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Phytoremediation study of Copper-Contaminated Soil Using Soybean (*Glycine Max* (L) Merril) with Compost Addition

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ABSTRACT: Phytoremediation study of Cu-contaminated soil using soybean (*Glycine Max* (L) Merril) with compost addition was conducted. This study was aimed to determine the Cu concentration in soil and soybean plant, to examine the feasibility of soybean plant (*Glycine Max (L)* Merril) as a hyperaccumulator plant for Cu metals with compost addition. Analysis methods used in this study included voltammetry, translocation factor, and enrichment factor. Study results indicated that Cu concentration in soil and plant was 87.363 mg/g and 68.509 mg/g, respectively. Soybean plant (*Glycine Max* (L) Merril) was classified as Cu hyperaccumulator with EF value > 1 and total accumulated Cu for control and compost treatment group was 80.444 mg/g and 63.234 mg/g, respectively. The addition of compost was capable of inhibiting the heavy metal Cu rate in the soil.

KEYWORDS: Phytoremediation, Copper, *Glycine max* (L) Merril, compost.

1 INTRODUCTION

Soil is the habitat for many living organisms including plants and human. The contaminated soil will jeopardize the survival of living organisms including human. Soil contamination can be resulted from excessive and perpetual use of fertilizers and pesticides containing specific chemical agents, particularly heavy metals. The contaminants such as heavy metals that get into soil water are naturally less degradable and toxic to organisms. Among the heavy metals potentially to contaminate environment are cadmium (Cd), chromium (Cr), iron (Fe), lead (Pb), nickel (Ni), copper (Cu) and others. According to [5], environmental pollution sources can be from industrial wastes and anti-corrosion paint manufacturers. Those wastes will be decomposed gradually into leachate. The leachate formation process can transfer the heavy metals from rooting layer to underlying soil layer, making the soil contaminated and potentially to retard the plant growth [13].

Copper (Cu) has been found in abundant numbers in water, soil, and air either in its ionic or compounding forms. Despite its toxicity, Cu is highly needed by human in trace level. [7] suggested that copper pollution sources are metal welding waste, industrial or domestic wastes, mineral mining and leaching. Copper is derived also from pulp industrial wastes [4]. The toxicity of Copper will be activated when this metal gets into organism body in big quantity or exceeding the organism tolerance level threshold. In high concentration of copper can damage the liver organ [2].

Various attempts have been made to control the heavy metal pollutions, either physically such as electrolysis and electrodialysis or chemically such as precipitation [3]. These methods are considered less effective with relatively expensive operational cost. The use of biological material, therefore, is a proposed alternative solution in managing the heavy metal wastes. It can remove or reduce the pollutants, organic or inorganic, in an environment is known as phytoremediation [9]. According to [11], phytoremediation is a technology that utilizes plants to clean up environmental pollution and some advantages in its application are relatively low cost, environmentally friendly, and cost saving up to 90%. In addition, Indonesia has a large plants and microorganisms biodiversity and capable of degrading and immobilizing heavy metal compounds and other organic compounds [8]. Phytoremediation was implemented in various research fields from the management of alkaline soil, oil spills until researches on agricultural plants that absorb and accumulate heavy metals. Some of the plants that have been reported as phytoaccumulators for heavy metals are land cress (*Ipomea reptans* Poir) and *Brassica rapa* that are potential as hyperaccumulator for nickel with phytoextraction ability of 699.9 mg/Kg and translocation factor of 1.25 and 2.15, respectively [9]. *Brassicaceae, Asteraceae, Pteridaceae, Thlaspi sp, Halophytes* [1] and *Ipomoea* species *Ipomoea alphine* have been found to accumulate 12,300 mg/Kg copper (Cu) in its leaves [6,10].

Soils contaminated by heavy metals has a very limited ability in providing nutrients needed by plants. This situation requires the addition of organic materials that are able to enrich nutrients in the soil. Organic materials enrichment can be made by, for example, compost addition [12]. In addition to enriching nutrients in the soil, compost is also useful in improving the soil physical structure, increasing and stabilizing soil pH, inhibiting the heavy metals movement to prevent leaching into the soil [13]. Microorganisms in the soil degrade the compost inhibiting heavy metal rate. Thus, in long period,these metals will be fee elements (nutrients) that will be absorbed by plants for growing process of plants such as soybean. Soybean plant is one of the important vegetables with high economic value and suitable to be developed in tropical region like Indonesia. A study by [13] found that vetiver plant (*Vetiver zizanioides*) can restore the mercury-contaminated soil by 65.252% using compost with contaminated-soil to compost ratio of 90%:10%. Based on this result, it is considered important to conduct a phytoremediation study of Cu-contaminated soil using soybean (*Glicine max* (*L*) Merril)with compost addition.

