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Submission date: 18-Mar-2020 05:13PM (UTC+0700)

Submission ID: 1277495315

File name: L.Herlina.docx (108.41K)

Word count: 4875

Character count: 26378

JPII 9 (1) (2020) XXX

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

PHYTOREMEDIATION POTENTIAL OF *CORDYLINE FRUTICOSA* FOR LEAD CONTAMINATED SOIL

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DOI: …

Accepted: … Approved: … Published: …

ABSTRACT

Phytoremediation is a practical, environmentally-friendly, low-cost technological solution used to clean various types of pollution, including metals, pesticide residues, and oils from contaminated soil and water. In this study, *Cordyline fruticosa* was planted in the lead-contaminated soil. Each pot was given 250 mg/kg and 375 mg/kg of lead. The parameters observed included biomass (mg), lead content in the root, stem, and leaf, bioaccumulation factor, translocation factor, metal tolerance index, and amount of metal extraction, which were analyzed after 30, 60, and 90 days. The results revealed that root, stem and leaf biomass (g) were significantly different from control (T0). The lead contents were root<stem <leaf, while the translocation factor value was more than one, except for lead exposure 375 mg/kg (T2) in the second month and 250 mg/kg lead (T1) in the third month. The bioaccumulation factor for all treatments was less than one, and the metal tolerance index ranged from 90.87% - 93.07%. Besides, the amount of root metal extraction was smaller than the shoot. In sum, *C. Fruticosa* is potential phytoremediation.

Keywords: phytoremediation; contaminated soil; lead; *cordyline fruticosa*

INTRODUCTION

One of the serious environmental problems worldwide is heavy metal contamination. As widely known, metal contaminants are particularly harder to remediate from the soil, water, and air than the organic pollutants. Unlike the metal contaminants, the organic pollutants can be degraded to harmless. While toxic elements such as lead, mercury, cadmium, copper, and zinc, are immutable to biochemical reactions. Moreover, lead (Pb) is one of the heavy metals poisonous for microbes, plants, animals, and humans (Zhou et al., 2014), which ranked the second after arsenic (USEPA, 2000). Furthermore, it is a non-significant matter in the process of metabolism and could be poisonous to kill an organism even if absorbed in a minor amount. Lead gets into plants through the absorption of contaminated water and accumulates in plant tissues, as it cannot be metabolized (Al-Akeel, 2016). Lead is a significant contaminant deploy throughout the environment (Mangkoedihardjo, 2008). The spread can be enlarged through a food chain mechanism and accumulated in soil and waters that can pose risks to human health and the environment (Khan et al., 2010).

Naturally, lead occurs in soil and outspread to the environment in a small amount through volcano explosions and geochemical processes (Parizanganeh et al., 2012; Wuana & Okieimen. 2011), and anthropogenic activities related to this lead has increased significantly in recent decades. These activities include combustion results of additives in fuel for motor vehicles and industry. Potential industries as a source of lead pollution include casting, battery, fuel, cable, and other chemical industries that use dyes (Srivastava et al., 2015). Lead concentration in soil tends to increase due to man activities, such as mining, smelting, fuel combustion, synthetic fertilizers, and various industrial processes. Therefore, phytoremediation is needed to solve this problem.

Phytoremediation is a process of removing pollutants from contaminated air, water, and soil by employing plants to detach Ar and Cr pollutants (Kalve et al., 2011; Vithanage, 2012), Pb and Cd (Varun et al., 2015; Liu et al. , 2008), Ni and Mn (Doganlar et al., 2012), Cd (Bauddh & Singh, 2012; Huang, 2011), Hg and Pb (Kumar et al., 2017), Pb (Mahar et al., 2016), Pb (Mani et al., 2015), As, Pb, Cd, Cu and Zn (Namgay et al., 2010). Plants can absorb and degrade organic matter and nutrients as well as they absorb heavy metals; hence, they can be utilized in controlling and restoring polluted environments.

