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Assessment of plants as lead and cadmium accumulators for phytoremediation of contaminated rice field

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Abstract. *Hidayati N, Rini DS. 2020. Assessment of plants as lead and cadmium accumulators for phytoremediation of contaminated rice field. Biodiversitas 21: 1928-1934.* Heavy metals contamination in agricultural land becoming a serious problem since this causes declining in agriculture production and quality and thus food safety. Meanwhile, conventional efforts for remediation of the contaminated agricultural lands have not been widely implemented due to high-cost constraints. A low-cost technology that can be applied in contaminated sites is phytoremediation. This technique is based on the fact that plants have the ability to extract and accumulate heavy metals. This research aimed to study the potentials of some plant species as accumulators for phytoremediation in rice fields contaminated by heavy metals of lead (Pb) and cadmium (Cd). Six selected accumulator plant species, namely *Colocasia* sp., *Ipomoea fistulosa* Mart. ex Choisy, *Eichhornia crassipes* (Mart.) Solms, *Hymenachne amplexicaulis* (Rudge) Nees), *Saccharum spontaneum* L., and *Acorus calamus* L., were tested in *in-situ* field to identify the performance of the plants as accumulators for Pb and Cd. Parameters observed were plant growth and biomass production, and the accumulation of Pb and Cd in plants which is formulated as: bioconcentration factor (BCF) to indicate concentration ratio of metal in plant to soil, and translocation factor (TF) to indicate metal transportation ratio of shoot to root. The results showed that plants with the highest growth rate under contaminated conditions were *E. crassipes*, *A. calamus*, and *H. amplexicaulis*. The highest value of BCF for Pb accumulation was recorded in the shoot of *H. amplexicaulis* and *E. crassipes* and in the root of *H. amplexicaulis* and *A. calamus*, whereas the highest value of TF for Pb was observed in *E. crassipes*, *S. spontaneum*, and *H. amplexicaulis*. Meanwhile, the highest value of BCF for Cd in the shoot and in the root was observed in *Colocasia* sp and *H. amplexicaulis* whereas the highest value of TF for Cd was identified in *A calamus* and *Colocasia* sp. With regards to the performance of plant growth, biomass production, and accumulation of Pb and Cd, it is suggested that three plant species, namely *E. crassipes*, *A. calamus*, and *H. amplexicaulis* are considered as potential Pb and Cd accumulators for phytoremediation of contaminated rice fields. Our findings suggest that some plants can produce high biomass and absorb high contaminants while other plants cannot, implying that plants respond differently to different environmental conditions. Therefore continuous research is required to obtain the best plant species for phytoremediation.

Keywords: Accumulators, cadmium, lead, phytoremediation, species, wild

INTRODUCTION

Soil and water pollution is becoming a serious problem nowadays. Pollution can be resulted from industrial wastes, fertilizer and pesticide residues, and motor vehicle fumes (Coleman et al. 2005; Fuleker et al. 2009). The form of these contaminants can be various elements and hazardous chemical substances, such as heavy metals, and organic and inorganic compounds, which can result in environmental disruption (Garbisu and Alkorta 2003). Contamination by heavy metals, such as Cd, Zn, Pb, Cu, Cr, Se, Hg, and Ni, requires much attention due to the toxicity. Once released into the soil and waters, the heavy metals are strongly retained and their effects can last for a long time (Kramer and Chardonnens 2001).

About 75% of agricultural lands in Indonesia are categorized as critical lands where soil fertility continues to decline (Sidik 2011). Consequently, it has a major impact on reducing agricultural productions. Several factors that cause the declining quality of agricultural land are the continuous use of agrochemical fertilizers and pesticides in high doses and the contamination of the agricultural field by heavy metals pollutants sourced from industrial wastes disposed in the river flow which then is used as a source of water irrigation. The contaminated agricultural field would not only reduce the quality of agricultural fields but also reduce crop yields.

