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UPTAKE AND TRANSLOCATION OF ZINC AND CADMIUM BY *Ricinus communis* PLANTED IN SEWAGE SLUDGE CONTAMINATED SOIL

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ABSTRACT

An estimated 5 million m^3 of sewage sludge is produced annually in Malaysia. By 2020 it is expected to increase to 7 million m^3. Phytoremediation is a method using plants to reduce soil contamination. An experiment was conducted to evaluate the potential of *Ricinus communis* as a phytoremediator. A greenhouse study was conducted at Universiti Putra Malaysia. Treatments (soil + sewage sludge) were: T1 (100% soil, control), T2 (25% sewage sludge + 75% soil), T3 (50% sewage sludge + 50% soil), T4 (75% sewage sludge + 25% soil) and T5 (100% sewage sludge). Cd and Zn concentrations were analyzed using atomic absorption spectrophotometer (AAS), texture by the pipette gravimetric method, pH by glass electrode pH meter and total carbon by CHNS analyzer. Cd was highly concentrated in the stems (0.29 ppm) while Zn in the leaves (43.29 ppm). The highest translocation factor for Cd was in treatment T4 (3.53) while for Zn in treatment T3 (2.18). The highest bioconcentration factor of Cd was in treatment T5 (0.21) while treatment T2 for Zn (0.69). This species was able to tolerate and accumulate high concentrations of Cd and Zn and can be used as a potential phytoremediator for sewage sludge contaminated soils to reduce soil pollution.

Key words: *Ricinus communis*, phytoremediation, sewage sludge, cadmium, zinc, translocation factor, bioconcentration factor

INTRODUCTION

It has been estimated that by 2020 Malaysia will produce about 7 million m^3 tons of sewage sludge a year. This is mainly due to uncontrolled development, urbanization and increase in population. The high production of sewage sludge without proper disposal will contribute to serious environmental problems. The total cost of managing sewage sludge is now about RM 1.07 billion per year (Kadir and Mohd, 1998). Sewage sludge is a product generated from municipal wastewater and it has been stabilized by adding chemicals to the waste to hasten decomposition and eliminate pathogens but heavy metal concentrations are still high. Heavy metals of potential hazards are Cd, Cr, Pb, Zn, Fe, and Cu (Akota *et al.,* 2008; Harrison and Alloway, 2001). They are also the most dangerous substances in the environment due to their durability and toxicity to organisms (Alkorta *et al*., 2004). Improper disposal of sewage sludge can cause soil contamination which results in environmental problems and reduce soil quality and can also affect human health. Soil composition and characteristics will be changed when contaminated with heavy metals. The environmental problems are associated with plant productivity, food quality and human health (Alloway, 1990). The use of plants to remediate contaminated soil is promising in terms of reducing disposal cost and more efficient compared to conventional methods. This study was initiated to: (1) determine Cd and Zn uptake and translocation in *Ricinus communis* and; (2) evaluate the potential of *Ricinus communis* as a phytoremediator to absorb Cd and Zn from sewage sludge contaminated soil.

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MATERIALS AND METHODS

The experiment was conducted over a four-month period in a greenhouse at Universiti Putra Malaysia. The average temperature of the greenhouse in the morning was 26°C, 36°C at noon and 30°C in the evening. The growth media is soil mixed with five levels of sewage sludge mainly: T1 = 100% soil, T2

= 25% sewage sludge + 75% soil, T3 = 50% sewage sludge + 50% soil, T4 = 75% sewage sludge + 25% soil, and T5=100% sewage sludge. Uniform and healthy seedlings of *Ricinus communis* were collected from Kuala Sawah, Negeri Sembilan. This species was chosen due to its hardiness, fast growing and produces high biomass. The experiment was laid out in a Complete Randomized Design (CRD) with four replications. Seedlings were transplanted into the pots after filling the pot with 10 kg growth medium based on the above combinations. Watering was done twice daily and weeding when necessary to ensure normal growth of seedlings. Soil samples before planting and at harvest were collected from each pot and air dried. At the end of the fourth month after planting, plant samples were collected, air dried and kept in plastic containers. Plant and growth media samples were analyzed for physical and chemical properties. The concentrations of Cd and Zn were analyzed using Atomic Absorption Spectrophotometer (AAS). Texture was analyzed using the pipette gravimetric method. Soil pH and total carbon were measured using glass electrode pH meter and CHNS analyzer, respectively. ANOVA test was done to detect any significant differences among treatments.

