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Comparing the potential of three *dracaena* species to remove lead (pb) from artificial aqueous media

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ABSTRACT

The study was undertaken to compare the lead accumulation and removal of Dracaena sanderiana, Dracaena reflexa, and Dracaena deremensis on artificial lead solutions to apply plants in lead pollution treatment. The experiment consisted of 6 treatments corresponding to 3 investigated species of Dracaena. Each treatment was grown on 2 types of solution with Pb and without Pb used as control. The results indicated that the growth of D. sanderiana, D. reflexa, and D. deremensis was not affected at Pb concentrations of 100 ppm. All three plant species had the ability to absorb and accumulate Pb. In which D. sanderiana was a typical lead excluder because the lead concentration in roots (1952.14 mg/kg), shoots (221.78 mg/kg), and leaves (166.46 mg/kg) of the plants were the highest among the three plants tested. The most of lead accumulated in the root, and transportation of lead in D. sanderiana, D. reflexa, and D. deremensis from root to shoot was restricted. Besides, the highest % removal of Pb was found at D. sanderiana (93.16%) and the minimum of 66.77% at D. reflexa. D. sanderiana is the best choice among the three Dracaena species used for phytoremediation of lead contaminated wastewater.

Keywords: *Dracaena deremensis, Dracaena reflexa, Dracaena sanderiana, lead, Phytoremediation*

1. Introduction

The contamination of the environment due to the presence of lead can result in serious negative consequences, such as dismantling ecosystems, contamination of soil and water resources, and economic damage (Raicevic et al., 2005). Pb is known to be a highly toxic metal and has no biological roles for plants, animals, and humans (ATSDR, 1993). Pb can potentially cause phytotoxicity by damaging plant tissue ultrastructures, cellular components, and biomolecules, leading to inhibition of normal cellular functioning, damage to agricultural productivity, and severe human and animal health problems (Raicevic et al., 2005). The toxicity of lead, the existence of lead in the environment, and uptake by plants have been the subject of much research.

Currently, lead clean-up technologies are often high-priced and energy-consuming, therefore the importance of soft and low-cost technologies, such as those afforded in ecologically engineered systems, is rising (Mitsch, 2003).

In these conditions, phytoremediation could be the cheapest and simplest option among the available lead cleanup strategies (Susarla, 2002). Phytoremediation shows promise as a sustainable alternative to remove Pb from contaminated soil and water in a cost-effective, ecologically friendly, and socially acceptable way (Peuke, 2005). Lead removal from polluted areas by plants (phytoremediation) has been extensively studied and successfully utilized for decades. Plants previously shown to take up Pb >1000mg/kg include Lemna species (duckweed), *Jatropha curcas*, *Helianthus annuus*, *Triticum aestivum*, *Coronopus didymus*, *Brachiaria mutica* (Kumar et al., 2018). These plants are quite varied, from perennial shrubs and trees to small annual herbs. Although a number of plants capable of up taking Pb have been identified. However, selecting an appropriate plant species to be applied in a lead contaminated environment poses a number of challenges.

D. sanderiana, D. reflexa, and *D. deremensis* are species of *Dracaena* genus native to Viet Nam. *Dracaena* is a genus of 150 species of shrubs and herbs that can take up lead from contaminated solutions. Native varieties are preferable to avoid risks to environmental caused by invasive species. *D. sanderiana*, *D. reflexa*, and *D. deremensis* have been studied for its ability to remove Cu, Cr, Ni, Hg, Cd (Ten Yi Hao, 2011). The overall objectives of this research were: (1) to determine the concentrations of Pb in plant biomass growing on a polluted environment; (2) to identify removal efficiency of lead of three species. The results of this study provided insight into using native plants to treat lead. Introduction of plants with phytoremediation potential of a lead in the environment.

2. Materials and methods

***Plant samples**:* The study used 3 species of *Dracaena* genus including *D. sanderiana*, *D. reflex*, and *D. deremensis*. Three *Dracaena* species are selected on the basis: the group of shrubs in the genus *Dracaena*, native varieties, inedible plants, with similar morphological, ecological, growth, and development characteristics. After collecting, shoots 40cm were cut from the trees and planted in moistened sand. Use deionized water to irrigate the plants twice a day. After 60 days, healthy plants were selected and used as model plants.