Various plants are prospective phytoremediators yet have a distinct ability to accumulate and absorb heavy metals (Nouri et al., 2009). This difference is due to root architecture, water efficiency, rhizospheres' chemical content, expression and membrane protein transport on the root surface, metal transportation by xylem, plant translocation, age, and stage of plant growth. Besides, these factors could influence metal concentration in plants (Elekes, 2014; Nouri et al., 2009). To be called a phytoremediator, a plant has to fulfill several capabilities, i.e., the ability to sop up pollutants, store it in organ tissue, and stabilize it (Gupta et al., 2013). The heavy metals are accumulated in plant organs, including root, stem, leaf, flower, and fruit (Nasser et al., 2014). Phytoremediator efficiency relies on the chemical properties of the element/metal to be extracted, translocated, and distributed to the harvested plant organs (Susana & Suswati, 2013). The time needed for plants to reduce the number of heavy metals in contaminated soil depends on the amount of biomass produced by plants and the bioconcentration factor(Zhang, et al., 2010).

If bioaccumulation of heavy metals in plants produces health hazards through the potential for entry into humans and livestock; it becomes a challenge in phytoremediation. Therefore, the plants used are those that cannot be consumed but are economically and socially beneficial to the community (Pandey & Singh, 2011). Non-consumable plants will reduce the risk of heavy metals entering the food chain (Liu et al., 2008). One of the plants that have high aesthetic, economic and ecological value has several benefits for daily life and industry, namely ornamental plants. The use of ornamental plants in active remediation is sustainable, feasible and beneficial (Mani & Kumar, 2014). Various ornamental plants have the potential as metal phytomemediators among *Sansevieria trifasciata*, *Codiaeum varie*gatum (Sidauruk, 2015), *Celosia cristata pyramidalis* (Cui et al, 2013), *Catharanthus roseus* (Subhashini, 2013).

Ornamental plants that can accumulate heavy metals have economic benefits. Besides improving contaminated soil, they can also beautify the environment at the same time. One such ornamental plant is *Cordyline fruticosa* (local: Hanjuang), which is often used as a protective plant and hedgerow. In this research, the hanjuang plant (*C. fruticosa*) was used for the remediation of lead-contaminated soil. The literature studies revealed that there had not been much research that studies the potential of Hanjuang plants as phytoremediation of lead metal. Haryanti's (2013) research results showed that the efficiency of lead absorption by *C. fruticosa* was 44.28% in Ceptisol; thus, it needs to be further investigated about the potential of *Cordyline fruticosa* plants in accumulating lead metal and lead toxicity to plant growth. This result could be referred to as a consideration of using *C. fruticosa* plants in the remediation of lead metal. Based on the background, this study aims to evaluate the lead tolerance potential of *C. fruticosa*, determine the growth with lead tolerance in these plants and how translocation of leads in *C. fruticosa* plants in itsroots, stems and leaves.

METHODS

Sample and Soil Analysis

The soil used was taken from the Gedanganak sub-district, Ungaran Timur District, Semarang Regency, Central Java. It was excavated from a 30-cm depth, the dried and sieved with a 2 mm mesh filter. The physical and chemical characteristics of the soil were as follows: soil texture (sand 42.55%, dust 45.78% and clay 11.67%, pH 6.61, C-organic 0.44%, P_2O_5HCl 25% 137.93 mg/100g, K_2OHCl 25 % 13.23 mg /100g, CEC 16.6 CMO (+), kg-1, permeability 2.22 cm/hour, water content 11.25%, soil volume 1/18 g/cm3, density 2.15 g/cm3 and porosity 45.12% and lead metal 27.47 mg/kg.

Plant Materials and Growth Conditions

The *C. fruticosa* plant used in this study was one month old and ± 30 cm in height, which was provided by ornamental plant farmers in Ambarawa District, Semarang Regency, Central Java. The used media consisted of a mixture of soil and vermicompost in the ratio of 2: 1. Plastic pots used had a 30.35 cm diameter containing 1500 g of soil and 500 mg vermicompost. Trays were placed under the pots to avoid missing elements due to watering.

Furthermore, 250 mg/kg soil (T1) and 375 mg/kg soil (T2) and 27.47 mg/kg soil (T0) of Pb $(NO_3)_2$ were given in each treatment and were repeated three times. Plants were harvested once every month for three months, and separated for three parts; root, stem, and leaf. The separated plants were washed to remove the remaining soil then dried in an oven at 80° C until a constant weight was obtained. These dry weights of root, stem, and leaf were to determine the biomass.