RESULTS AND DISCUSSION

Changes in soil properties of the growth media

The texture of the growth medium was clay loam while 100% sewage sludge was clay. There was a significant difference ($p \leq 0.05$) in soil pH before planting and at harvest. Total carbon before planting was also significantly different ($p \leq 0.05$) between the treatments. Percentage total carbon varied from 3.11% to 19.79%. Table 1 shows selected physical and chemical properties of the growth media.

Cd and Zn concentrations in the growth medium

Cadmium and zinc concentrations in the growth media were significantly different ($p \leq 0.05$) among treatments. Before planting, the concentrations of Cd among treatments were significantly different ($p<0.05$), ranging from 0.7 ppm to 1.7 ppm. T5 had the highest concentration of Cd (1.708 ppm) while the lowest was in T1 (0.693 ppm). It is apparent that T5 has the highest Cd since it is 100% sewage sludge. The pH is also very acidic (3.94) and this renders the heavy metals to be readily available for root absorption. Tsadilas *et al.* (2005) also reported similar results in their study when as pH decreased the amount of Cd increased due to increased bioavailability of the metal. Cadmium concentration decreased at harvest compared to before planting in all treatments (Fig. 1). At harvest it ranged from 0.45 ppm to 0.97 ppm and the highest was in T5 (0.97 ppm) and lowest in T1 (0.45 ppm). Similarly the concentrations of Zn were also significantly different ($p<0.05$) among treatments. Zn concentrations before planting ranged from 75.80 ppm to 240.49 ppm (Fig. 2). T5 had the highest Zn (240.49 ppm) while the lowest was in T1 (75.80 ppm). At harvest the concentration of Zn in all treatments decreased and this might be due to higher plant uptake. Zn concentrations at harvest ranged from 20.87 ppm to 74.49 ppm. The highest concentration was in T5 (74.49 ppm) and the lowest in treatment T1 (20.87 ppm). The results showed that Zn concentration in the growth medium decreased at harvest due to absorption by plant roots. Zn concentration also increased with increasing quantity of sewage sludge because higher amounts of sewage sludge contain more Zn but other factors mainly pH, texture, carbon also affected Zn availability. Xiong *et al.* (2005) also reported that when pH decreased the concentration of Zn in the soil increased indicating that the concentration of Zn is influenced by pH.

Cd and Zn concentrations in plant tissues

Cadmium accumulation in the plant parts was also significantly variable among treatments and plant parts (Fig. 3). The highest accumulation of Cd was in the stems followed by roots and the lowest in the leaves. Foliar Cd was highest in T5 (0.133 ppm) and lowest in T1 (0.037 ppm). In the stems the highest concentration of Cd was in T5 (0.286 ppm) and the lowest (0.077 ppm) in T1. In the roots the highest was in T5 (0.202 ppm) and lowest in T1 (0.083 ppm). Zinc accumulation in the plant parts was also significantly variable among treatments and plant parts. The highest accumulation of Zn was in the leaves followed by roots and stems (Fig. 4). This result was in accordance with that of Anongo *et al.* (2014) who reported that leaves accumulated more Zn compared to the stems and roots. Pal *et al.* (2013) stated that heavy metal uptake and

Table 1. Physicochemical properties of the control and contaminated sewage sludge

Growth medium	Texture	pH	Total C (%)	Total N (%)	Total P (%)	Total K (%)	Cd conc. (ppm)	Zn conc. (ppm)
Soil	Clay loam	5.34	3.11	0.40	0.002	0.003	0.69	75.80
Sewage sludge	clay	3.94	19.79	3.11	0.003	0.006	1.71	240.49