Figure 1. Photograph of the experimental plants (*D. reflex*, *D. deremensis*, *D. sanderiana* – from left to right)

***Experiment**:* The experiments were performed in 45 × 32 × 20 cm containers, each filled with 15 L of tap water containing concentrations of Pb 100mg/L [$Pb(NO_3)^2$, Sigma–Aldrich]. Each container included five plants that were evenly distributed and suspended in the solution by means of a plastic bar around the stem through a perforated lid. All the treatments were performed for 30 days. The initial solution pH was approximately 4.5 (selected based on our preliminary data and Fischer et al., 2016) and was not adjusted throughout this experiment. The plants that were not exposed to Pb were maintained alongside those of each experimental group and served as controls. The experiment was carried out in the research greenhouse, at Thu Dau Mot University, Binh Duong Province, Vietnam. The average relative humidity of the greenhouse was 60% and the dark and light average temperatures were 28°C and 34°C respectively.

Plant harvesting and Pb analysis

The height (cm) and dry biomass (g) of the plants were analyzed at 0, 10, 20 and 30 days of the experiment. Use a ruler to measure the height from the stump to the top of the longest leaf. Dry biomass was measured by drying the sample and then weighing it to determine the dry biomass.

At each sampling interval (0, 10, 20, 30 days), three plants were harvested from each treatment. The plants were then thoroughly washed with deionized water to remove the surface-bound Pb, blotted dry gently to remove excess water, and weighed. After being separated into roots, stems, and leaves, the samples were oven dried at 70°C, ground into fine powder, and then stored at 4°C until analysis. Approximately 1.0g of dried tissue was digested in 14.0mL of a mixture of nitric acid: perchloric acid: hydrogen peroxide with the ratio 10:2:2 (Perkin-Elmer Corp, 1996). The mixture was subsequently heated overnight at 70°C. The digestate was then allowed to cool to room temperature, diluted to 25mL via 5% nitric acid solution, and subjected to Pb quantification through an atomic absorption spectrometer (AA-7000, Shimadzu, Japan).

100mL of water from each treatment of the experiment into a conical flask, add 5mL of HNO_3 65% and gently boil to dryness, and cool to room temperature. Dissolve the sample with HNO_3 5% and makeup to 50mL, then filter again with filter paper. Samples were subjected to Pb quantification through an atomic absorption spectrometer.

***Bioconcentration factor (BCF*)**: BCF was calculated as a ratio of the concentration of Pb in plant roots to that of water (8Ghosh and Singh, 2005).

$$BCF = \frac{Pb\ concentration\ in\ plant\ root\ tissue}{Initial\ concentration\ of\ Pb\ in\ substrate\ (water)}$$

Translocation factor (TF): TF is the ratio of Pb concentration in the shoots to the roots (Marchiol et al., 2004).

$$TF = \frac{Pb\ concentration\ (stems + leaves)}{Pb\ concentration\ (roots)}$$

Percentage Removal: The percent removal of lead from solution was calculated:

$$\%\ Removal = \frac{Co - Cf}{Co} \times\ 100$$

Where Co is the initial concentration of Pb and Cf is the final concentration of Pb

Analysis of data*:* The data are presented as the means ± standard deviations (SDs) of triplicates. Analysis of variance (ANOVA) and post hoc comparisons of means via Tukey's honestly significant difference tests to determine significant differences ($p < 0.05$). The concentrations of Pb in three species were calculated on a dry weight (dw) basis.

3. Results and discussion

Growth of three Dracaena species

The height is one of the important indicators to compare the growth of *D. sanderiana*, *D. reflexa*, and *D. deremensis* in Pb exposore. In addition to tree height depending on the genetic characteristics of the variety; plant height was more concerned with environmental conditions. The study results (Figure 2) show that the growth in height of *D. sanderiana*, *D. reflexa*, and *D. deremensis* at 100 ppm Pb rapidly increased with increasing period of the experiment and ranged from 44.6 ± 1.1 to 45.5 ± 2.1cm after 30 days of exposure. *D. sanderiana* had height growth rate higher than *D. reflexa*, and *D. deremensis*. The lowest height growth rate was shown in *D. reflexa*.