Several reports stated that heavy metals of Pb, Cd, and Hg have been detected in rice (Kasno et al. 2000; Miseri et al. 2000; Tomiyasu et al. 2013; Tomiyasu et al. 2017), implying that these pollutants are brought to food chains. For example, approximately 21-40% of 106,000 ha of rice fields along with West Java coastal areas (PANTURA), Indonesia are polluted by heavy metals (Sidik 2011). This is the case in Karawang District which is known as one of rice production centers in Indonesia. Agricultural lands in Karawang have been polluted by Pb and Cd in which 4-7 % of them are categorized as heavily polluted by Pb with contamination level of more than 1.0 ppm (Kasno et al. 2000; Miseri et al. 2000). In Karawang District, Pb levels in irrigated rice fields and sediments reached 16.33-68.35 ppm and Cd 0.5-6.4 ppm. In the rice harvested from contaminated rice fields in Karawang and Bekasi, the contamination of heavy metals of Pb and Cd reached 1.5-

12.1 ppm and 0.5-1.1 ppm, respectively. These are very alarming since the standard for Pb and Cd element for agricultural commodities is 2.0 ppm and 0.1 ppm, respectively (Hidayati and Rini 2017).

Lead is a heavy metal that normally found in soils and waters in high levels and is often found in the form of Pb 2+. The Pb quality standard in soil is 1.0-100 ppm and in water is 0.08-2.0 ppm. Lead considered as one of the most toxic heavy metals for human that can cause disorders of hemoglobin synthesis, disorders of the nerves, kidneys, reproductive system and lungs and cause acute disease. In children can cause low IQ and mental disorders USEPA (1999).

Heavy metal Cd is widely distributed in water and soil as a non-essential toxic metal. It exists in nature as Cd (OH)2, CdCO3 and CdSO4. Cd also precipitates in the form of arsenates, phosphates, chromates, sulfides, etc. The permissible limit of Cd2+ in soil and plant is less than 1mg L^{-1} and 0.005-0.02mg L^{-1} , respectively, according to USEPA (1999) or 0.1-7.0 ppm in soil and 0.05-0.1 ppm in water. Cd exposure to human bodies results in accumulation of Cd in the liver and kidneys which cause cardiovascular disorders and bone degradation.

Conventional efforts for remediation of the contaminated agricultural lands have not been widely implemented due to high-cost constraints. A low-cost technology that can be applied in contaminated sites is phytoremediation. This technique is based on the fact that plants have the ability to extract and accumulate heavy metals (Wislocka et al. 2006). Phytoremediation technology by using bioacumulator plants to clean up pollutants has been proven to be highly applicable (Prasat and Frietas 2003; Rodriguez et al. 2007; Yu et al. 2005), especially in the country like Indonesia which has high biological diversity that can be utilized as hyperaccumulator plants (Hidayati 2005). Detoxification of heavy metals contaminants by plants seems to be a feasible option for cleaning soils and waters, therefore screening appropriate plant species adapted to local conditions should be seriously considered in phytoremediation practices. Some cases show that it is highly possible of using plants for remediation of mercury in aquatic environments (Prasat and Frietas 2003; Hidayati 2005; Yu et al. 2005; Rodriguez et al. 2007).

The plant types that are of particular interest for use as remediation are those that absorb, store and detoxify contaminants (Gerth, 2000). Hyperaccumulators are plant species, typically endemic, that can both accumulate and tolerate shoot concentrations of heavy metals to level 100 times greater than those normally observed (Ebbs et al. 2000). Hyperaccumulators are plants that can accumulate specific trace elements to concentrations in their shoots far higher than other plants growing on the same substrates (Reeves et al. 2018). The hyperaccumulation threshold values are set at: 100 µg g^{-1} for Cd, Se, and Tl; 300 µg g^{-1} for Co, Cr and Cu; 1000 µg g^{-1} for As, Ni and Pb; 3000 µg g^{-1} for Zn; and 10 000 µg g^{-1} for Mn (van der Ent et al. 2013a). Some reports revealed that some plant species accumulate considerably high concentration of heavy metals. For example, *Hymenachne amplexicaulis* (Rudge) Nees (rumput paitan) that accumulates 65.35 ppm of Pb and 2.27 ppm of Cd, *Colocasia sp.* (L.) Schott (talas liar) that accumulates 41.7 ppm of Pb and up to 11.66 ppm of Cd, *Panicum paludosum* Roxb (rumput torpedo) that accumulate 40.20 ppm Pb and 5.10 ppm Pb, *Cyperus sp* (rumput teki) that accumulates 38.5 ppm Pb and 4.6 ppm Cd (Rahmansyah 2009; Juhaeti et al. 2009a; Juhaeti et al. 2009b; Hidayati and Rini 2018).

