Subject Area 5.3: Phytoremediation and ecosystem restoration

Research Article

Phytoextraction of Lead-Contaminated Soil Using Vetivergrass (*Vetiveria zizanioides* L.), Cogongrass (*Imperata cylindrica* L.) and Carabaograss (*Paspalum conjugatum* L.)*

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Abstract

Background, Aims and Scope. The global problem concerning contamination of the environment as a consequence of human activities is increasing. Most of the environmental contaminants are chemical by-products and heavy metals such as lead (Pb). Lead released into the environment makes its way into the air, soil and water. Lead contributes to a variety of health effects such as decline in mental, cognitive and physical health of the individual. An alternative way of reducing Pb concentration from the soil is through phytoremediation. Phytoremediation is an alternative method that uses plants to clean up a contaminated area. The objectives of this study were: (1) to determine the survival rate and vegetative characteristics of three grass species such as vetivergrass, cogongrass and carabaograss grown in soils with different Pb levels; and (2) to determine and compare the ability of the three grass species as potential phytoremediators in terms of Pb accumulation by plants.

Methods. The three test plants: vetivergrass (*Vetiveria zizanioides* L.); cogongrass (*Imperata cylindrica* L.); and carabaograss (*Paspalum conjugatum* L.) were grown in individual plastic bags containing soils with 75 mg kg^{-1} (37.5 kg ha^{-1}) and 150 mg kg^{-1} (75 kg ha^{-1}) of Pb, respectively. The Pb contents of the test plants and the soil were analyzed before and after experimental treatments using an atomic absorption spectrophotometer. This study was laid out following a 3 x 2 factorial experiment in a completely randomized design.

Results. On the vegetative characteristics of the test plants, vetivergrass registered the highest whole plant dry matter weight (33.85–39.39 Mg ha^{-1}). Carabaograss had the lowest herbage mass production of 4.12 Mg ha^{-1} and 5.72 Mg ha^{-1} from soils added with 75 and 150 mg Pb kg^{-1}, respectively. Vetivergrass also had the highest percent plant survival which meant it best tolerated the Pb contamination in soils. Vetivergrass registered the highest rate of Pb absorption (10.16 ± 2.81 mg kg^{-1}). This was followed by cogongrass (2.34 ± 0.52 mg kg^{-1}) and carabaograss with a mean Pb level of 0.49 ± 0.56 mg kg^{-1}. Levels of Pb among the three grasses (shoots + roots) did not vary significantly with the amount of Pb added (75 and 150 mg kg^{-1}) to the soil.

Discussion. Vetivergrass yielded the highest biomass; it also has the greatest amount of Pb absorbed (roots + shoots). This can be attributed to the highly extensive root system of vetivergrass with the presence of an enormous amount of root hairs. Extensive root system denotes more contact to nutrients in soils, therefore more likelihood of nutrient absorption and Pb uptake. The efficiency of plants as phytoremediators could be correlated with the plants' total biomass. This implies that the higher the biomass, the greater the Pb uptake. Plants characteristically exhibit remarkable capacity to absorb what they need and exclude what they do not need. Some plants utilize exclusion mechanisms, where there is a reduced uptake by the roots or a restricted transport of the metals from root to shoots. Combination of high metal accumulation and high biomass production results in the most metal removal from the soil.

Conclusions. The present study indicated that vetivergrass possessed many beneficial characteristics to uptake Pb from contaminated soil. It was the most tolerant and could grow in soil contaminated with high Pb concentration. Cogongrass and carabaograss are also potential phytoremediators since they can absorb small amount of Pb in soils, although cogongrass is more tolerant to Pb-contaminated soil compared with carabaograss. The important implication of our findings is that vetivergrass can be used for phytoextraction on sites contaminated with high levels of heavy metals, particularly Pb.

Recommendations and Perspectives. High levels of Pb in localized areas are still a concern especially in urban areas with high levels of traffic, near Pb smelters, battery plants, or industrial facilities that burn fuel ending up in water and soils. The grasses used in the study, and particularly vetivergrass, can be used to phytoremediate urban soil with various contaminations by planting these grasses in lawns and public parks.