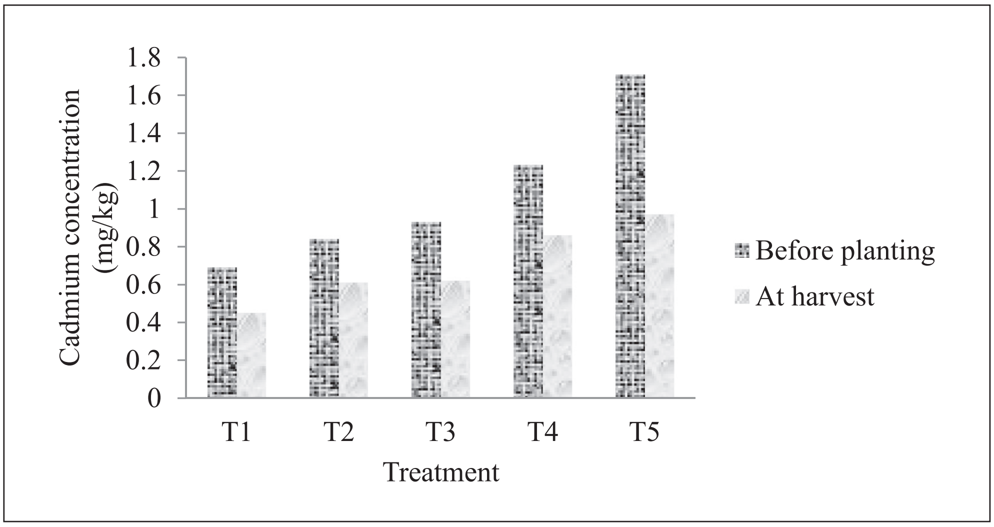

Fig. 1. Cadmium concentrations in growth medium

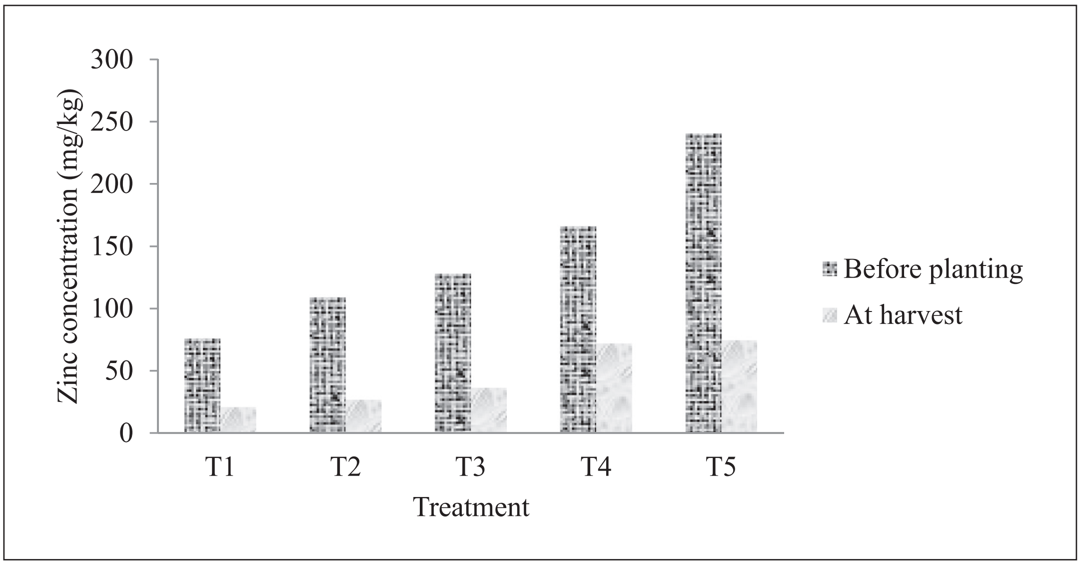

Fig. 2. Zinc concentrations in growth medium

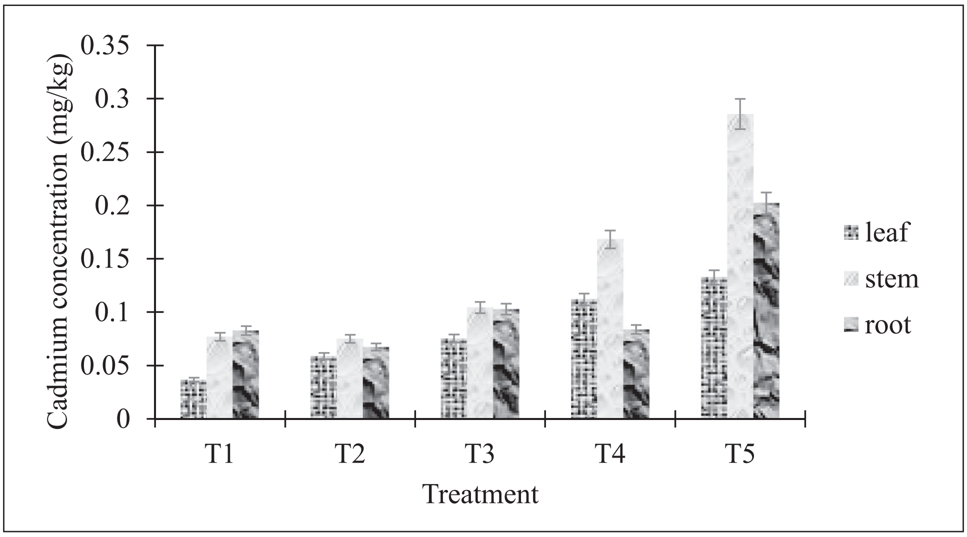

Fig. 3. Cadmium concentrations in plant tissues

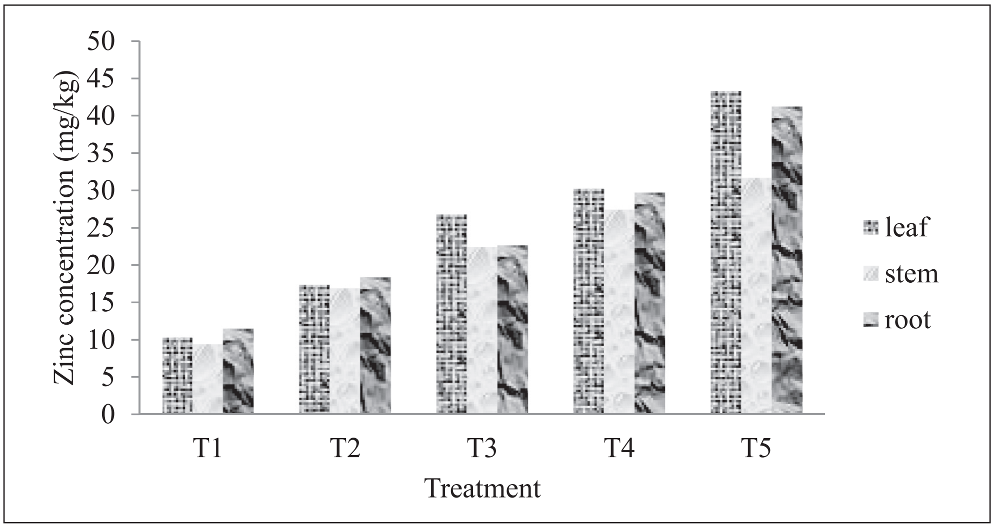

Fig. 4. Zinc concentrations in plant tissues

distribution differ among plant organs. Majid *et al.* (2011) also reported highest accumulation of zinc in the leaves followed by roots and the lowest in the stems which are similar to the results of this study. The highest foliar Zn was in T5 (43.29 ppm) and the lowest in T1 (10.29 ppm). In the stems the highest concentration of Zn was in T5 (31.66 ppm) and the lowest in T1 (9.42 ppm). The highest concentration of Zn in the roots was in T5 (41.19 ppm) and the lowest was in T1 (11.49 ppm). Zn is an important element for plant growth but at higher concentrations may cause toxicity and limit root and shoot growth (Fontes and Cox, 1998).

Bioconcentration factor and translocation factor

Bioconcentration factor (BCF) of cadmium and zinc is presented in (Fig. 5). In case of Cd the highest BCF value was in T5 (0.21) and the lowest was in T4 (0.10). For Zinc the highest BCF was in T2 (0.69) and the lowest was in T4 (0.41). In this study bioconcentration factor values were less than one which indicates that heavy metal concentrations in the roots were less than in the soil. It may be due to a saturation of Zn uptake from the root to the shoot when the internal concentration was high (Pence *et al.,* 2000). The highest translocation factor for Cd was in T4 (3.53) while the lowest in T1 (1.39) (Fig. 6). The highest translocation factor for Zn was in T3 (2.18) while the lowest in T1 (1.72). Bioconcentration factor and translocation factor are not affected by the increase in heavy metal concentration due to the restriction in soil-root and root-shoot transfer when the concentration of heavy metal in the soil is high. The results showed that the translocation factor for both heavy metals in all treatments were >1. This indicates efficient ability to transport metals from root to shoot and the existence of tolerance mechanisms to cope with high concentrations of metals (McGrath and Zhao, 2003).