2 Material and Method

2.1 Materials

Materials were used in this study consisted of contaminated soil (laboratory waste), *Glycine max* (L) Merril seeds, aquadest, $CuSO_4$, HNO_3 65%, H_2O_2 30%, HCl, NPK fertilizer, and compost.

2.2 Method

The study was conducted in an experimental and greenhouse setting and samples were analyzed using voltammetry method. This study was conducted in four steps: preparation of Cu-contaminated growing medium, seeding and planting of the plants, growth observation during growing period, and harvesting. The contaminated soil was put into both of control and treatment lysimeter added with compost in the ratio of 9:1 kg contaminated soil and compost. The used plants were soybean plants *Glycine max (L) merril* that had been pre-planted for 4 month. After the specified growing period elapsed, the soybean plants were harvested and separated based on its morphology (roots, stems, leaves, and fruits). they were cleansed and dried in oven for 24 hours at 100^{o}C. Before analysis, the dried biomass of the samples was destructed by 9 mL aquaregia. The obtained filtrate was analyzed using Ingsen 1030 voltammeter. To identify the plant potential as a hyperaccumulator plant, the Translocation Factor (TF) and the Enrichment Factor (TF) were calculated with the following formula:

$$\text{Translation Factor (TF)} = \frac{\text{[Metal] Leaves}}{\text{[Metal] Roots}} \text{ mg/g} \quad (1)$$

$$\text{Enrichment Factor (EF)} = \frac{\text{[Metal] Leaves}}{\text{[Metal] Soil}} \text{ mg/g} \quad (2)$$

3 Results and Discussion

3.1 Soil Physicochemical Parameters Test

The first step in this study was the test of physicochemical parameters to determine the composition and fertility level of the soil used in this study. The results of physicochemical analysis areshown in Table 1. The important chemical properties of the soil medium included pH, cation exchange capacity (CEC), and essential nutrients. The pH of soil is very important to know because it dictates the absorbability of nutrient ions by the plant.

Table 1. Physicochemical properties of the soil

Parameter	Level	Parameter	Level
Water content	8.52 %	C	-
Clay	45 %	N	0.24 %
Dust	35 %	P_2O_5(ppm)	15.68
Sand	20 %	K	0.8 %
Texture class	Clay	Zn	0.058 %
CEC (cmol/Kg)	32.24	Ca	5.82%
Soil pH	6.8	Mg	-
		Na	-
		Al	10.45

According to the texture analysis results, the medium soil was found to have relatively high clay fraction (45%). According to Hanafiah, K.A., (2012), such texture condition is categorized as clay. The soil pH measurement in lysimeter during growing period indicated average pH of 6.8 and 6.7,either in control or compost-treated plot. They were normally for plants to absorb nutrients in the medium despite the available nutrients. CEC value of the medium has a very important role in term of nutrients supply and has an effect on medium buffering capacity. The soil sample used in this study has a high ability in storing and releasing cations and high buffering capacity. Nutrient analysis in the soil sample indicated that the essential nutrients content such as K, Ca, and Mg were categorized as low and less fertile.

3.2 COPPER (CU) CONCENTRATION IN SOIL AND SOYBEAN PLANT

Analysis was repeated three times for more accurate results. Table 2 and Figure 1 show the comparison of total Cu concentration in soil and those in plants, where the Cu concentration was higher in plant compared to in soil, either in control or compost-treated lysimeter.

Table 2. Comparison of Cu concentration in soil and plant

Sample	Cu concentration (mg/g)	
	Control	+ compost
Soil	6.91	5.27
Plant	80.44	63.23

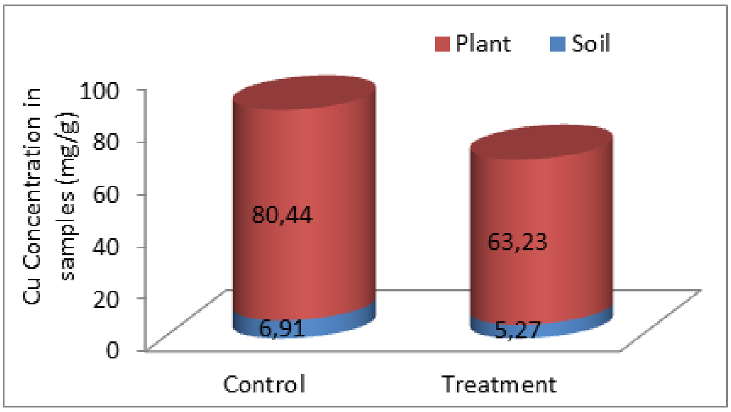

Figure 1. Comparison of Cu in soil and plant

The results of this study (Figure 1) indicate that Cu concentration in plant is higher than in soil, either in control or compost-treated lysimeter. This indicates that soybean plants have a high ability to accumulate Cu in soil. In addition, compost addition in lysimeter inhibited and retardedthe influx rate or accumulation of Cu into plant as shown in Figure 1, where the concentration of accumulated Cu by plant in compost-treated lysimeter was lower compared plant in control lysimeter. The Cu concentration was 62.23 mg/g (compost-treated lysimeter) and 80.44 mg/g (control lysimeter).