1 Background, Aim and Scope

The global problem concerning contamination of the environment as a consequence of human activities is increasing. Most of the environmental contaminants are chemical by-products and heavy metals (Ona et al. 2006, Sigua 2005). The human activities that contaminate soils with large quantities of heavy metals are industrial and mining industries, fuel burning and fuel production, intensive agriculture and sludge dumping (Sigua 2005, Sigua et al. 2005, Sigua et al. 2004a, Sigua et al. 2004b). Heavy metals accumulated in soil can affect flora, fauna, and human living in the vicinity or downstream of the contaminated sites (Ona et al. 2006). More than 800,000 children between the ages of one to five in the U.S. alone could have been affected by Pb poisoning (Pirkle et al. 1998).

Lead is naturally occurring, but is often released into the environment from artificial sources. Lead has been mined, smelted, refined and used for hundreds of years. It has been used as an additive in paints and gasoline, leaded pipes, solders, crystals and ceramics. Natural levels of Pb in soil are usually below 50 mg kg^{-1}, but mining, smelting, and refining activities have resulted in substantial increase in Pb levels in the environment, especially near mining and smelting sites, near some types of industrial and municipal facilities, and in areas adjacent to highways. Lead released into the environment makes its way into the air, soil and water. Lead can remain in the environment indefinitely as dust. The Pb in fuels contributes to air pollution, especially in urban areas. Soils near highways, freeways, and smelting facilities have higher levels of Pb than soils in other areas because of their exposure to Pb dust, which accumulates over time (Ona et al. 2006). Lead may also contribute to a variety of health effects. When Pb is absorbed in the body, it will produce different behavior, psychological and cognitive changes, especially in children (Ona et al. 2006). It affects an individual in such a way that its respective accumulation within the body leads to a decline in the mental, cognitive, and physical health of the individual.

Various techniques are used for cleaning up Pb-contaminated soils. Recently, heavy metal phytoextraction has emerged as a promising, cost-effective alternative to the conventional engineering-based remediation (Salt et al. 1998, Chaney et al. 1997, Raskin et al. 1994). Phytoremediation is an alternative method that uses plants to clean up a contaminated area (Uera et al. 2007, Blaylock 1998, Berti 1997, Huang et al. 1997, Huang and Cunningham 1997, Huang and Cunningham 1996). It is relatively easy to implement, and can reduce remedial costs while restoring the habitat. However, the plant species being used must grow well in toxic levels of heavy metal conditions and can produce high biomass (Berti 1997). The success of phytoremediation is greatly dependent upon the choice of plant species to be used. Plant species must adapt to the extreme conditions and must be relatively tolerant to a high concentration of metals in soil (Uera et al. 2007).

Vetivergrass *(Vetiveria zizanioides* L.) due to its unique morphological and physiological characteristics is widely known for its effectiveness in erosion and sediment control (Green-

field, 1995). This tropical grass was found to be highly tolerant to extreme soil conditions, including heavy metal contamination (Truong and Baker 1996). Cogongrass (*Imperata cylindrica* L.) generally occurs on light textured acid soils with clay subsoil that can tolerate a wide range of soils from strongly acidic to slightly alkaline. It is a hardy species, tolerant to shade, high salinity and drought. It can be found in virtually any ecosystem, especially those experiencing disturbances (Mekonnen 2000, Johnson and Shilling 1998). It is a hardy species, tolerant to shade, high salinity and drought. Carabaograss (*Paspalum conjugatum*) is a vigorous, creeping perennial grass with long stolons and rooting at nodes. It is adapted to humid climate and found growing gregariously under plantation crops and along stream banks, roadsides and in disturbed areas. This grass can adapt easily to a wide range of soils (Mannetje 1992).