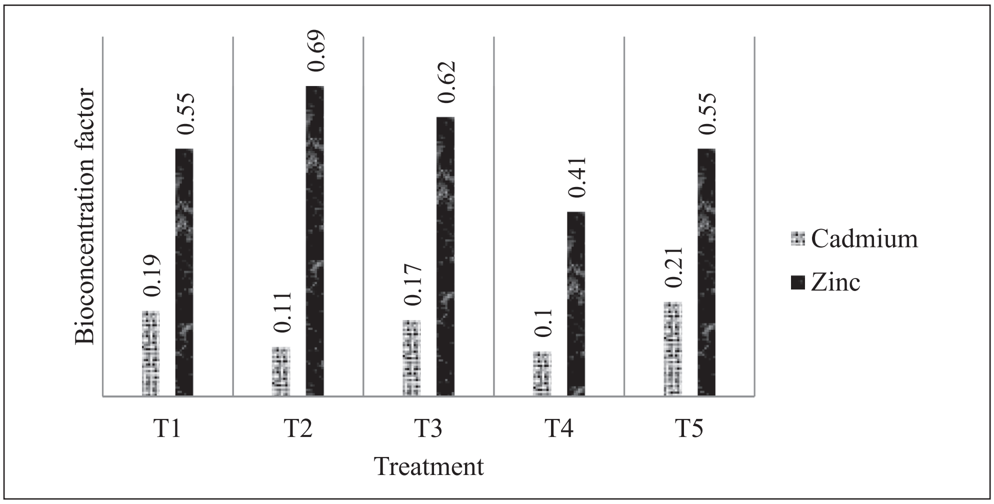

Fig. 5. Bioconcentration factor of cadmium and zinc in *Ricinus communis*

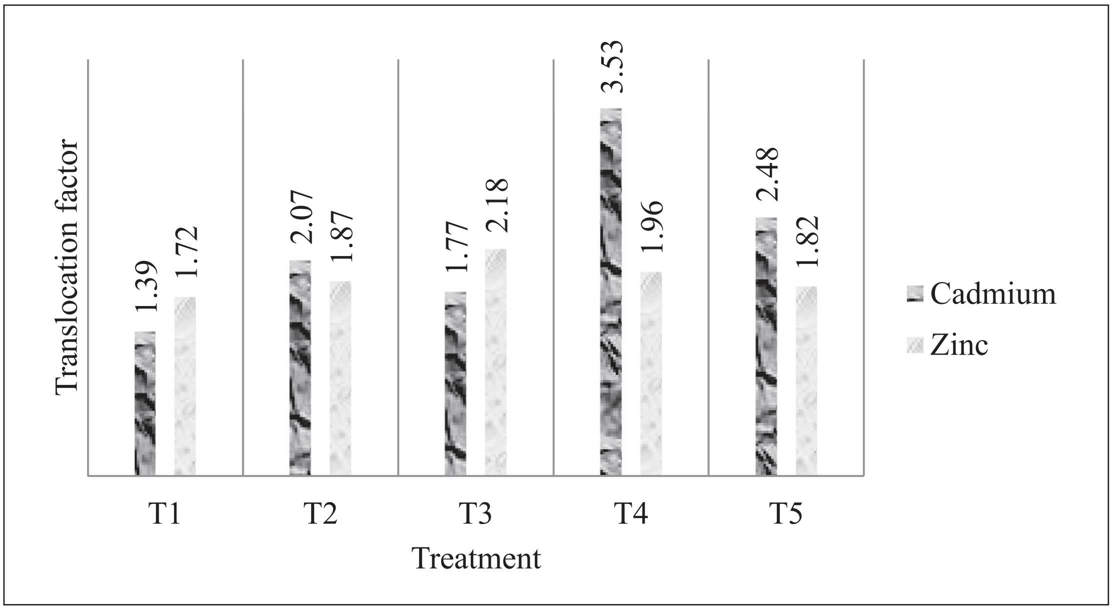

Fig. 6. Translocation factor of cadmium and zinc in *Ricinus communis*

CONCLUSION

Cadmium and zinc concentrations in the growth medium reduced at harvest compared to before planting indicating that *Ricinus communis* was able to remove these two elements from the contaminated soil. The highest reduction of Cd and Zn concentrations in the growth medium was in treatment T5. *Ricinus communis* was able accumulate high concentrations of Cd and Zn. This species could be suggested as a potential plant for phytoextraction due to the high value of TF even though the value of BCF was low.

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