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Vetiver Grass for the Remediation of Soil Contaminated with Heavy Metals

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ABSTRACT

Three vetiver grass ecotypes, Kamphaeng Phet, Ratchaburi and Surat Thani were planted in soil supplemented with different amounts of manganese (Mn), zinc (Zn), copper (Cu), cadmium (Cd) and lead (Pb). It was found that these heavy metals did not affect the growth of the vetiver grass, even though the uptake amount increased as the applied amount increased. Ratchaburi ecotype gave the highest shoot dry weight and lowest root weight and at the same time had significantly higher Mn, Zn and Cd amounts in shoots than Surat Thani and Kamphaeng Phet ecotypes. However, Ratchaburi and Kamphaeng Phet ecotypes showed similar copper uptake. The root of Ratchaburi ecotype could also absorb significantly higher amounts of Zn, Cd and Pb than those of Surat Thani and Kamphaeng Phet ecotypes. For Mn and Cu, Ratchaburi and Surat Thani ecotypes could uptake more than those of Kamphaeng Phet.

As expected, the residual heavy metal in soil increased as the applied amount increased. The soil planted with Ratchaburi vetiver ecotype had less residual heavy metals than that planted with the other two ecotypes since it absorbed more heavy metals. Therefore, this specific ecotype would be useful for remedying soil contaminated with heavy metals.

Key words: Vetiver, heavy metals, remediation

INTRODUCTION

Vetiver (*Vetiveria zizanioides* (Linn.) Nash) belongs to the same grass family as maize, sorghum, sugarcane and lemon grass. There are several unique characters of vertiver as reported by the Land Development Department (1998), the National Research Council (1993) and the Office of Royal Development Projects Board (2000). Internationally, vetiver is well known as a useful agent for erosion control because of its steady straight shoot and robust long dense root system. In Thailand, His Majesty the King Bhumipol Adulyadet has initiated and supported the use of vetiver for soil and water conservation since 1991. The subsequent results clearly affirmed that vetiver can be used according to His Majesty's initiative, and the application activities on its uses have been promoted.

The global problem concerning contamination of environment as a consequence of human activities is increasing. Most of the environmental contaminants are chemical by-products and heavy metals. 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. Heavy metals accumulated in soil can affect flora, fauna and human living in the

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vicinity or downstream of the contaminated sites. Methods used for decontamination have often been done by chemical treating the contaminants, burying and removing them from the site. These methods are expensive and difficult to carry out as the volume of contaminated materials in most cases is very large. Phytoremediation is an alternative method that uses plants to clean up a contaminated area. It is relatively easy to implement, and also can reduce remedial cost and restore the habitat. However, the plant species used in this means must grow well in toxic level of heavy metal condition and can produce high biomass. As vetiver was found to be highly tolerant to extreme soil conditions including heavy metal contamination (Truong and Baker, 1998), therefore, the experiment was conducted to compare three Thai native vetiver ecotypes on their abilities to tolerate toxic levels of manganese (Mn), zinc (Zn), copper (Cu), cadmium (Cd) and lead (Pb) and on the ability to accumulate these heavy metals in shoots and roots. The subsequent result is expected to be further developed as an effective and low-cost method to alleviate heavy metal contamination in the environment.

MATERIALS AND METHODS

The pot experiment was carried out at the Department of Applied Radiation and Isotopes, Faculty of Science, Kasetsart University, using a 3×5 factorial experiment in Completely Randomized Design (CRD) with 3 replications. Three Thai native vetiver ecotypes were used in the experiment: Surat Thani, Kamphaeng Phet and Ratchaburi vetiver. These three ecotypes are naturally grown in a wide range of land condition from low land to high land (Land Development Department, 1998 and Office of the Royal Development Projects Board, 2000). The vetiver seedlings from the tissue culture laboratory at the Department of Botany, Kasetsart University, were planted in pots containing 10 kg of Hupkaphong series sandy soil (coarse-loamy, siliceous isohyperthermic Ustoxic Dystripepts). The 0-15 cm layer of the soil has pH 5.5 (1:1, H_2O:soil), 0.8 % organic matter (Walklay and Black, 1934), 0.77 mineral-N (NH_4^+ + NO_3^-) (Bremner, 1965), 11 mg kg^{-1} available P (Bray and Kurtz, 1945) and 68 mg kg^{-1} extractable K (Knudsen *et al*., 1982) and CEC of 4.38 meq/100 g (Jackson, 1958). The plants were grown outdoors under natural daylight and fertilized with 15-15-15 fertilizer at 2.56 g pot^{-1}. Five 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 given to one-month vetiver (Table 1).

