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Uptake Potential of Some Heavy Metals by Vetiver Grass

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ABSTRACT

The uptake potential of upland vetiver grass (*Vetiveria nemoralis*) ecotype Kamphaeng Phet and lowland vetiver grass (*Vetiveria zizanioides*) ecotypes Ratchaburi and Surat Thani, for different heavy metals was evaluated. Varying amounts of manganese (Mn), zinc (Zn), copper (Cu) cadmium (Cd) and lead (Pb) were applied to one-month old vetiver grass planted in pots. Vetiver grass plants were harvested at 60 and 120 days after the heavy metal application and the concentrations of the heavy metals in shoot and root parts were determined using atomic absorption spectrophotometry. The results indicated that at the concentrations tested, the heavy metals applied had no significant effect on growth of all vetiver grass ecotypes. Vetiver grass harvested at 120 days yielded more shoot dry matter than those harvested at 60 days. The Ratchaburi ecotype demonstrated significantly increased in root mass at the 120-day harvest. No obvious increase for Kamphaeng Phet and Surat Thani and no significant difference in root between these ecotypes mass were observed.

For the three vetiver grass ecotypes tested, the uptake of heavy metals was proportional to the concentration of the applied heavy metals. The Ratchaburi ecotype had the highest concentration of the heavy metals in shoots, except at the 120-day harvest, Pb concentration was significantly lower than that of the Kamphaeng Phet ecotype. The concentration of heavy metals in vetiver grass shoots harvested at 120 days was lower than that of the 60-day harvest due to dilution effects. However, heavy metal concentration in roots was increased from 60- to 120- day harvest. This may be due to the spatial limitations of the pot or the restricted translocation of heavy metals from roots to shoots which resulted in an accumulation of the heavy metals in the roots. Therefore, when utilizing vetiver grass for the phytoremediation of heavy metal contaminated soil, the above ground biomass should be regularly cut to stimulate regrowth and the translocation of heavy metals to shoots.

Key words: vetiver grass, heavy metals, manganese, zine, copper, cadmium, lead

INTRODUCTION

Agricultural chemicals and off-site pollution from industrial areas are the potential sources of toxic substances that through mis-management may contribute significantly to soil contamination. At elevated levels, these toxic substances pose a significant risk to human and animal health and may cause phytotoxic reductions in crop yields. There are several methods to alleviate or prevent heavy metal diffusion to other sources. Recently, due to low management costs as compared with soil removal or replacement, there has been considerable interest in the use of plants to remove heavy metals from the soil (Chaney *et al*., 1997). Heavy metal-tolerant plants species are used for removing heavy metals from the soil and translocating them to the above ground biomass which is subsequently

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harvested and utilized. Vetiver grass has a long fibrous root system that penetrates deep into the soil. His Majesty the King, has initiated the use of vetiver grass, primarily for soil and water conservation. The harvested shoots and roots of vetiver grass can be used for roof thatching, soil mulching and handicrafts. Vetiver grass can tolerate extreme soil conditions including elevated levels of heavy metals (Troung, 1996; Troung and Baker, 1998; Zheng *et al*., 1998).

This research aims to evaluate the uptake potential of three vetiver grass ecotypes for Mn, Zn, Cu, Cd and Pb. Heavy metal concentrations in shoots and roots at 60 and 120 days after heavy metal application will also be investigated.

MATERIALS AND METHODS

Two pot experiments using 3¥5 factorial in Completely Randomized Design (CRD) with 3 replications were performed. Three vetiver grass ecotypes, Kamphaeng Phet upland ecotype and Ratchaburi and Surat Thani lowland ecotypes, were planted in pots containing 10 kg of Hupkaphong series sandy soil (coarse-loamy, siliceous isohyperthermic Ustoxic Dystripepts) with 0.8 % organic matter, 11 mg kg^{-1} available-P and 68 mg kg^{-1} extractable-K. The plants were fertilized with 15-15-15 fertilizer at 2.56 g pot^{-1}. Four levels of heavy metal salt solution consisting of $MnCl_2.4H_2O$, $ZnCl_2$, $CuCl_2.2H_2O$, $CdCl_2.2.5H_2O$ and $Pb(NO_3)_2$ were applied to one-month old vetiver grass (Table 1).