lant species from wide group of families have been recognized as Pb and Cd hyperaccumulators in the last two decades. Different hyperaccumulating plants have varied abilities to accumulate, sequester, and detoxify Pb and Cd at physiological and molecular levels. Despite the developments made in field of Pb and Cd phytoremediation from contaminated soils and waters, only a limited number of research studies that taking place on an *in-situ* condition, particularly in agricultural soils, which had been irrigated with wastewater and contaminated with heavy metals. Hence, there is an urgent need for research on improving experimental design of phytoremediation relevant to Pb and Cd concentration in soil and water (Mahajan and Kaushal 2018). The purpose of this study is to assess the potentials of wild species as heavy metal Pb and Cd accumulators and to examine its usefulness in the remediation technique to clean up the contaminated agriculture lands, especially rice fields.

MATERIALS AND METHODS

Study area

This study was performed to test the possible use of several wild plant species as bioaccumulator to absorb heavy metals Pb and Cd on the *in-situ* trials of contaminated rice fields in District of Karawang, West Java, Indonesia. The choice of field location for testing is based on the following criteria: (i) Close to rivers and irrigation which are polluted by a high level of Pb and Cd according to the previous observation. In this case, the location of the *in-situ* field is located close to Citarum River; (ii) Agricultural fields are exposed by a high level of Pb and Cd; (iii) The accessible location makes it easy for supervision and maintenance; (iv) The representative of the rice field area. For example, the study site is surrounded by 4000 ha-4500 ha of rice fields.

The *in-situ* plot was located in Sukamulya Village, Cilamaya Kulon Sub-district, Karawang (S 06º14'09.40"; E 107º31'27.87"). The status of Pb and Cd in the experimental plot is as follows: (i) West Tarum irrigation water: the level of Pb was 8.33 ppm, and Cd was 0.783 ppm; (ii) West Tarum irrigation sediments: the level of Pb was 6.28 ppm, and Cd was 0.325 ppm; (iii) Rice field in study site: the level of Pb was 5.75 ppm, Cd was 0.783 ppm. Meanwhile, the value of the standard quality of Pb in water is 0.08-2.0 ppm, in soils is 1.0-100 ppm and in rice is 2.0 ppm. The standard quality of Cd in water is 0.05-0.1 ppm, in soils is 0.1-10 ppm and in rice is 0.24 ppm (Hidayati and Rini 2018). Therefore, the status of Pb and Cd levels in the testing plots were categorized as above standard quality.

Experimental procedure

Six candidates of Pb and Cd accumulator plants based on the previous *ex-situ* selection were tested, namely 1) *Colocasia* sp. (talas liar); 2) *Ipomoea fistulosa* Mart. Ex Choisy. (tablo); 3) *Eichhornia crassipes* (Mart.) Solms. (eceng gondok); 4) *Hymenachne amplexicaulis* (Rudge) Nees.(rumput paitan) ; 5) *Saccharum spontaneum* L. (kaso) and 6) *Acorus calamus* L. (rumput manggala). The basic standard dosage of inorganic fertilizer was applied to optimize the harvested biomass. The experiment was designed in a randomized block trial consisting of six types of accumulator plants with three replications. The plants were subjected to heavy metal contamination in the *in-situ* field for 10 weeks, starting from the mid of August 2018 until the end of October 2018.

Variables observed were the agronomic traits (i.e. adaptability, plant growth rate and harvested shoot and root biomass). Plant growth rate was simply calculated as the increment of biomass per week. Total biomass production was measured as root and shoot biomass harvested after 10 weeks, as a given time interval for all of the plant. Variable of heavy metals status was measured as heavy metals concentrations in the soil, before planting and after harvesting and heavy metals concentration in the plant shoots and roots before planting and after harvesting.

Sampling was performed twice, before planting and after harvesting (after 10 weeks). Samples that consists of harvested biomass were collected from three individuals of plant in each treatment as replications. Biomass samples were measured separately between roots and shoots. The plant samples (separated roots and shoots) were thoroughly washed by distilled water to remove all adhering soil particles. Samples were then and cut into small pieces and oven-dried to constant weights at 80 ºC. Each dried sample was ground to powder using a wearing blender. Soil samples were collected from each treatment plot as composites with three replications. In order to determine total levels of heavy metals, the composite soil samples were air-dried to constant weights. They were then ground into fine powder for analysis. Approximately 5g for each sample (roots, shoots, and soils) from each replication was provided for analysis.