Lead Content in Soil

To produce white ash, the samples of dried plants were chopped, finely grounded using mortar and pestle, and heated in a porcelain glass at a temperature of 450 °C - 500 °C for 5-7 hours. Then it was soluble in a solution of HNO_3 and $HClO_4$. It was heated to dissolve the remaining residue and then was sieved with strainer paper. The atomic absorption spectrophotometer (AAS) and Perkin Elmer Analyst 400 at a wavelength of 217 nm were used to calculate the determination of lead. The methods used were according to Wang et al. (2014) and Zhang et al. (2014), such as the Metal Extraction Amount (MEA) and Metal Tolerance Index (MTI). To assess potential Among in relative indices for phytoextraction, Translocation Factor (TF) and Bioconcentration Factor (BCF) based on the method of Wu et al. (2011) were used.

MT1 (%) = [(plant biomass under treatment)/(plant biomass under control)] x100................(1)

MEA (mg/ plant) = Metal content in plants tissue x biomass .... (2)

TF = (metal content in plant shoot)/(metal content in root) .... (3)

BAF = (metal content in plant tissue)/ (metal content in soil)...(4)

Statistical Analysis

The parameter of plant growth, metal content in root, stem, and leaf, the value of MEA, TF, and BAF were tested using the ANOVA and continued to LSD test to see the differences between treatments. All of the statistical analysis was done by the SPSS program.

RESULTS AND DISCUSSION

Plant Growth

Root, stems and leaves biomass of *C fruticosa* due to exposure and time of lead exposure are presented in Figure 1. Root, stems and leaves biomass decreased with increasing concentration, except for root biomass, exposure 375 mg/kg (T2) greater than exposure to 250 mg/kg (T1). The lowest root, stem and leaf biomass were respectively0.92 g, 3.27g, and 2.46 g.

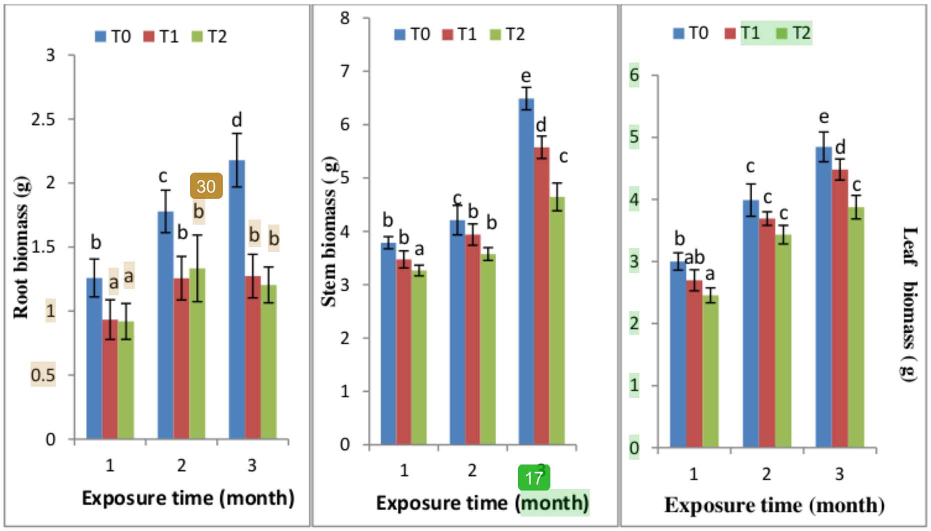

Figure 1. Plant biomass (g) of root, stem, and leaf(mean ± SD) at various levels of Pb concentrations. Based on the significant difference test (LSD), the data with different letters show a significant difference at p <0.05

The analysis showed that the factor of concentration, exposure duration, and interaction between the two factors has significant influence (p<0.05) on the root, stem, and leaf biomass. At the root biomass of Pb exposure for 1 and 3 months, T0 was not significantly different from T1 and T2. At the stem biomass of Pb exposure for 2 and 3 months, T0 was significantly different from T1 and T2, whereas at leaf biomass for Pb exposure for 2 months all treatments were not significantly different.