The shoot and root parts of vetiver grass in the experiment were harvested 60 days after the application of heavy metals, and then analyzed for heavy metal content using atomic absorption spectrophotometry (Baker and Amacher, 1982; Burau, 1982; Gambrell and Patrick, 1982). The second experiment followed the first one using the same pots and vetiver ecotypes with the same amount of the heavy metals applied. The plants were harvested at 120 days after the application of heavy metals and analyzed as previously mentioned.

RESULTS AND DISCUSSION

Vetiver grass growth

The vetiver grass can grow well on the soils contaminated with heavy metals. Increasing the amount of heavy metals applied to soils did not affect the growth and dry weight of the vetiver grass. The three vetiver grass ecotypes harvested 120 days after the application of heavy metals yielded higher shoot dry weight than those harvested 60 days after application (Figure 1). In general, dry root weight did not change throughout the experiment, except the Ratchaburi ecotype, which

Table 1 The amount of heavy metal salts (g) applied to vetiver grass grown in pots.

Heavy metal salt	Level of heavy metal salts[1/]				
	1	2	3	4	5
	Amount of heavy metal salts (g pot^{-1})				
$MnCl_2.4H_2O$	na	3.6024	7.2048	10.8072	14.4096
$ZnCl_2$	na	1.0423	2.0846	3.1269	4.1692
$CuCl_2.2H_2O$	na	0.2683	0.5366	0.8049	1.0732
$CdCl_2.2.5H_2O$	na	0.0102	0.0204	0.0306	0.0408
$Pb(NO_3)_2$	na	0.2398	0.4796	0.7194	0.9592

[1/] The amounts vary according to their toxicity.
na = no application.

showed significantly high dry root weight when cut at 120 days comparing to the Kamphaeng Phet and Surat Thani ecotypes (Figure 2). It seems that root growth was limited due to the confined area of the pot. In addition, the highest level (level 5) of applied heavy metals might not be phytotoxic to vetiver grass. Department of Land Development (1998) reported that Cd and Cu were toxic to vetiver grass at 10-20 and 50-100 mg kg^{-1} soil, respectively.

Heavy metal content in shoot

The concentration of heavy metals in shoots increased as the amount of the applied heavy metals increased. For both harvesting time, the Ratchaburi ecotype had significantly higher Mn and Zn concentrations as compared with the Kampheang Phet and Surat Thani. For all three ecotypes, the concentrations of Mn and Zn in the shoots harvested 60 days after application were higher than those harvested at 120 days, especially at the highest level or level 5 (Figures 3a and 3b).

The Ratchaburi ecotype had the highest shoot concentrations of Cu and Pb when havested at 60 days. For the 120-day harvest, the shoot concentrations of Cu and Pb decreased significantly. Similarly, the Kamphaeng Phet ecotype also had the highest concentration of Cu and Pb in shoots (Figures 3c and 3d).

The shoot concentration of Cd was very low ranging from 0-3 mg kg^{-1} and was detectable only at 60-day harvest while the 120 day harvest was undetectable. In all three ecotypes, there was no significant difference in shoot Cd concentration. However, the Ratchaburi ecotype had tendency to uptake more Cd than the other two ecotypes (Figure 3e).

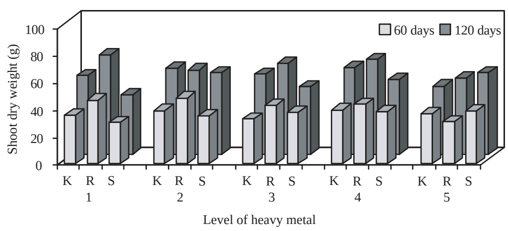

Figure 1 Shoot dry weight (g) of three vetiver grass ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soils contaminated with different levels of heavy metals, harvested at 60 and 120 days after application.