Investigations on dry biomass of *D. sanderiana*, *D. reflexa*, and *D. deremensis*, results (Figure 3) show that they have quite similar trends compared to the height of the tree. The dry biomass of *D. sanderiana*, *D. reflexa*, and *D. deremensis* also increased with increasing period of the experiment (Figure 3). After 30 days of the experiment, the dry biomass of *D. sanderiana*, *D. deremensis*, and *D. reflexa* increased by 0.24g, 0.21g, and 0.18g, respectively. The highest dry biomass was in *D. sanderiana*. Thus, 100ppm concentration of Pb had different effects on the growth of 3 investigated *Dracaena* species. After 30 days of exposure, *D. sanderiana* had the highest growth rate in height and dry biomass (0.08cm/day of plant height and 8mg/day of dry biomass).

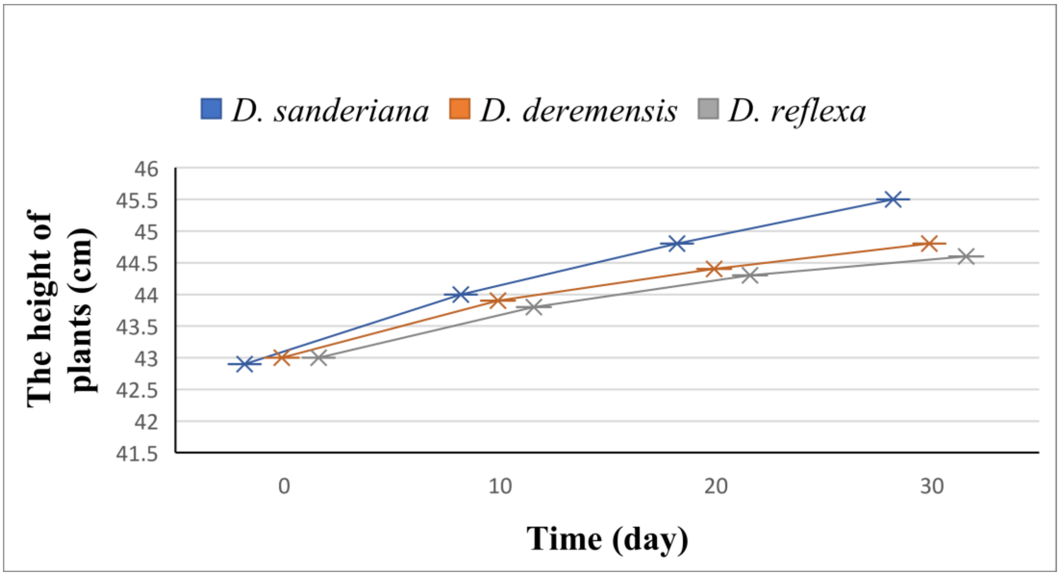

Figure 2. Plant height growth of three species of Dracaena

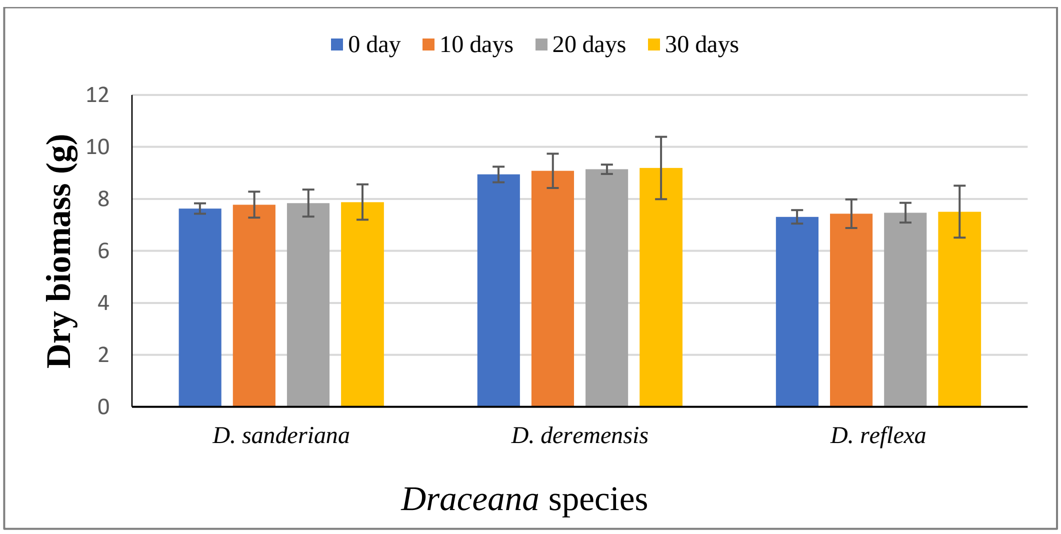

Figure 3. Dry biomass growth of three Dracaena species

As known, lead is not an essential element for plants. Lead affects the activity of many enzymes with different metabolic pathways. In addition, Pb promotes the formation of oxidative reactions in plants, causing plant stress (Ghosh and Singh 2005).