Lead Content in Plants

Lead content increased with prolonged exposure to root, stem, and leaf(Figure 2). The Pb content inside was wider those in stem and leaf. The highest lead content of root, stem, and leaf was 1478.57 mg/kg, 67.17 mg/kg, and 50.81 mg/kg, respectively. The set of lead content in the *C. fruticosa* plant is dependent on the substance contained in the accretion instrument.

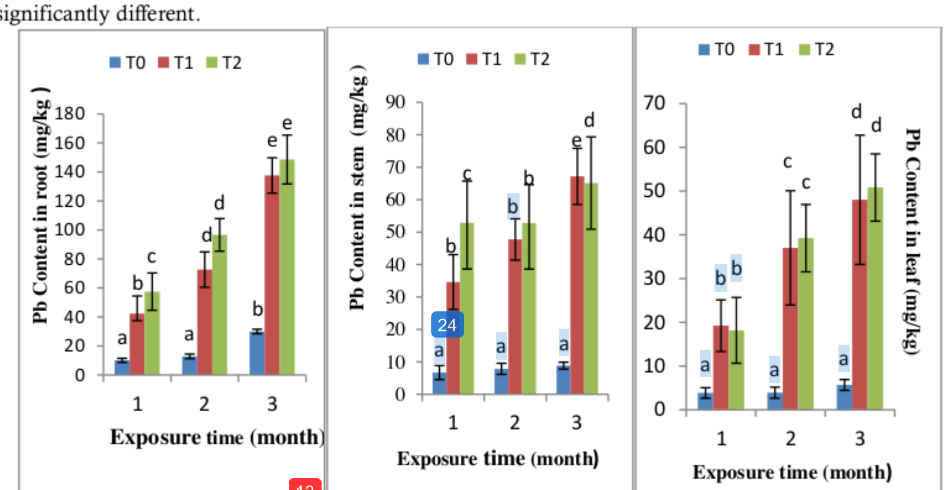

Figure 2. Lead contents (mg/kg) in root, stem, and leaf(mean ± SD) at various levels of Pb concentrations. Based on the significant difference test (LSD), the data with different letters show a significant difference at p <0.05

The analysis showed that the factor of concentration, duration of exposure, and the interaction between the two factors had a significant effect (P <0.05) on lead content in root, stem, and leaf. The Pb content in roots during 2 and 3 months exposure, T1 did not differ significantly from T2. The Pb content in stems during 1 and 3 months of exposure, all treatments differed significantly, while the Pb content in T1 leaves did not differ significantly from T2 during Pb exposure of 1, 2 and 3 months.

Translocation and Bioaccumulation Factor

The translocation factor (TF) showed the ability of heavy metals to be translocated from the root to other organs. Based on Figure 3, The TF value decreases with the duration of lead exposure. The TF of *C. fruticosa* plants, which value more than 1, indicated that most of the heavy metal was accumulated in the root. Meanwhile, the less than 1 TF value showed that the metal was translocated from the root to the shoot. The value of TF *C. Fruticosa* ranged between 0.4836 - 1.2810.

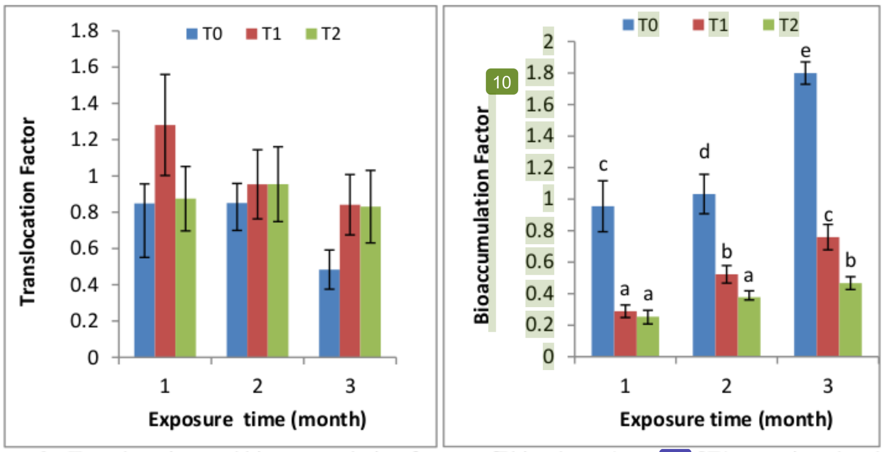

Figure 3. Translocation and bioaccumulation factors ofPbin plants (mean ± SD) at various levels of Pb concentrations. Based on the significant difference test (LSD), the data with different letters show a significant difference at p <0.05