Data analysis

Data on heavy metal concentrations from both sediments and plants (shoots and roots) were used to calculate the bioconcentration and translocation factors. Phytoextraction potential can be estimated by calculation of bioconcentration factor (or biological absorption coefficient) and translocation factor. Bioconcentration factor (BCF) is commonly used to indicate the ability of plants to remove metal compounds from the soil. The bioconcentration factor (BCF), which is defined as the ratio of the total concentration of element in the harvested plant tissue (C plant) to its concentration in the soil in which the plant grows (C) (Mellen et al. 2012), was calculated as follows:

$$BCF = \frac{\text{Concentration in plant organ}}{\text{Concentration in sediment}}$$

Meanwhile, translocation factor (TF) is a variable that is commonly used to indicate the ability of the compound to be transferred from plant roots to other organs/shoot (Mellen et al. 2012). Parameters of BCF and TF were analyzed to assess whether plants could be categorized as accumulators which were calculated as follows:

$$TF = \frac{\text{BCF of shoot}}{\text{BCF of root}}$$

Data on plant growth, biomass production, heavy metals accumulation as well as bioconcentration factors and translocation factors, were analyzed using SAS program and Windows Excel and are presented in table and chart format. Plant botanical identification was conducted in Herbarium Bogoriense, Research Center for Biology, Indonesian Institute of Sciences as well as the *ex-situ* and molecular selection that have been conducted prior to this *in-situ* study. Analysis of Pb and Cd accumulation was done in Research Center for Biology, Indonesian Institute of Sciences, and Chemistry Laboratory of IPB University, Bogor, Indonesia.

RESULTS AND DISCUSSION

Performance of plant growth

Agronomic performance of the six plants tested showed significant growth differences since they had different characteristics and responses to the environmental conditions. *E. crassipes*, *A. calamus*, and *H. amplexicaulis* produced the highest biomass after a 10-week growing period, therefore these three species are suitable to the rice field environment. The total biomass increment of *E. crassipes*, *A. calamus*, and *H. amplexicaulis* was 78.61 kg, 60.16 kg, and 54.55 kg, resulting in the growth rate of 7.86 kg/week, 6.02 kg/week, and 5.46 kg/week, respectively within 10 weeks (Figure 1 and Table 2). Meanwhile, *Colocasia* sp., *S. spontaneum*, and *I. fistulosa* produced 5.30 kg, 3.58 kg and 3.14 kg biomass, respectively. Among the six plants tested, *S. spontaneum* and *I. fistulosa* showed the most inferior performances, therefore, these two plants were not suitable to the *in-situ* rice field trials. *S. spontaneum* and *I. fistulosa* belong to terrestrial plants that require better drainage for their growing environments. Meanwhile, rice field growing condition was fully irrigated and excess water during the growing period, consequently, such an environment was not suitable for these two accumulator candidates.

The results of the present study revealed that agronomic performance of plant wild species grown in contaminated sites varied significantly (Table 1). This result is in line with other studies that showed the performance of wild accumulator plants varied according to their adaptability to the heavy metal contaminations. For example, *Acorus calamus*, *Eichhornia crassipes* and *Saccharum spontaneum* showed superior performance compared to other plants subjected to by Pb up to 300 ppm (Hidayati and Rini 2018). Some wild plants namely *S. spontaneum* and *I. fistulosa* and *Paspalum conjugatum* were superior in the contaminated mine tailing (Rahmansyah 2009).