Previous studies have shown that most plants have unfavorable effects on growth and development when they are exposed to Pb, even at low concentrations (Chen et al., 2016; Piwowarczyk et al., 2018). However, in this study, the height and dry biomass of three Dracaena species were still increased after exposure to 100ppm of Pb for 30 days. This shows that *D. sanderiana*, *D. reflexa*, and *D. deremensis* can resist Pb at a concentration of 100ppm, of which D. *sanderiana* has the highest resistance ability.

Dry biomass is a parameter to evaluate plant health. If the dry biomass content of the experimental plants does not change compared to the control, the plants are resistant to Pb. Other studies assessing the dry biomass content of *Monoraphidium braunii* and *Stephanodiscus hantzchii* exposed to Pb, found these exhibited phytotoxic symptoms (Gattullo et al., 2012; Li, 2009). *D. sanderiana*, *D. reflexa*, and *D. deremensis* withstands the effects of Pb without phytotoxic symptoms, showing promise in a long-term phytoengineering technique.

Pb accumulation proficiency of three species of Dracaena

All three surveyed plant species had the accumulation ability of Pb in the roots, stems, and leaves. The total Pb concentration in *D. sanderiana*, *D. deremensis*, and *D. reflexa* was recorded at 2340.38mg/kg, 1843.48mg/kg, and 1741.00mg/kg, respectively. *D. sanderiana* always accumulated the highest concentrations of Pb, while *D. reflexa* accumulated the lowest concentrations of Pb ($p < 0.05$) (Table 1). Total accumulated Pb concentration in *D. deremensis* accounted for 78.77% and in *D. reflexa* for 74.39% compared with *D. sanderiana*.

According to studies previously on the number of plants which have capable of accumulating Pb (Kumar and Prasad, 2018), the results indicated that *D. sanderiana*, *D. deremensis*, and *D. reflexa* have higher Pb accumulation capacity than plants such as *Gophyllum fabago*, *Acalypha indica*, *Ophora japonica*, *Iris lacteal*, *Pisum sativum*, *Pluchea sagittalis* when compared under the same conditions.

TABLE 1. Pb accumulation in *D. sanderiana*, *D. deremensis,* and *D. reflexa* exposed to 100ppm Pb concentrations for 30 days

***Dracaena* species**	**(*)**	**Pb concentration (mg/kg dw)**		
		Roots	**Shoots**	**Leaves**
D. sanderiana	Not detected	$1952.14^{a} \pm 140.4$	$221.78^{a} \pm 1.7$	$166.46^{a} \pm 4.3$
D. deremensis	Not detected	$1695.70^{b} \pm 33.4$	$46.67^{c} \pm 1.7$	$101.11^{b} \pm 7.3$
D. reflexa	Not detected	$1578.72^{bc} \pm 55.1$	$104.86^{b} \pm 9.1$	$57.42^{c} \pm 8.6$

(The letters in each different column represent the statistically significant difference at P<0.05); (*): Pb concentration in the plants before the experiment; Detection threshold = 0.006 ppm)

There is a similarity in accumulated Pb concentration in plant tissues of *D. sanderiana* and *D. reflexa*. Pb concentration in the roots, shoots, and leaves were in the descending order of roots>shoots>leaves. While it is different in *D. deremensis,* Pb concentration were in the descending order of roots>leaves>shoots. It was also found that roots always accumulated significantly higher Pb than shoots ($P < 0.05$). Singh et al (2012) and Sharma (2016) reported that Pb absorption, accumulation, and distribution are different among plant species and plant parts.

Bioconcentration factor (BCF) and Translocation factor (TF) of three species of Dracaena

The Bioconcentration Factor (BCF) of metals was used to determine the quantity of heavy metals that the plant from the water absorbs. This is an index of the ability of the plant to accumulate a particular metal with respect to its concentration in the water (Ghosh and Singh, 2005). The higher the BCF value the more suitable the plant for removing metals. BCF Values > 2 were regarded as high values.

