threat to food safety", Science of Total Environ., Vol. 371, pp. 63–73, 2006.

[17] M. A. Kashem, B. R. Singh, H. Kubota, R. S. Nagashima, N. Kitajima, T. Kondo, "Assessing the potential of Arabidopsis halleri ssp. gemmifera as a new cadmium hyperaccumulator grown in hydroponics", Can. J. Plant Sci., Vol. 87, pp.499–502, 2007.