Bioaccumulation (BAF) values increase with the time of lead exposure, Bioaccumulation factor of lead in *C. Fruticosa* plants ranged from 0.2539 - 1.7997 (Figure 3). The BAF value of T0 is less than 1 during one-month lead exposure, but the lead exposure at T1 and T2 is more than 1. The Anova test results conveyed that the time of exposure and lead concentration influenced the bioaccumulation factor, and there was an interaction between the two. The highest BAF value was significant in control (T0) for three months.

Metal Extraction Amount (MEA) on Plants

The MEA value in root increased in the second month then decreased in the third month, while the MEA value in stem and leaf decreased in the second and third months (Table 1). The MEA in root was relatively high in the second month, while the stem and leaf MEA value was relatively high in the first month.

Table 1. Metal extraction index (MEA)(mg/plant) lead in root, and shoot (stem+leaf)

		First month	Second month	Third month
Root	T0	0.01144±0.00180 a	0.01456±0.00187 a	0.01222±0.00168 a
	T1	0.03332±0.00604 b	0.04745±0.00512cd	0.04663±0.00352 c
	T2	0.03462±0.00745 b	0.05561±0.00543 d	0.03353±0.00673 b
Stem+leaf	T0	0.06413±0.00253 a	0.00446±0.00344 a	0.01082±0.01052 a
	T1	0.62327±0.02213 e	0.03346±0.03298 b	0.04255±0.01934 c
	T2	0.49469±0.01480 d	0.02982±0.02779 b	0.03956±0.03377 b

Data with different letters show a significant difference at p <0.05

The analysis results unveiled that the concentration and time of exposure, as well as the interaction between the two, had a significant effect (P <0.05) on the metal extraction index on root and stem and leaf. In the root, MEA of all treatments differed significantly during the first, second, and third month of lead exposure, while in the stem and leaf, MEA of all treatments differed significantly, except T1 and T2 were not significant for the second month.

Metal Tolerance Index (MTI) on Plants

As seen in Table 2, the MTI of *C. fruticosa* plants ranged from 82.80% - 95.0 %. The higher the concentration and duration of exposure, the lesser the MTI price.

Table 2. Metal Tolerance Index(%)

Treatment	One month	Two month	Three month
T1	95.0 ± 9.667	91.07 ± 5.222	89.73 ± 4.131
T2	92.03± 2.611	89.30 ± 6.071	82.80 ± 3.609

The Growth of *C. fruticosa* Plants

Growth is an essential outtake of measuring plants' adaptation on heavy metal-contaminated media. This has something to do with tolerance and plants' ability to absorb heavy metal. Biomass, on the other hand, is the alert of energy accumulation on plants. Plants have an adaptation skill to survive in the heavy metal-contaminated environment, yet in line with the increase in heavy metal level, physiological changes may happen and were expressed in the form of growth disturbance.

Growth inhibition is a typical response to plants towards mental pressure, which is one of the essential cultivation indexes of metal tolerance (Jiang & Liu, 2010). The influence of lead may differ depending on the species, cultivar, organ, and metabolism process. The lead treatment has shown the toxic effect on biomass to cause a decrease in biomass. High lead concentrations could cause a reduction in root hair growth and stunted growth by reducing the rate of photosynthesis (Kabir et al., 2010). The root is more responsive to lead in the environment as it is the organ that experiences direct interaction with the contaminant source. Generally, lead toxicity significantly affects root compared to the upper part of a plant. This is related to the accumulation of lead, which stored higher in the root cell wall than other parts of a plant (Kaur, 2014). The inhibition effect was higher on the root than shoot as root assimilates better than leaves so that toxicity symptoms are more likely seen on root than shoot (aboveground parts). This is in line with Boonyapookana et al. (2005), who elucidated that the decrease in root extension due to heavy metals pressure causes lower water absorption and nutrient transportation to the aboveground parts of the plant, and thus affects shoots the same as total plant biomass.