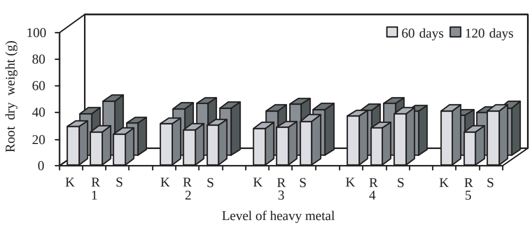

Figure 2 Root dry weight (g) of three vetiver grass ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soils contaminated with different levels of heavy metals, harvested at 60 and 120 days after application.

Heavy metal content in root

The concentration of heavy metals in roots increased as the amount of heavy metals applied to the soil increased. On the contrary, vetiver grass harvested at 120 days had higher heavy metal concentration in roots as compared with the 60-day harvest. At the 60-day harvest, for all three vetiver ecotypes, heavy metal concentrations were found to be higher in shoots as compared to roots. At the 120-day harvest, root heavy metal concentrations exceeded shoot concentrations. Therefore, more mature vetiver grass (120-day harvest) had higher heavy metal concentration in root. Among the three ecotypes, the Ratchaburi ecotype had the highest concentrations of Mn and Zn whilst the Surat Thani ecotype had the highest root concentrations of Cu, Cd and Pb. The Kamphaeng Phet ecotype had the lowest root concentration of these heavy metals (Figures 4a-4e).

As for the pot experiments, when vetiver plants were mature or had more top growth, the

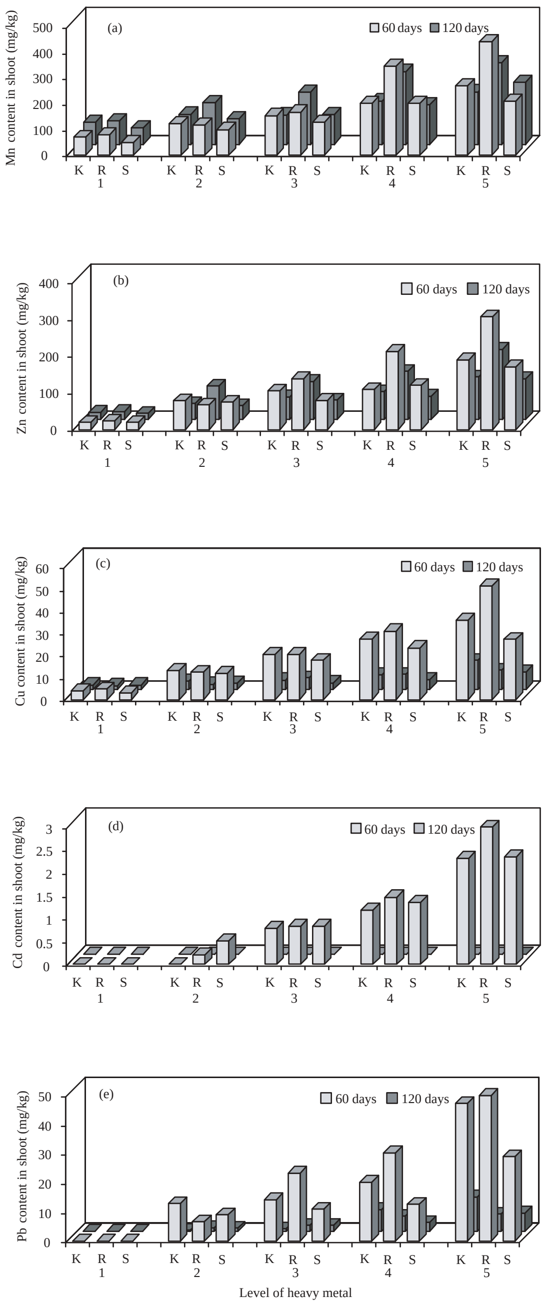

Figure 3 The concentration of Mn (a), Zn (b), Cu (c), Pb (d) and Cd (e) in shoot of three vetiver grass ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soils contaminated with different levels of heavy metals, harvested at 60 and 120 days after application.