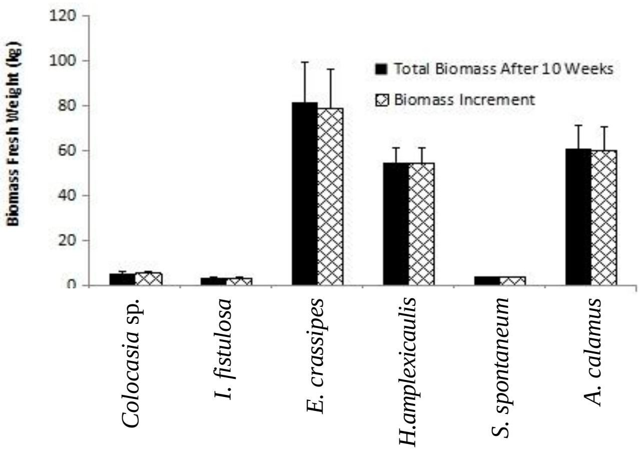

Figure 1. Plant biomass production after a 10-week growing period

Some plants are wild found to have high adaptability to polluted environments. The adaptability is proven to be related to the genetic and physiological characteristics of each plant species (Nkumar 2018; Rahmansyah 2009; Hidayati and Rini 2018). Since the success of the phytoremediation, technique is determined by increasing plant biomass and accumulation of heavy metals in accumulator plants (Karger et al. 2015). Therefore some remarks need to be considered in the phytoremediation practices in order to achieve the optimum results. Appropriate agronomic practices need to be applied, based on insights from laboratory and field tests, to maximize yields of the selected accumulators (Nkumar 2018). Local plant species are highly recommended as accumulators due to their adaptation to local climate conditions. In addition, to improve plant growth and metal uptake it can be employed combination of inorganic fertilizer and compost as a chelator such as *Agrobacterium sp*. (Rostiati 2018).

Heavy metal Pb and Cd accumulation in plants

The main variable determining the potential of plants as bioaccumulator is the capacity to accumulate heavy metals in the plant organs (above and below ground). Therefore, observation of the increasing of Pb and Cd accumulation in a 10-week growing period in Karawang was performed. The results indicated that some plants showed a higher level of Pb and Cd accumulations. The highest Pb accumulation in the shoot was found in *Colocasia* sp. with 2.501 ppm, followed by *A. calamus* with 2.223 ppm, *I. fistulosa* with 1.893 ppm, *S. spontaneum* with 1.826 ppm, and *E. crassipes* with 1.599 ppm. Meanwhile, the highest Pb accumulation was observed in the root of *Colocasia sp*. with 3.289 ppm, followed by *H.amplexicaulis* with 2.892 ppm, *E. crassipes* with 2.819 ppm, *A. calamus* with 2.875 ppm, and *I. fistulosa* with 2.842 ppm (Figure 2).

The highest level of Cd in the shoot was found in *Colocasia sp*. with 0.292 ppm, followed by *I. fistulosa* with 0.246 ppm, *E. crassipes* with 0.217 ppm, *S.spontaneum* with 0.211 ppm and *H.amplexicaulis* with 0.187 ppm (Figure 3). The highest level of Cd in the roots was found in *Colocasia sp*. with 0.354 ppm, followed by *E. crassipes* with 0.339 ppm, *I. fistulosa* with 0.328 ppm, *S.spontaneum* with 0.326 ppm, and *H.amplexicaulis* with 0.296 ppm.

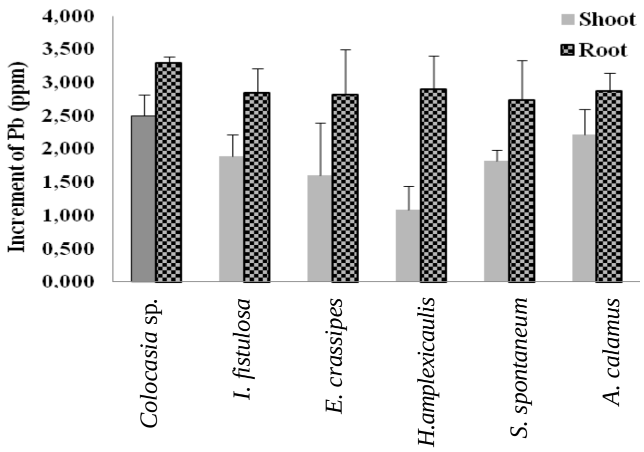

Figure 2. Increment of Pb accumulation in the tested plants after a 10-week growing period

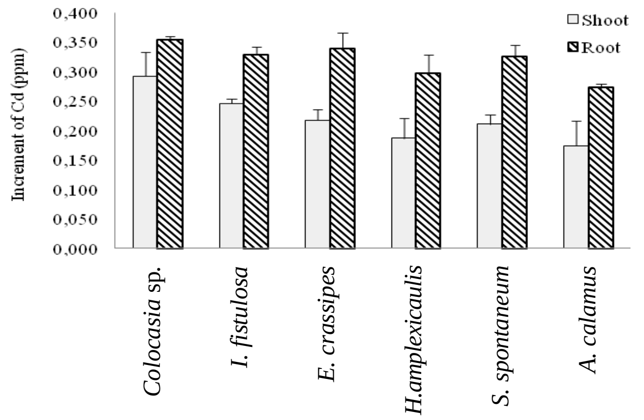

Figure 3. Increment of Cd accumulation in the plants after a 10-week growing period