The Pb bioconcentration factors were 19.5, 17, and 15.8 for *D. sanderiana*, *D. deremensis* and *D. reflexa*, respectively (Table 2). Based on these values shows that all of three plant species highly accumulated these Pb in the roots part, and they were very useful for phytostabilization of Pb. The results show that the maximum BCF of 19.5 was obtained at *D. sanderiana* and the minimum of 15.8 at *D. reflexa*. This result indicates the efficiency of *D. sanderiana* in accumulating Pb is higher than the other two plant species.

TABLE 2. Bioconcentration factor (BCF) and Translocation factor (TF) of three species of *Dracaena*

	Các loài *Dracaena*		
	D. sanderiana	***D. deremensis***	***D. reflexa***
BCF	19.5	17	15.8
TF	0.20	0.09	0.10

To evaluate the potential of plants for phytoextraction the translocation factor (TF) was used. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant (Marchiol et al., 2004). Metals that are accumulated by plants and largely stored in the roots of plants are indicated by TF values < 1 and with values > 1 indicating that the metals are stored in the stems and leaves.

The results also found that most of Pb was accumulated in the underground parts (roots) and less in the aboveground parts (shoots and leaves) of all experimental plants (TF <1). The concentration of Pb mainly in the roots in this result is consistent of Vanek et al (2005). Vanek et al (2005) determined that Pb mobility is low, about 20% of Pb was transported to the upper parts of the plant. The distribution of Pb in plant tissues is related to the movement of Pb from the roots to the upper parts of the plant (metabolism). Unlike most other phytochemicals, the ability to transport Pb to stem and leaf parts in most plants is very low (Dogan et al., 2018). The low mobility of Pb from roots to aboveground tissues is likely due to its strong affinity for cell walls (Das et al., 2021). Additionally, due to the lack of efficient transport channels in plants, Pb is bound to carboxylic groups of uronic acids within mucilage on root surfaces (Kabata-Pendias and Pendias, 2011); (Das et al., 2021). On the other hand, low root-to-shoot translocation may help alleviate oxidative damage to photosynthetic tissues and the respiratory system in aboveground plant parts (Xu, 2019)..

Pb removal from aqueous media by three species of Dracaena

D. sanderiana, *D. deremensis*, and *D. reflexa* were tested for their ability to remove Pb (100mg/L) from artificial aqueous media in a greenhouse setting. The results indicated that both three species removed a significant amount of Pb in 30 days (Table 2) compared to no-plant controls. Pb concentrations were reduced by 93.16%, 84.38%, and 66.77% in the presence of *D. sanderiana*, *D. deremensis*, and *D. reflexa*, respectively. Controls didn't exhibit a decline in Pb (table 3).

The concentration of lead remaining in the test solution is least in *D. sanderriana* (6.84 mg/L). *D. sanderiana* showed higher Pb removal rates compared to *D. deremensis*, *D. reflexa*, and plants in previous studies [Lemna minor (76% at 20mg/L), Eichhornia crassipes (30% at 10mg/L) (Singh Divya et al., 2012; Patel, 2018), providing a probable explanation for the higher Pb tolerance compared to other plants at similar or greater concentration.

TABLE 3. Pb removal efficiency of *D. sanderiana*, *D. deremensis*, and *D. reflexa*

Experimental periods (days)	Pb concentration in aqueous media (mg/L)			
	Controls	***D. sanderiana***	***D. deremensis***	***D. reflexa***
0	100	100	100	100
30	100	6.84 ± 1,55	15.62 ± 0,92	33.23± 0,62
Pb removal efficiency **(%)**	**0**	**93.16**	**84.38**	**66.77**

4. Conclusions

Pb concentration of 100 ppm did not inhibit the growth the height and dry biomass of *D. sanderiana*, *D. reflex* and *D. deremensis*.

The trend of overall accumulation of Pb by the three species between plant organs was Pb accumulated mainly in the roots of the tree, then in shoots and leaves.

The highest accumulation (2340.38) and % removal of Pb (93.16%) was found at *D. sanderiana.*

The highest bioconcentration potential of Pb was observed at *D. sanderiana* (19.5) and the minimum at *D. reflexa* (15.8).

In an ecosystem or waste water system of abundant Pb *D. sanderiana* can be used effectively to remove the Pb contaminants than *D. reflex, and D. deremensis.*

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