3.3 COPPER (CU) DISTRIBUTION IN SOYBEAN PLANTS

Data on Cu distribution were presented in Table 3 and Figure 2.

Table 3. Cu distribution in plants according to control and compost treatment groups

Plant organ	Control (mg/g)	Treatment (mg/g)
Root	36.2	42.86
Stem	11.15	5.85
Leave	6.44	7.72
Fruit	26.63	6.79

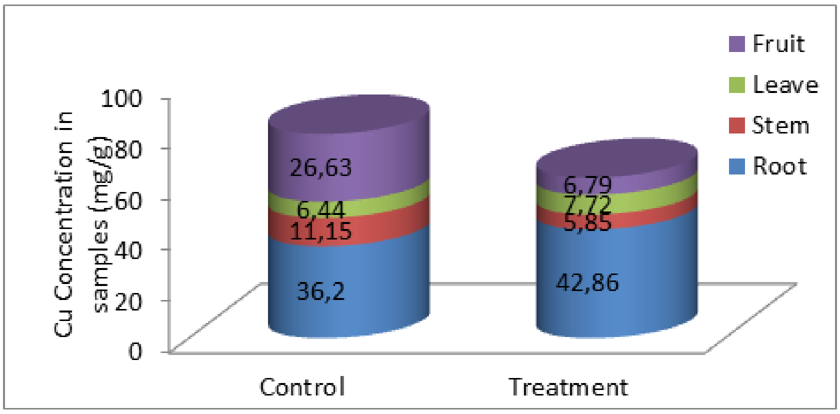

Figure 2. Comparison of Cu distribution in plant parts of control and compost treatment group.

Table 3 and Figure 2 indicate Cu concentrate more on roots of soybean (36.20 mg/kg for control and 42.86 mg/g for compost treatment) compared to stem, leaves, and fruits. This was related to the plant that localize metal elements by accumulating them in roots part as a way to anticipate toxicity by metal elements to plant cell, thus not inhibiting the plant metabolism process (Collins, 1999).

3.4 IDENTIFICATION OF PHYTOREMEDIATION MECHANISM AND HYPERACCUMULATOR PLANT

Phytoremediation mechanism can be established by determining the translocation factor and enrichment factor value (Lorestani et. al., 2011 and Branquinho, et. all., 2006). Translocation factor was determined by calculating the comparison between metal concentration in leaves and roots. Whereas the enrichment factor was determined by calculating the comparison between metal concentration in leaves and in soil. According to Lorestani (2011), when a plant has TF >1 and EF >1, it is categorized as a hyperaccumulator plant. The determination of TF and EF value for Cu by soybean plants is presented in Table 4 and Figure 3.

Table 4. Relationship between Cu metal TF and EF in soybean plant

Lysimeter	**Cu**	
	TF	**EF**
Control	0.18	0.93
+ compost	0.18	1.46

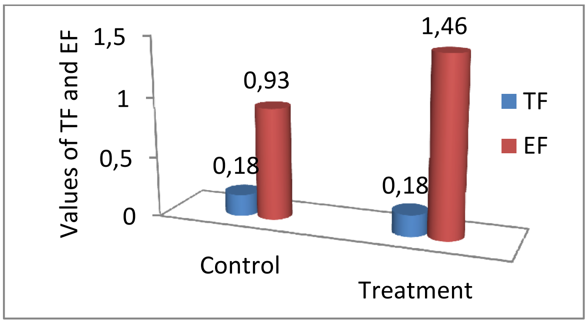

Figure 3. Relationship between TF and EF according to Cu concentration

According to Table 4 and Figure 3, they were found that TF of Cu in control and compost-treated plant were 0.175 and 0.180, respectively. The data showed phytoremediation mechanism of Cu using soybean plant, either in the both of control or compost treatment lysimeter, tended to follow phytostabilization mechanism. This was due to Cu that concentrates more in roots than in leaves.

EF value of Cu for control soybean plant was lower than EF value for compost-treated plant, namely 0.93 and 1.46, respectively (Figure 4). Based on these values, soybean plant with compost treatment is categorized as Cu hyperaccumulator plant.

4 CONCLUSION

Copper (Cu) concentration in soil and plant were 87.763 mg/g and 68.509 mg/g, respectively. Soybean plant (*Glycine max* (L) Merril) could be categorized as Cu hyperaccumulator plant with EF value > 1 and total accumulated Cu 80.444 and 63.234 mg/g, respectively. Compost can inhibit the Cu rate in soil.

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