The increment in height of vetiver plant was investigated monthly. Three months after the application of heavy metals, vetiver plants were harvested. The heavy metal content in shoot and root parts and those remained in soil was analyzed using atomic absorption spectrophotometry (Baker and Amacher, 1982; Burau, 1982; Gambrell and

Table 1 Concentration of heavy metal (mg kg^{-1}) added in five levels to soil used in the experiment.

Heavy metal	Level of heavy metals				
	1	2	3	4	5
Mn	0	100	200	300	400
Zn	0	50	100	150	200
Cu	0	10	20	30	40
Cd	0	0.5	1	1.5	2.0
Pb	0	15	30	45	60

Patrick, 1982). Data were statistically analyzed using analysis of variance and Duncan's Multiple Range Test for mean comparison. A probability level of $P< 0.05$ was considered for significant difference.

RESULTS AND DISCUSSION

Vetiver growth in contaminated soil

It was found that all three vetiver ecotypes could grow well in the soil contaminated with heavy metals as shown in Figures 1 and 2. There was an increase in plant height until harvest three months after heavy metals added. However, the vetiver height of Surat Thani ecotype was significantly greater than those of Kamphaeng Phet and Ratchaburi ecotypes. The different amounts of heavy metals added showed no significant difference concerning vetiver height (Figure 1).

As for shoot and root dry weight, there was

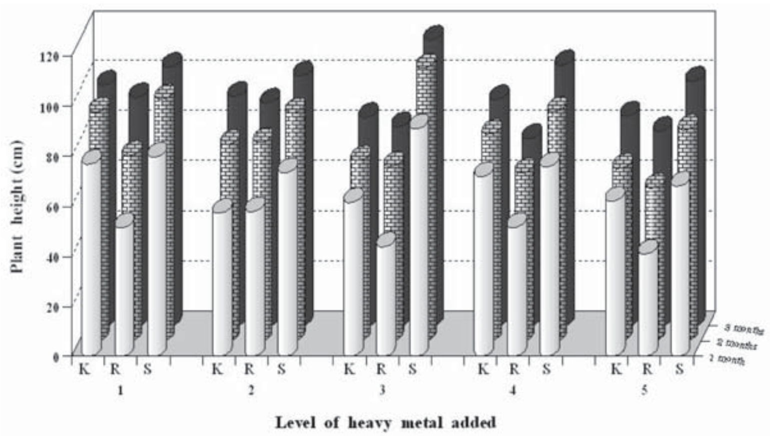

Figure 1 Height (cm) of three vetiver ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soil contaminated with heavy metals added in 5 levels, taken at 1, 2 and 3 months after application.