Many remediation techniques have been employed to address the rising number of heavy metal contaminated soils (Cholpecka et al. 1996, Cunningham 1996, Cunningham et al. 1995). Most of the traditional methods such as incineration, vitrification, electrokinetics and land filing are extremely expensive (Pulford and Watson 2003, Mulligan et al. 2001). A promising and relatively new technology for remediation of heavy metal contaminated sites is phytoextraction. The use of the plants (grasses in this study) in phytoremediation may be cost effective and could be environmentally friendly, but the practical phytoremediation tool for the control and remediation of Pb contamination in soil using tropical grasses is not well understood. The objectives of the study were: (1) to determine the survival rate and vegetative characteristics of three grass species grown in soils with different Pb levels; and (2) to determine and compare the ability of the three grass species as potential phytoremediators in terms of Pb accumulation by plants' roots and shoot organs.

2 Materials and Methods

2.1 Preparation of test plants

The three test plants: vetivergrass (*Vetiveria zizanioides* L.); cogongrass (*Imperata cylindrica* L.); and carabaograss (*Paspalum conjugatum* L.) were grown in individual plastic bags containing soils (50 kg) with 75 mg kg^{-1} and 150 mg kg^{-1} of Pb, respectively. Young seedlings of vetivergrass and cogongrass from Little Baguio, Central Luzon State University served as test plants for the vetivergrass and cogongrass trials. Young seedlings of carabaograss from the Institute of Graduate Studies Dormitory served as starting test plants for the carabaograss trials. For each type of grass, 20 plants were planted in each pot. Individual bags were inspected almost daily for possible leakage that may compromise the results of the study. The general study site is shown in **Fig. 1**. All treatments were given approximately three liters of distilled water every four days for a period of six weeks to keep the moisture content of the soils at field capacity (21%). Distilled water was used in the experiment to make sure that water is free from impurities, chemicals and pollutants, which are potential sources of contamination.
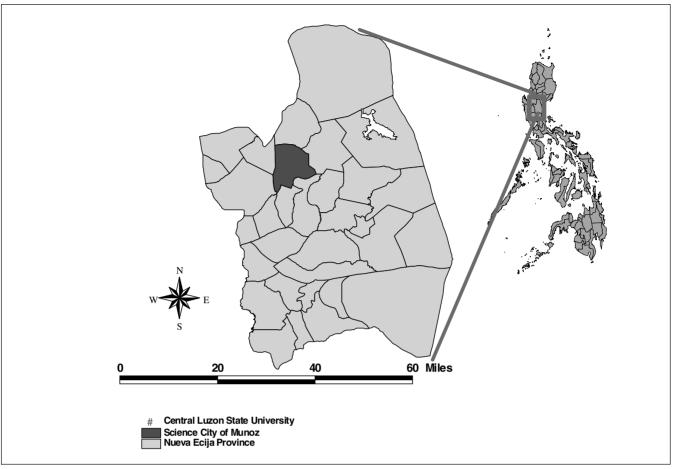
Fig. 1: General location of the study site

2.2 Soil and plant assays for Pb

Lead concentrations in the soil and plant samples were measured by atomic absorption spectrophotometer. Analysis of Pb was done in plants and soils before planting, which served as the initial Pb concentration, and after harvesting, which served as the final Pb concentration of the samples.

Plant samples weighing 0.20 g were placed in porcelain crucibles heated for three hours at 300°C and an additional two hours at 500°C inside a muffle furnace. Three ml of 5 $\underline{N}$ nitric acid was added to the samples and heated at 200°C for 15 minutes to remove traces of organic matter. Samples were then placed in a hot plate for drying, followed by the addition of 5 ml of 2 $\underline{N}$ nitric acid to dissolve the residue of salts. The mixtures were transferred to a filter paper catching the filtrate into a 50-ml volumetric flask. The filtrate was stored in the refrigerator until required for Pb analysis. Ten grams of air-dried soil samples were added with diethylene triamine penta acetic acid. The bottles then were transferred to a horizontal shaker for two hours at a speed of 120 cycles per minute. The soil suspension was filtered using Whatman # 42. The filtrate was then transferred to an acid-washed polyethylene bottle, stored in the refrigerator until required for Pb analysis. Soil and plant analyses of Pb were conducted at the Science and Research Institute of De La Salle University, Taft Avenue, Manila.