The accumulation of Pb and Cd observed in this study varied among the species tested. The results of the present study correspond to a study which reported that high Pb and Cd accumulations were found in some plants growing in the contaminated agricultural area, namely *Hymenachne amplexicaulis* with 65.3 ppm Pb and 52.3 ppm Cd, *Colocasia sp.* with 41.7 ppm Pb and 11.7 ppm Cd, *Panicum paludosum* with 40.2 ppm Pb and 5.1 ppm Cd, *Cyperus sp* with 38.5 ppm Pb and 4.6 Cd, *Alternanthera sessilis* with 38.5 ppm Pb and 4.6 ppm Cd (Hidayati and Rini 2018). It was also indicated that various indigenous plant species, such as *Paspalum* sp., *Cyperus* sp., *Caladium* sp., *Digitaria* sp., *Lindernia* sp., and *Zingiber* sp. accumulated heavy metals more than 20 ppm (Rahmansyah et al. 2009). Considerably high Pb and Cd content were also found in some wild plants namely *Hymenachne amplexicaulis*, *Ipomoea fistulosa* and *Eichhornia crassipes* subjected to various Pb concentration up to 300 ppm and Cd concentration up to 75 ppm under greenhouse condition (Hidayati and Rini 2018).

Singh et al. (2017) reported some wild plants can be accumulators for some heavy metals. Among aquatic plants, *Panicum antidotale* is a hyperaccumulator for one or other metals up to six metals (Cd, Co, Fe, Mn, Pb, and

Zn). Among terrestrial plants, *Lantana camara* and *Ageratum conyzoides* are hyperaccumulators for Cd, Cu, Fe, Mn, Pb, and Zn. It is evident that all these plant species have potential to remediate various inorganic pollutants and can act as bioaccumulator. The content of cadmium in different aquatic plant samples varied from 5.20 mg/kg (*E. crassipes* petiole) to 9.13 mg/kg (*E. crassipes* root) while in terrestrial plants was from 6.75 mg/kg (*Malvastrum coromandilianum* leaf) to 9.59 mg/kg (*Achyranthes aspera* leaf) (Singh et al. 2017). Meanwhile, the lead content contained in terrestrial plants varied from 23.47 mg/kg (*Prosopisjuliflora* leaf) to 83.39 mg/kg (*Lantana camara*) (Singh et al. 2017). The observed content of Pb was higher than the natural plant content of noncontaminated sites (i.e. 4.2 mg/kg) (Singh et al. 2017).

Although the levels of Pb and Cd increased significantly in the plant during the testing period, they have not been associated with a decrease in Pb and Cd levels in the soil of testing plot. The Pb level in the soil before planting was 5.75-6.75 ppm, while the Cd status in the soil before planting was 0.783-0.883 ppm. In this study case, however, the Pb and Cd levels in the soil before and after harvesting cannot be used as a benchmark for the effectiveness of phytoextraction. This is because the system applied in the experimental plot is not a closed system where water regulation in the experimental plot must also be adjusted to the water regulation for the surrounding agricultural areas. This system still be exposed by Pb and Cd from the flowing-in contaminated irrigation water continuously as all of the rice fields in the area are also irrigated from. Similar *in-situ* test and results were performed that the use of wastewater as a source of continuous irrigation can accumulate heavy metals significantly (Ma et al. 2015).

Bioconcentration factor and translocation factor

Bioconcentration factor (BCF) is the ratio of the metal concentration of plants to the soil. These parameters can be used as parameters to determine whether a plant can be categorized as an accumulator. The value of translocation factors for heavy metals in plants should be more than one in order to be considered as bioaccumulators (Siahaan et al. 2013). In the present study, BCF fop Pb for all tested plants did not seem significantly different (Tables 1 and 2). The BCF values for Pb ranged between 0.551 in *S.spontaneum* shoot to 0.571 in *A. calamus* root (Tables 1 and 2). The second highest was *H. amplexicaulis* root and shoot (0.569) (Table 1). The BCF values for Cd ranged between 0.316 in *A. calamus* shoot to 0.581 in *Colocasia* sp. root for Cd, followed by *H. amplexicaulis* root with 0.519 and *S. spontaneum* root with 0.505 (Tables 1 and 2).