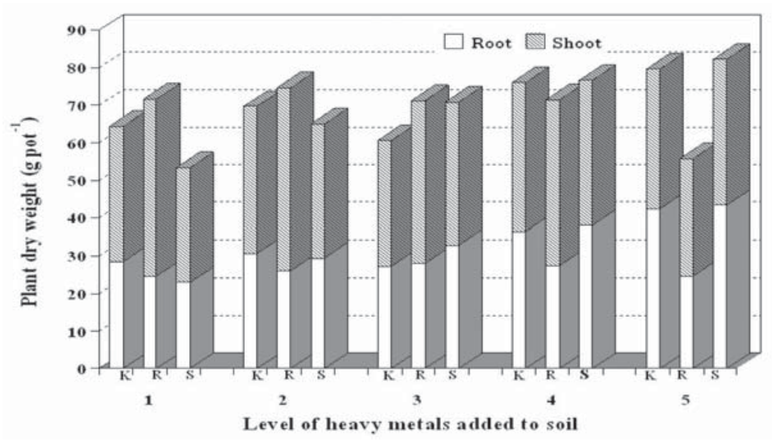

Figure 2 Plant (shoot and root) dry weight (g pot^{-1}) of three vetiver ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soil contaminated with heavy metals added in 5 levels, harvested at 3 months after application.

no significant difference among vetiver ecotypes regarding shoot dry weight. Ratchaburi ecotype gave the highest shoot dry weight but lowest root weight comparing to those of the other two ecotypes. Surprisingly, root dry weight increased as concentration of heavy metals in soil increased except that of Ratchaburi. Vetiver grown in soil with the highest heavy metal level gave a root dry weight significantly higher than those of levels 1-3. However, vetiver ecotypes and amounts of the heavy metals added had no significant effect on the total dry matter yield of vetiver (Figure 2).

It might be concluded that heavy metals in soil even at the level above critical value to plant growth had no negative effect on vetiver growth. This finding was similar to the results of Troung (1999), Roongtanakiat and Chairoj (2001).

Concentration of heavy metals in vetiver shoots and roots

In general, vetiver could take up more amounts of heavy metals when there were plenty of heavy metals in the soil (Figures 3 and 4). It was found that Ratchaburi vetiver ecotype took up significantly higher concentrations of manganese, zinc and cadmium in shoot than those in Surat Thani and Kamphaeng Phet ecotypes. The copper and lead concentrations in shoot of Ratchaburi and Kamphaeng Phet ecotypes were not different. They were higher than those in Surat Thani ecotype (Figure 5). It might be concluded that vetiver ecotype was a factor influencing heavy metal uptake variation. Alloway (1997), Baker and Senft (1997) reported that plant species as well as cultivars differ widely in their uptake ability and accumulation of heavy metals.

The average highest heavy metal concentrations in the shoot of the three vetiver ecotypes for cadmium, lead, zinc and manganese were 2.9, 55.1, 253.8 and 299.5 mg kg^{-1}, respectively. They were lower than the toxic threshold levels in vetiver shoot except for that of copper (46.6 mg kg^{-1}) that was higher than the toxic threshold level (13-15 mg kg^{-1}) (Truong, 1999). The low pH (5.4) of soil in this study might cause the increase in copper absorption as reported by Baker and Senft (1997) that a decrease in pH enhances Cu^{2+} absorption by plant root.

In vetiver roots, Ratchaburi ecotype could accumulate the highest amount of heavy metals.

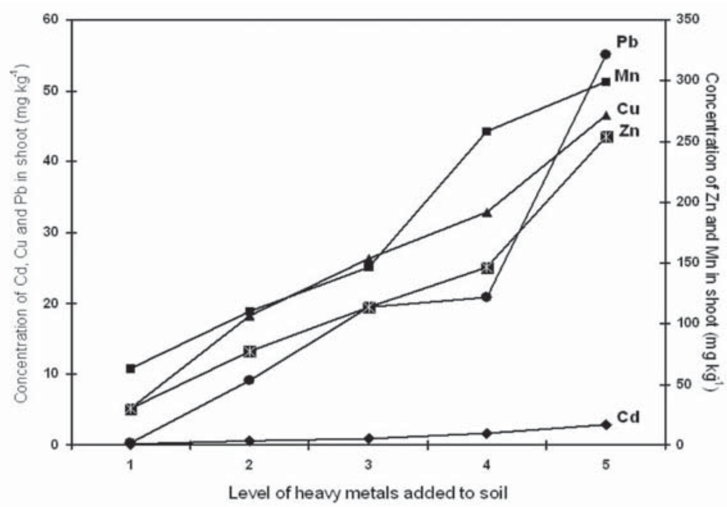

Figure 3 Concentrations of Cd, Cu, Pb, Mn and Zn in shoots of vetiver planted in soil contaminated with heavy metals added in 5 levels.