2.3 Experimental design and data analysis

This study was laid-out following the principles of a 3 x 2 factorial experiment in a completely randomized design with three replications per treatment combinations. The following were the experimental treatments:

Factor A (Type of grass)	Factor B (Amount of Pb added to soil) *
A1 = Vetivergrass	B1 = 75 mg kg^{-1} (37.5 kg ha^{-1})
A2 = Cogongrass	B2 = 150 mg kg^{-1} (75 kg ha^{-1})
A3 = Carabaograss	

* The soil used in the study contained 1.55 mg kg^{-1} of Pb (n = 20), which is within the natural concentration of Pb in most mineral soils of 5-25 ug g^{-1}. Because of the relatively low or negligible concentration of Pb in the soils that were used for the study, control treatment was not added in Factor B. With or without the control treatment, the results may not be different from the results being reported in this study.

The effects of Pb addition on survival rate, vegetative characteristics and uptake of three grass species were analyzed statistically following the PROC GLM (two-way) procedures (SAS 2000). Where the F-test indicated a significant ($p \leq 0.05$) effect, means were separated, following the method of the LSD test, using appropriate mean squares (SAS 2000).

3   Results and Discussion

3.1   Survival rate

Survival of plants differ significantly (p ≤ 0.001) among the three grasses, but was not affected by the varying amount of Pb added to the soil, and the interactions between grass types and amount of Pb (**Table 1**). Among the grasses, vetivergrass recorded the highest percentage of plant survival of 97.5 ± 4.2% (**Table 2**). Survival rate of vetivergrass was statistically comparable with the survival rate of carabaograss (87.5 ± 11.7%). Cogongrass registered the lowest plant survival rate of 52.5 ± 18.1%. For the effect of Pb added to the soils, results showed a comparable percentage plant survival across grass types at 75 and 150 mg Pb kg^{-1} with mean survival rates of 78.9 ± 19.9% and 79.4 ± 27.2%, respectively (see Table 2).

The comparably higher plant survival between vetivergrass and carabaograss was due to tolerance of vetivergrass and carabaograss to the presence of stress, which was the Pb added to the soils. This could also be attributed to the extraordinary features of vetivergrass having massive and deep root systems, aside from a tolerance to extreme climatic conditions including heavy metal toxicities. Similar findings were observed previously by Roongtanakiat and Chairoj (2001) who reported that vetivergrass was highly tolerant to an extremely adverse condition and could therefore be used for rehabilitation of mine tailings, garbage landfills and industrial waste dumps which are often extremely acidic or alkaline, high in heavy metals and low in plant nutrients.

The lower plant survival of cogongrass could be attributed to its characteristics by way of propagation. Cogongrass is creeping at the surface of the soil and rooting at nodes where new shoots develop at every rooted node. Carabaograss adapts very easily to the stress and developed resistance to Pb without harmful effects to its growth and development. This implies that vetivergrass and carabaograss were more tolerant to elevated Pb than cogongrass.

3.2   Plant dry matter yield (Herbage)

The whole plant dry weight was highly (p ≤ 0.001) influenced by the different types of grasses, but not by the amount of Pb applied nor affected by the interactions between grass types and Pb added to the soil (see Table 1). Among the three grasses harvested from soils treated with 75 and 150 mg Pb kg^{-1}, vetivergrass recorded the highest plant dry matter yield of 33.85 Mg ha^{-1} and 39.39 Mg ha^{-1}, respectively (**Fig. 2**). Carabaograss had the lowest plant dry matter yield that ranged from 4.12 Mg ha^{-1} to 5.72 Mg ha^{-1} from soils treated with 75 and 150 mg Pb kg^{-1}, respectively (see Fig. 2). Grasses planted in soil with 75 mg Pb kg^{-1} had an average plant dry matter yield of 15.87 Mg ha^{-1} compared with the average dry matter yield of 18.51 Mg ha^{-1} for grasses that were harvested from soils with 150 mg kg^{-1} of Pb. This implies that the plant dry matter yield of the three grasses was not affected by the levels of Pb addition in the soil.