Meanwhile, Translocation Factor (TF) is the ratio of metal transportation from shoots to roots. The TF values for Pb ranged from 0.960 in *Colocasia sp*. to 1.028 in *E. crassipes* and *S. spontaneum*, followed by *H. amplexicaulis* with 1.00. Meanwhile, TF values for Cd ranged between 0.738 in *S. spontaneum* to 0.788 in *A. calamus*, followed by the second-highest of 0.777 in *Colocasia sp*. and 0.774 in *I. fistulosa* (Tables 1 and 2). Although the values of TF were not significantly different between plant species, however considering the differences it can be concluded that the plant with TF values more than one can be considered potential as Pb and Cd accumulators for phytoremediation in contaminated rice fields.

Table 1. Bio-concentration factor (BCF) and translocation factor (TF) values after 10 weeks growing period. Lead (Pb) status in the soil before planting was 6.75 ppm and cadmium (Cd) status in the soil before planting was 0.783 ppm.

Plant name (local name)		Pb in plant (ppm)					Cd in plant (ppm)				
		Pb soil	Before	After 10 weeks	TF	BCF	Cd soil	Before	After 10 weeks	TF	BCF
Colocasia sp.	Shoot	6.486	0.562	3.524	0.960	0.543	0.726	0.036	0.328	0.777	0.452
(Talas)	Root	6.486	0.858	3.672		0.566	0.726	0.068	0.422		0.581
I. fistulosa	Shoot	8.859	0.926	4.893	0.978	0.552	0.876	0.072	0.318	0.774	0.363
(Tablo)	Root	8.859	1.144	5.002		0.565	0.876	0.083	0.411		0.469
E. crassipes	Shoot	8.426	1.042	4.734	1.028	0.562	0.816	0.078	0.295	0.741	0.362
(Eceng)	Root	8.426	0.785	4.606		0.547	0.816	0.059	0.398		0.488
H.amplexicaulis	Shoot	6.924	1.033	3.979	1.000	0.569	0.684	0.077	0.264	0.744	0.386
(Paitan)	Root	6.924	0.953	3.939		0.569	0.684	0.059	0.355		0.519
S.spontaneum	Shoot	7.586	0.774	4.180	1.028	0.551	0.732	0.062	0.273	0.738	0.373
(Kaso)	Root	7.586	0.546	4.066		0.536	0.732	0.044	0.370		0.505
A. calamus	Shoot	7.278	0.882	4.080	0.982	0.561	0.788	0.075	0.249	0.788	0.316
(R.Manggala)	Root	7.278	1.027	4.153		0.571	0.788	0.084	0.356		0.401

Table 2. Statistical analysis of plant growth rate, bioconcentration factor (BCF) and translocation factor (TF)

Plant species	Plant growth rate (kg/week)	BCF for Pb	TF fo Pb	BCF for Cd	TF for Cd
Colocasia sp.	0.53b	0.566a	0.960a	0.581a	0.777a
I. fistulosa	0.31c	0.565a	0.978a	0.469ab	0.774a
E. crassipes	7.86a	0.562a	1.028a	0.488a	0.741a
H.amplexicaulis	5.46a	0.569a	1.000a	0.519a	0.744a
S.spontaneum	0.36c	0.551a	1.028a	0.505a	0.738a

Note: Different alphabetical notation behind the values indicate according analysis (ANOVA p 0.05), the values are significantly different