There were significantly higher concentrations of zinc, cadmium and lead in Ratchaburi ecotype compared to those found in Surat Thani and Kamphaeng Phet ecotypes. The concentrations of manganese as well as copper in root of Ratchaburi and Surat Thani ecotypes were not different, but the two ecotypes had higher concentrations of manganese and copper than those in the Kamphaeng Phet ecotype (Figure 6).

Comparing the distribution of heavy metal concentrations in shoot and root parts, zinc, copper and manganese were almost evenly distributed. However, lead was translocated more to shoot while cadmium was accumulated more in root. Our result was agreeable with Troung's report (Troung, 1999) on the distribution of zinc and cadmium. He found that a small amount of cadmium and a moderate proportion of copper and lead were

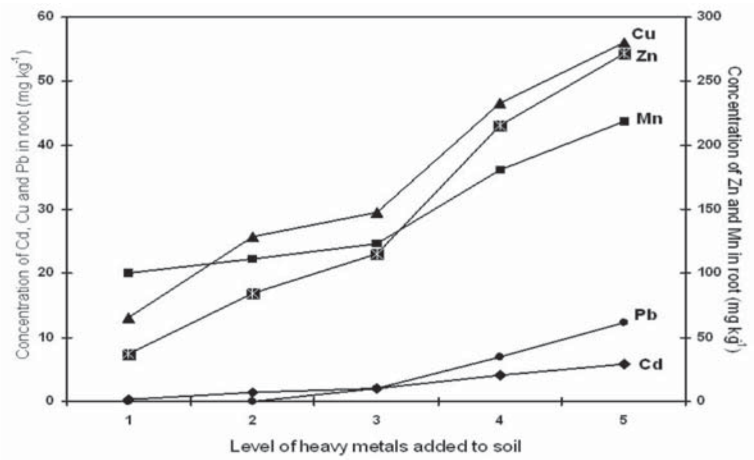

Figure 4 Concentrations of Cd, Cu, Pb, Mn and Zn in roots of vetiver planted in soil contaminated with heavy metals added in 5 levels.

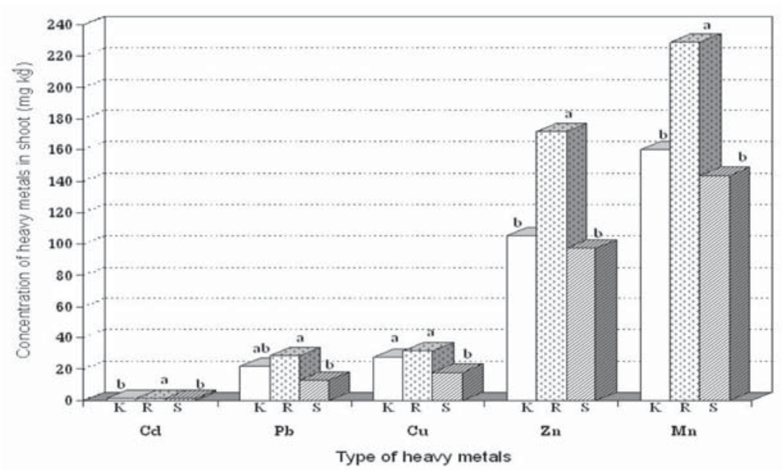

Figure 5 Concentrations of Cd, Cu, Pb, Mn and Zn in the shoots of three vetiver ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soil contaminated with heavy metals added in 5 levels.

translocated to the shoot, while zinc was evenly distributed in shoot and root. These finding suggested that the vetiver ecotypes as well as the soil type could cause the difference in heavy metal distribution in vetiver plants. The season of planting should also be considered as a factor effecting heavy metal uptake as reported by Devies (1997).