Vetivergrass produced the highest plant dry matter yield (see Fig. 2). This could be attributed to its massive and extensive root system, and heavier root and shoot biomass. It also had a higher number of leaves and a high percent increase in height, as well as a significantly higher survival rate (see Table 2). This plant, which is fast growing and can survive in harsh environment, is versatile and hardy, and tolerant to extreme soil conditions including high metal concentrations. Normally, vetivergrass can produce approxi-

Table 1: F-values and levels of significance

Sources of variation	Plant survival (%)	Plant dry matter yield (Mg ha^{-1})	Pb levels in whole plants (mg kg^{-1})	Plant uptake of Pb (kg ha^{-1})
Grass (**G**)	18.00 [b]	181.57 [a]	77.20 [a]	85.49 [a]
Lead (**L**)	0.01 [c]	3.28 [c]	1.54 [c]	0.43 [c]
G x L	0.48 [c]	1.01 [c]	3.57 [c]	0.70 [c]
Model	7.39 [b]	73.69 [a]	32.62 [a]	34.56 [a]

[a] significant at p ≤ 0.0001
[b] significant at p ≤ 0.001
[c] not significant

Table 2: Plant survival (%) and levels of Pb absorbed by whole plants (roots + shoots) of vetivergrass, cogongrass and carabaograss at planting and at harvest

Grass types	Plant survival (%)	Initial levels of Pb at planting (mg kg^{-1})	Levels of Pb adsorbed (mg kg^{-1})
Vetivergrass	97.50±4.2 [a§]	0.91	10.16±2.81 [a]
Cogongrass	52.50±18.1 [b]	0.55	2.34±0.52 [b]
Carabaograss	87.50±11.7 [a]	0.01	0.49±0.56 [c]
LSD$_{0.05}$	**17.2**		*1.8*

[§] Means in respective column with the same letter(s) are not significantly different at 5% level of significance
[a] significant at p ≤ 0.0001
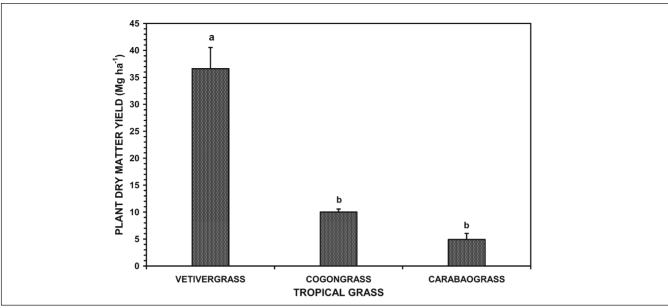[b] significant at p ≤ 0.001
[c] not significant

Fig. 2: Plant dry matter yield of three grasses grown in soils amended with Pb. Plant dry matter yields are significantly different (p ≤ 0.05) when superscripts located at top of bars are different

mately 16.43 Mg to 32.14 Mg ha^{-1} of dry matter yield. Herbage yield of vetivergrass under fertile and moist conditions can be as high as 100 Mg ha^{-1} (Mekonnen 2000). It can survive in harsh environments and is highly tolerant to extreme soil conditions (Roongtanakiat and Chairoj 2001, Chen 2000, Truong 1999, Knoll 1997, Randolff et al. 1995). The significantly lower whole plant dry matter yield of cogongrass and carabaograss could be attributed to their lower root and shoot biomass (data not reported). According to Johnson and Shilling (1998), cogongrass can produce 18.50 Mg ha^{-1} of dry matter, while a yield of 19.00 Mg ha^{-1} can be obtained from carabaograss, which are significantly lower than the normal dry matter of vetivergrass (16.43–32.14 Mg ha^{-1}). These could be the reasons why vetivergrass had higher plant dry matter yields than cogongrass and carabaograss.