Lead content in plants

Lead content in *C. fruticosa* root was higher than the stem and leaf. This supports other similar studies that reported the Pb content in root was higher than the Pb content in the stem and root of *Pisum sativum* (Malecka et al., 2008) and *Allium sativum* (Jiang & Liu, 2010).

Lead has low solubility and translocation lower from root to other plant organs (Arshad et al., 2008; Zaier et al., 2010). At the time of translocation in the body of the plant, the metal entering the root cell is then transported to other parts of the plant through the transport tissue. After the metal penetrates the root endodermis, the heavy metal follows the flow of transpiration to the top of the plant through tissues, mainly xylem vessels (Jabeen et al., 2009; Saxena & Misra 2010), then carried all through all parts of the plant by phloem where the metal is kept in vacuoles. Moreover, the lead forms complex compounds in the absorption process of lead from the root to the leaves, then it is brought to plant tissue (Thakur, 2016).

The Pb storage in the root involves binding to the cell walls and extracellular deposition mainly in the form of lead carbonate, which is stored inside the cell walls. At a low concentration, lead could transport through tissues of root, either apoplast or symplast, then accumulated in the endodermis. The endodermis functions as a barrier to lead displacement from root to shoot (Siswanto, 2009), and this is thought to be one of the reasons why Pb is found higher in root than stem or leaf. Pb storage in the stem is mostly accumulated in the pith cells and vessels. The storage of Pb in most is accumulated between cells, cell walls, and vacuoles in cell walls and vacuoles. On the other hand, lead storage in leaves depends on the age of the leaf

Translocation and Bioaccumulation Factor

The *C. fruticosa* exposed to lead has TF <1, except for lead exposure of 250 mg/kg for one month. TF> 1 indicates that there is a translocation of lead from the root to other organs, but if TF <1, lead accumulates in the root. The BAF value of *C. fruticosa* was > 1, except for the control in 1 month.

Plants are useful for phytoextraction and phytostabilization because it can tolerate and collect heavy metals. Plants with more than one value of BAF and TF (TF and BAF> 1) have the potential to be used in phytoextraction. Besides, plants with BAF higher than one and TF less than one (BAF> 1 and TF <1) have the potential for phytostabilization. The phytoextraction process is the existence of heavy metal translocation to the upper organs, while the phytostabilization process is the ability to reduce metal translocation from the root to the upper organs.

Metal Extraction Amount (MEA) on Plants

In measuring the phytoextraction efficiency of a plant, it uses a vital indicator of the MEA (Zhang et al., 2010). In this research, the root MEA was 0.01144-0.0556, while the stem and leaf MEA ranged between 0.02982-0.62327.

Metal Tolerance Index (MTI) on Plants

The plant capability to vegetate can be measured by using The Metal Tolerance Index (MTI) at metal concentrations compared to the control (Zacchini et al., 2009). The classification based on MTI) was 0 ≤ 25 = very sensitive, 25 ≤ 50 = sensitive, 50 ≤ 75 = moderate, 75 ≤ 100 = tolerant, and ≥ 100 = very tolerant. Thus, plants owning a high tolerance can be used in contaminated areas

In general, the value of the *C. Fruticosa* tolerance index tended to decrease along with the increase in concentration. Based on the tolerance index value, the *C. fruticosa* is identified as a Pb-tolerant;Plants that are adaptive when absorbing metals form reductase enzymes in the root, where the enzymes function to reduce metals, which then are transported inside the root membrane (Arisusanti & Purwani, 2013).

CONCLUSION

Phytoremediation with ornamental plants minimizes the risk of heavy metal toxicity in biological systems and remains an innovative, environmentally-friendly, and sustainable technology, especially for the recovery or management of contaminated soil. Based on the value of the metal tolerance index, translocation factor, and bioaccumulation factor, *C. fruticosa* is a lead-tolerant plant anda lead accumulator.

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