The remaining heavy metals in soil

After harvesting, the soils were analyzed for the remaining heavy metals. It was found that there were more heavy metals remained in the soil of higher level added (Figure 7). The soil of Ratchaburi vetiver ecotype had lower heavy metals remained than those of other two ecotypes as the result of its high heavy metal uptake.

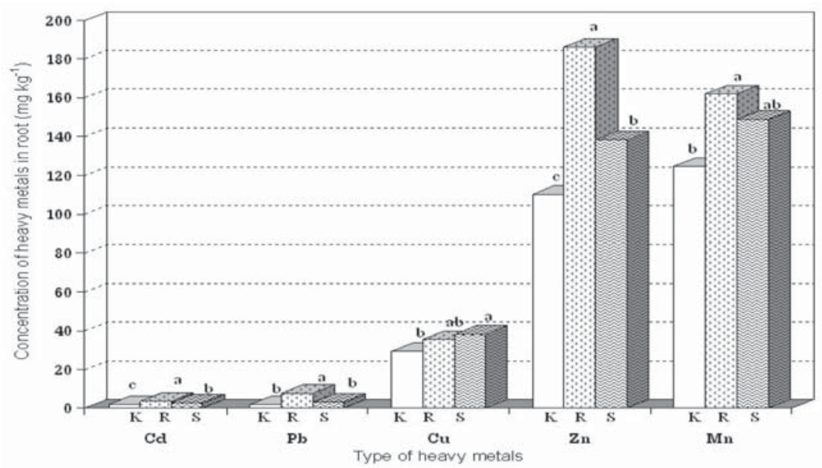

Figure 6 Concentrations of Cd, Cu, Pb, Mn and Zn in the roots of three vetiver ecotypes (Kamphaeng Phet, K; Ratchaburi, R; Surat Thani, S) planted in soil contaminated with heavy metals added in 5 levels.

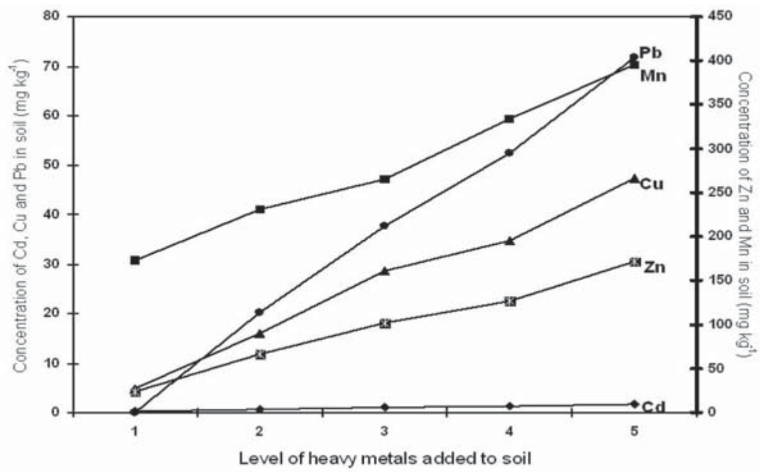

Figure 7 Concentrations of Cd, Cu, Pb, Mn and Zn remaining (after vetiver harvest) in soil contaminated with heavy metals added in 5 levels.

CONCLUSION

The results from the pot experiment demonstrated that vetiver of Ratchaburi ecotype had a high potential in absorbing heavy metals contaminated in soil.

Although vetiver is not a hyper-accumulator, it has been found to be highly tolerant to extremely adverse soil conditions. Therefore, vetiver could 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. Planting vetiver in rows or contour on the side slopes could prevent contamination of heavy metals in adjacent area polluted by erosion, leachate and runoff problems. The vetiver shoot should be cut regularly in order to stimulate their growth into thick clumps. Then heavy metals would be uptaken and translocated to the new shoot while contaminant level should be reduced gradually. Vetiver shoot and root could be disposed safely away from contaminated sites or be used as value-added material such as green fuel, handicraft product, roofing and mulching material.

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