3.3 Pb uptake and concentration of Pb in plants

The levels of Pb in the plant tissues (roots + shoots) differ significantly (p ≤ 0.0001) among the three grasses, but were not affected by the varying amount of Pb added to the soil and the interactions between grass types and amount of Pb (see Table 1). Among the three grasses (averaged across soil Pb), the highest amount of Pb (10.2 ± 2.8 mg kg^{-1}) was observed from vetivergrass, followed by cogongrass with a mean concentration of 2.3 ± 0.5 mg kg^{-1} (see Table 2). Carabaograss had the lowest concentration of Pb (0.5 ± 0.6 mg kg^{-1}). The concentration of Pb in the tissues across type of grasses were 4.8 ± 2.5 mg kg^{-1} and 3.9 ± 2.6 mg kg^{-1} from soils treated with 37.5 kg ha^{-1} and 75 kg ha^{-1} of Pb, respectively.

The uptake of Pb vary significantly (p ≤ 0.001) among the types of grasses, but was not affected by addition of Pb in the soil. Interaction effect between grass types and levels of

Pb in soils did not significantly affect the uptake of Pb (see Table 1). Vetivergrass absorbed the highest amount Pb (31.7 ± 9.1 mg kg^{-1}) compared with cogongrass (2.3 ± 0.5 mg kg^{-1}) and carabaograss (0.3 ± 0.03 mg kg^{-1}). The average plant uptake (13.9 ± 2.9 mg kg^{-1}) of the three grasses from soils with 37.5 kg Pb ha^{-1} was statistically (p ≤ 0.05) comparable with the uptake of Pb from soils with 75 kg Pb ha^{-1}, with a mean Pb uptake of 12.3 ± 3.3 mg kg^{-1}. This implies a comparable amount of Pb absorbed by three grasses in both levels of Pb addition in soils.

The significantly higher amount of Pb absorbed by vetivergrass is attributed to its heavier biomass and robust long dense root system (Roongtanakiat and Chairoj 2001) compared with cogongrass and carabaograss (see Table 2). This further implies that a higher biomass of vetivergrass means a greater amount of Pb absorbed by the plant. Moreover, vetivergrass is more efficient in absorbing certain heavy metals and chemicals due to the capacity of its root system to reach greater depths and widths (Truong 1998). This result emphasizes the relationship between Pb accumulation and absorption and plant biomass in Pb extraction (Gray 2000). Gray (2000) claimed that the more biomass the plant has, the more metal it can accumulate, since the metal uptake is a function of the overall plant biomass. Randolff et al. (1995) claimed that vetivergrass is highly tolerant to extremely adverse condition that could be used for rehabilitation of mine tailings, garbage landfills and industrial waste dumps. These are high in heavy metals but low in plant nutrients, thus extremely acidic or alkaline.

Extensive root system denotes more contact to nutrients in soil, therefore a higher likelihood of nutrient absorption and Pb uptake. According to Gray (2000), the total amount of phytoremediation is correlated with the plant's total biom-

Table 3: Estimated total uptake and removal of Pb by vetivergrass, cogongrass and carabaograss

Grass types	Total uptake of Pb (kg ha^{-1})	Normalized uptake of Pb [†] (g kg^{-1})	Estimated Pb removal (%)
Vetivergrass	31.74±9.01 [a§]	0.85	62.2 [a]
Cogongrass	2.33±0.53 [b]	0.23	4.4 [b]
Carabaograss	0.27±0.03 [b]	0.05	0.5 [b]
LSD$_{0.05}$	*6.8*		*17.2*

[§] Means in respective columns with the same letter(s) are not significantly different at 5% level of significance

[†] Normalized uptake of Pb = total uptake of Pb (g) / total plant dry matter yield (kg)