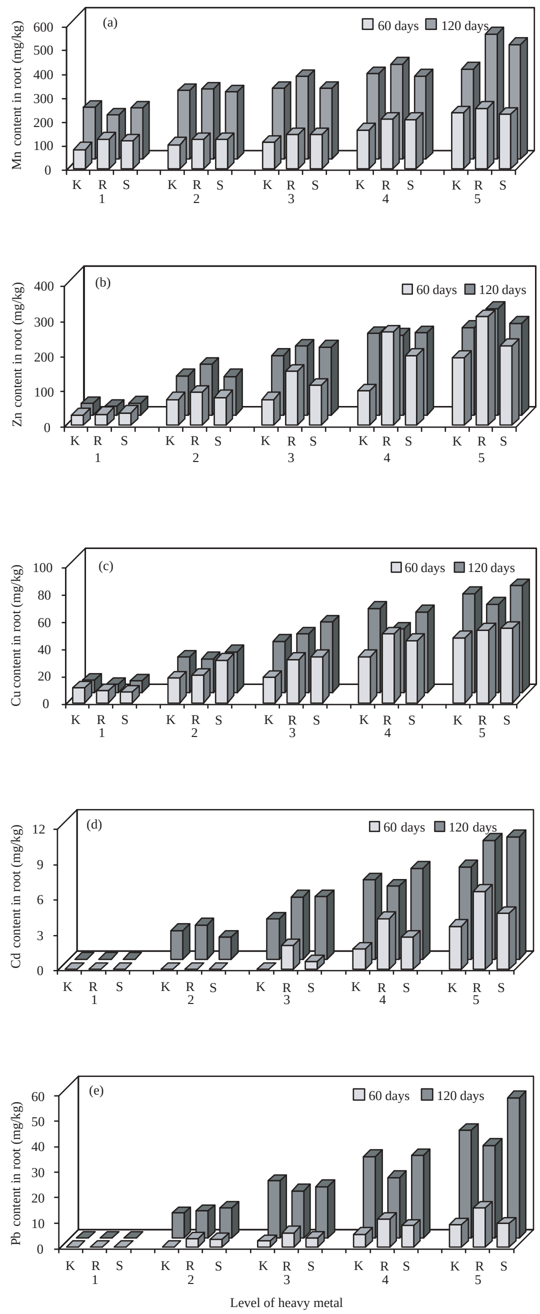

Figure 4 The concentration of Mn (a), Zn (b), Cu (c), Pb (d) and Cd (e) in root of three vetiver grass ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soils contaminated with different levels of heavy metals, harvested at 60 and 120 days after application.

shoot heavy metal concentration decreased. This phenomenon is possibly due to dilution effects, whilst the root heavy metal concentration increased. This is also due to the spatial limitation of pot on root growth or mass, resulting in the accumulation of heavy metals in the roots, especially if there is a restricted translocation of heavy metals from roots to shoots. In order to use vetiver grass to alleviate soil contamination with heavy metals, regular shoot cuttings for various uses, every 3-4 months, are required. The new shoot growth will stimulate more translocation of heavy metal from root to shoot and more heavy metal absorption. Consequently, the amount or level of contaminated heavy metals in soil will be decreased.

CONCLUSION

The three vetiver grass ecotypes can grow in soil contaminated with high levels of toxic heavy metals. In general, the mature (120 days of age) vetiver grass can absorb more heavy metals. For the pot experiments, when vetiver plants were more mature, the shoot heavy metal concentration decreased possibly due to dilution effects, whilst the root heavy metal concentration increased. The reason behind is due to the spatial limitation of pot on root growth or the restricted translocation of heavy metals from roots to shoots, thus resulting in the accumulation of heavy metals in the roots.

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