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 heavy metal application and the concentrations of heavy metals in shoot and root parts determined by atomic adsorption spectrophotometry. The results indicate that at the concentrations tested, the heavy metals applied had no significant effect on the growth of the vetiver grass ecotypes tested. Vetiver grass harvested at 120 days yielded more shoot dry matter than those harvested at 60 days. However, with the exception of the Ratchaburi ecotype, which demonstrated increased root mass at the 120-day harvest, no significant difference in root mass was observed between ecotypes.

In general, for the three-vetiver grass ecotypes tested, heavy metal uptake was inversely proportional to the concentration of heavy metals applied. The Ratchaburi ecotype had the highest shoot concentration of heavy metals as compared with the Kamphaeng Phet and Surat Thani ecotypes, except at the 120-day harvest, in which Pb concentration was significantly lower than that of the Kamphaeng Phet ecotype. The shoot concentration of heavy metals in vetiver grass harvested at 120 days was lower than that of the 60-day harvest due to dilution effects. However, heavy metal concentration in roots increased from 60-120 days. This may be due to the spatial limitations of the pot or the restricted translocation of heavy metals from roots to shoots thus resulting in the accumulation of heavy metals in the roots. Therefore, when using vetiver grass for the phytoremediation of heavy-metal-contaminated soils, the above surface biomass should be regularly cut to stimulate re-growth and the translocation of heavy metals to shoots.

Introduction

Agricultural chemicals and offsite pollution from industrial areas are potential sources of toxic substances which, through mismanagement, may contribute significantly to soil contamination. At elevated levels, these toxic substances pose a significant risk to human and animal health and may cause phototoxic reductions in crop yields. There are many 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 plant species are used to remove heavy metals from the soil and relocate them to above-ground plant biomass which is subsequently harvested and used. Vetiver grass sp. has a long fibrous root system that penetrates deep into the soil. His Majesty the King 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 handicraft. Vetiver grass can tolerate extreme soil conditions, including elevated levels of heavy metals (Troung et al. 1996; Troung and Baker 1998; Zheng et al. 1998).

This research aims to evaluate the potential of three vetiver grass ecotypes to uptake 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.

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Material and Methods

Two pot experiments using 3 x 5 factorial in complete randomized block design (CRD) with three 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 heavy-metal application and analysed for heavy-metal content using atomic absorption spectophotometry (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 heavy-metal application and analysed as previously mentioned.

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

Heavy metal salt	Heavy metal levels g pot[1/]				
	1	2	3	4	5
$MnCl_2.4H_2O$	-	3.6024	7.2048	10.8072	14.4096
$ZnCl_2$	-	1.0423	2.0846	3.1269	4.1692
$CuCl_2.2H_2O$	-	0.2683	0.5366	0.8049	1.0732
$CdCl_2.2.5H_2O$	-	0.0102	0.0204	0.0306	0.0408
Pb $(NO_2)_2$	-	0.2398	0.4796	0.7194	0.9592

- No application
[1]/ Amounts vary according to their toxicity

Results

Vetiver Grass Growth

Vetiver grass can grow well even on soil contaminated with heavy metals. Increasing the amount of heavy metal applied to soil did not affect the growth and dry weight of vetiver grass. The three vetiver grass ecotypes harvested 120 days after heavy-metal application yielded more shoot dry weight than those harvested 60 days after application. Dry root weight did not increase as age increased, except in the Ratchaburi ecotype, in which significantly higher dry root weight values were obtained from the 120-day harvest than with the Kamphaeng Phet and Surat Thani ecotypes. It seems that root growth was limited due to the confined area of the growing pot. In addition, the highest level (level 5) of heavy metal applied might not be phytotoxic to vetiver grass. Cd and Cu were toxic to vetiver grass at 10-20 and 50-100 mg kg^{-1} soil respectively (Anon. 1998)

Heavy Metal Content in Shoot

Shoot heavy-metal concentration increased as the amount of heavy metal applied to the soil increased. In both harvests, the Ratchaburi ecotype had a significantly higher shoot concentration of Mn and Zn than the Kampheang Phet and Surat Thani ecotypes. For all three ecotypes, the shoot concentrations of Mn and Zn in vetiver harvested 60 days after application were higher than the shoot concentrations at the 120-day harvest, especially at the highest level of heavy-metal application.

The Ratchaburi ecotype had the highest shoot concentration of Cu and Pb when vetiver grass was harvested on Day 60. For the 120-day harvest, the shoot concentration of Cu and Pb decreased significantly. The Kampheang Phet ecotype had the highest shoot concentrations of Cu and Pb.

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

Heavy Metal Content in Root

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

Conclusion and Discussion

The three vetiver grass ecotypes could be grown in soil contaminated with high levels of toxic heavy metals. In general, more mature vetiver grass can absorb more heavy metals. For the pot experiment conducted, when vetiver plants are more mature, the shoot heavy-metal concentration decreases, possibly due to dilution effects whilst the root heavy-metal concentration increases. This may be due to the pot-induced spatial limitation on root growth or the restricted translocation of heavy metals from roots to shoots resulting in the accumulation of heavy metals in the roots. For an effective use of vetiver grass to alleviate soil contamination, shoot cutting every 3-4 months is essential. The new shoot growth will stimulate more translocation of heavy metals from root to shoot and more heavy-metal absorption.

References

Anon. 1998. Special characteristics of vetiver grass useful to soil and water conservation system, natural resources and environmental rehabilitation. *In:* Vetiver Grass Overview. Land Development Department, Ministry of Agriculture and Cooperative, Bangkok, Thailand.

Baker, D.E.; and Amacher, M.C. 1982. Nickel, copper, zinc and cadmium. *In:* A.L. Page, R.H. Miller and D.R. Keeney (Eds.) Methods of Soil Analysis, Part 2, pp. 323-336. Amer. Soc. Agron., Madison, Wisconsin, USA.

Burau, R.G. 1982. Lead. *In:* R.H. Miller and D.R. Keeney (Eds.) Methods of Soil Analysis, Part 2, pp. 347-365. Amer. Soc. Agron., Madison, Wisconsin, USA.

Chaney, R.L.; Malik, M.; Li, Y.M.; Brown, S.L.; Angle, J.S.; and Baker, A.J.M. 1997. Phytoremediation of soil metals. Current Opinions in Biotechnology 8: 279-284.

Gambrell, R.P.; and Patrick, W.H., Jr. 1982. Manganese. *In:* A.L. Page, R.H. Miller and D.R. Keeney (Eds.) Methods of Soil Analysis, Part 2, pp. 313-322. Amer. Soc. Agron., Madison, Wisconsin, USA

Truong, P.V.; Gordon, I.; and Baker, D. 1996. Effect of heavy metal toxicities on vetiver growth. Contributed paper presented at ICV-1, Chiang Rai, Thailand, 4-8 Feb. 1996.

Truong, P.N.; and D. Baker. 1998. Vetiver grass for the stabilization and rehabilitation of acid sulphate soils, pp. 196-198. Proc. 2nd Nat. Conf. Acid Sulphate Soils. Coffs. Harbour. Australia.

Zheng, C.R.; Tu, C.; and Chen, H.M. 1998. A preliminary study on purification of vetiver for eutropic water. *In:* Vetiver Research and Development, pp. 81-84. China Agricultural Science and Technology Press, Beijing, China.