[a] significant at $p \leq 0.0001$

[b] significant at $p \leq 0.001$

ass. This implies that the higher the biomass, the greater the Pb uptake. Combination of high metal accumulation and high biomass production results in the most metal removal from the soil. The uptake of beneficial metals by plants occurs predominantly by way of channels, pores, and transporters in the root plasma membrane. Plants characteristically exhibit a remarkable capacity to absorb what they need and exclude what they do not need. However, most vascular plants absorb toxic and heavy metals through their roots to some extent, though to varying degrees, from negligible to substantial. Sometimes, absorption occurs because of the chemical similarity between beneficial and toxic chemicals. Some plants utilize exclusion mechanisms, where there is a reduced uptake by the roots or a restricted transport of the metal from root to shoots (Baker 1981). Furthermore, an active growth of roots in soil brings more contact with fresh areas of the soil and ions, therefore creating a higher likelihood of further absorption and uptake (Bussler 1981). Root hairs play a very important role in water transport. Water moves many times more rapidly along a root hair (Slatyer 1987).

3.4 Removal of Pb from soil

The total uptake of Pb, normalized uptake of P and estimated removal of Pb by three grasses from soils amended with varying levels of Pb is shown in **Table 3**. The highest average Pb removal from soils of 62.2% and the highest normalized uptake of Pb (0.85 g kg^{-1}) were observed from vetivergrass. Cogongrass and carabaograss had 0.23 and 0.05 g kg^{-1} of normalized Pb uptake (see Table 3). Overall, vetivergrass had the highest Pb removal compared with cogongrass of 4.4% and carabaograss of 0.5% (see Table 3).

Again, vetivergrass had shown its superiority over cogongrass and carabaograss in terms of total Pb removal from soil. Although vetivergrass is not considered to be a hyper-accumulator plant (Troung 2000), it is believed that it is more efficient in absorbing heavy metals and chemicals due to the capacity of its root system to reach greater depths and widths (Troung 1998). This statement agrees with the present findings with vetivergrass having a significant uptake since, as previously mentioned, the roots had the most contact to soil. This is attributed to greater root biomass, root hairs, and the longer roots of vetivergrass. The use of the vetivergrass

can be cost effective, environment friendly, and could be a practical phytoremediation tool for the control and remediation of Pb-contaminated soil. It uses only the natural ability of the grasses to remove Pb from the contaminated soil. This can reduce the remedial costs and restore the habitat. It can be used as an alternative to the common methods to treat contaminants such as chemical treatment with chelating agents, deep burial or removal from site which are generally expensive, impractical, and at times impossible to carry out, as the volume of contaminated materials in many cases is very large.

4 Conclusions

The present study indicated that vetivergrass possessed many beneficial characteristics to remove Pb from contaminated soil. It was the most tolerant and could grow in soil contaminated with a high Pb concentration (75 kg Pb ha^{-1}). Cogongrass and carabaograss are also potential phytoremediators since they can absorb a small amount of Pb in soil, although cogongrass is more tolerant to Pb contaminated soil compared with carabaograss. The important implication of these findings is that vetivergrass can be used for phytoextraction on sites contaminated with high levels of heavy metals, particularly of Pb. It can be used to remove Pb, thus gradually reducing the contamination levels. It is difficult for anyone to avoid exposure to the presence of harmful heavy metal in the environment, particularly Pb, since most Pb concentrations found in the environment are the results of human activities. Through the use of grasses to phytoremediate Pb contaminated soil, human exposure to Pb will be lessened since Pb contributes to a variety of adverse health effects, especially in children. The use of grasses is a very cost effective, environmentally friendly and practical phytoremediation tool for the control and remediation of Pb contamination in soil.

5 Recommendations and Perspectives

High levels of Pb in localized areas are still a concern, especially in urban areas with high levels of traffic, near Pb smelters, battery plants, or industrial facilities that burn fuel ending up in water and soils. The grasses used in the study, and particularly vetivergrass, can be used to phytoremediate urban soil by planting the grasses in lawns and parks. This

will minimize the exposure of humans to the threat posed by the presence of Pb. Moreover, vetivergrass and cogongrass should be recommended to the local government units of highly urbanized areas to use these grasses by planting them in the center islands, highways, parks, lawns, along road-sides and open landscapes to remove or remediate the Pb that accumulates in soil. Likewise, it is recommended that the local government units would require the inclusion of planting these grasses as part of every project proposal and comprehensive development plan.

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