The fact that the accumulation of heavy metals was higher in the root compared to the shoot is in line with earlier reports, which found the immobile nature of lead from soil and sediments to the above-ground organs of the plants (Hidayati 2013). Therefore heavy metal BCF in the roots is generally greater than in the shoot (stems and leaves) (Hidayati and Rini 2019). The highest translocation factors of Pb in *Avicennia* sp was found for root-to-stem translocation with values of 1.09 and while in *Rhizophora* sp. had the highest root-to-leaf translocation with 1.48 (Takarina and Pin 2017). This finding indicates that this mangrove tree is capable of translocating metals from the roots to the stems rather than to leaves (Takarina and Pin 2017). It was also reported that *Pinus sylvestris* can act as an accumulator with the value of Pb translocation factor of (2.43), *Pinus pinaster* Cd (1.85) and *Quercus rotundifolium* of Mn (3.54) in São Domingos (Andras et al. 2016). The predominantly low translocation factor values indicate that in most cases heavy metals are accumulated in roots and only in a few cases do they migrate to shoots (e.g. Zn in *Pinus* sp. and Co in P. *pinaster*) (Andras et al. 2016). The results of other studies showed that *Leersia hexandra*, *Commelina benghalensis, Sphaeranthus kirkii* and *Hoslundia opposite* had shoot-to-root quotients > 1 for lead. While *Ludwigia stolonifera, Commelina benghalensis, Typha capensis, Fuirena umbellata, Cyperus exaltatus, Crinum papilosum, Hoslundia opposita* and *Hygrophylla auriculata* had shoot-to-root quotients > 1 for cadmium. It seems that Pb and Cd are relatively easier to transport to plant shoots compared to Copper and Chromium (Mganga et al. 2011*)*.

The process of heavy metal binding in plants occurs via the mechanism of heavy metal accumulation and tolerance. The plant root is the organ that can contribute to the prevention of heavy metal accumulation in the surrounding environment where the high concentrations of heavy metal contaminants in sediments can be stored in the shoots (Takarina and Pin 2017). The metal concentration in plants increases as a function of metal concentration in the soil. The BCF value of an accumulator plant varies depending on the existing heavy metals in the contaminated area (Smitha and Sugandha 2019). Some studies suggested of using wild species as heavy metals accumulator since they have high potential to be used for phytoremediation (Cˇurlik et al. 2016; Mudarrisna and Siahaan 2014).

As Cd has low affinities with soil ligands because of its mobile nature, it is easily extracted by roots and further transported to other aerial portions of the plant. The factors responsible for remediation of Cd by plants are pH, temperature, its concentration in media, and even concentration of elements other than Cd. Significant and better uptake of Cd is observed in the hydroponic system as compared to soil cultures as BCF and TF were more than 1 but on high exposure of Cd (Mahajan and Kaushal 2018).

The process of transferring and accumulating heavy metals into plant organs is substantially affected by various factors, mainly by the metal-heavy content in the soil, soil characteristics, soil reactions, cation exchange capacity, and soil pH (Vamirali et al. 2010; Cˇurlik et al. 2016). Plants having bioconcentration and translocation factors of more than 1 can be used as a bioaccumulator, where bioconcentration values > 2 are considered to be high (Mellen et al. 2012). Plants having bioconcentration factors >1 and translocation factors <1 are considered as phytostabilizers and if they have bio-concentration factors < 1 and translocation factors >1 can be considered as phytoextractors (Usman et al. 2013). In a recent field study with Ganges ecotype of *T. caerulescen*, the role of soil geochemical factors and plant-soil interactions for Cd uptake are highlighted by hyperaccumulating plants (Mahajan and Kaushal 2018). Those studies imply the importance of understanding site-specificity heavy metals containment and soil properties to be considered before phytoremediation of actual field sites (Mahajan and Kaushal 2018).

It can be concluded that the highest value of Bioconcentration factor (BCF) for Pb accumulation was recorded in the shoot of *H. amplexicaulis* (Rudge) Nees) and *E. crassipes* (Mart.) and in the root of *H. amplexicaulis* (Rudge) Nees) and *A. calamus* L, whereas the highest value of Translocation Factor (TF) for Pb was observed in *E. crassipes* (Mart.), *S spontaneum* L. and *H amplexicaulis* (Rudge) Nees). Meanwhile, the highest value of BCF for Cd in the shoot and in the root was observed in *Colocasia* sp and *H. amplexicaulis* (Rudge) Nees) whereas the highest value of TF for Cd was identified in *A calamus* L. and *Colocasia* sp. It is suggested that three plant species, namely *H. amplexicaulis*, *E crassipes*, and *Acorus calamus*, are considered as potential Pb and Cd accumulators for phytoremediation of contaminated rice fields. Our study suggests that some plants are proven capable of extracting and accumulating heavy metals and can be effectively used as bioaccumulators in phytoremediation techniques to clean up heavy metals contamination in agricultural areas. Some plants can produce high biomass and absorb high contaminants while other plants cannot, implying that plants respond differently to different environmental conditions. Therefore continuous research is required to obtain the best plant species for phytoremediation.

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