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Phytoremediating Capacity of Copper Tolerant Plants in Mine Tailing Soil Materials with Compost Amendment in Mankayan Benguet, Philippines

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Abstract

This study aimed to identify phytoremediating plant species on copper-contaminated soils in abandoned tailings ponds in barangay Paco, Mankayan, Benguet, Philippines. It also examined and verified the role of organic matter in phytoremediation by utilizing growth media with varying concentrations of copper. Agricultural soil, tailings pond overlaid with tops soil and municipal biowaste (TP4), and abandoned tailings pond without rehabilitation (TP3) were amended with 4%, 8%, and 16% compost. These soil materials were placed in their respective 1x1 m^2 experimental plots and were allowed to be colonized by different plants. The study was conducted for three months at an abandoned agricultural field. All the plants that grew in the experimental plots were identified. The different species in each treatment plot with the highest Importance Values (IV) were considered as dominant. A total of 15 species representing 12 genera and 8 families were recorded in plots utilizing TP3 soil materials. The plant species with the highest importance value was Cynodon dactylon (L.) Pers. (54.30). Most of the regenerants were herbaceous flora and grasses. These plants are considered pioneers due to its ability to tolerate stressful conditions. Plots with TP4 soil materials had 18 plant species representing 17 genera and 8 families. The plant species with the highest importance value was Amaranthus spinosus L. (45.53). Among the plant species, Cynodon dactylon was observed to dominate different growth media with highly variable soil physical and chemical characteristics. This plant can be utilized as a phytostabilizing agent in different media types contaminated with copper.

Keywords: Copper; Heavy metal; Tailing ponds; Plant composition

1. Introduction

Mining is one of the greatest threats that results in loss of ancestral domain of indigenous people, loss of biodiversity and soil and surface water pollution (Turner *et al*, 2013). The environmental impacts of mining may extend well beyond the mine site. Impacts of mine extraction, processing and smelting would result in habitat loss/fragmentation, chemical contamination of surface and ground waters, siltation of rivers, declining species populations, toxicity impacts to organism, altered landscapes, the discharge of chemicals and other wastes to surface waters, emissions of sulphur dioxide and heavy metals and increased demand for electrical power (Miranda, *et.al.*, 2003).

Benguet province is one of the richest in terms of mineral deposits such as gold and silver. Large- and small-scale mining operations are taking place in the province. Lepanto Consolidated Mining Co. has been in operation at Mankayan, Benguet since 1936. Mining in the area is an underground tunnel type of mining where mine rocks are stored in tailings ponds. For more than seventy years of mining operation, there are four abandoned mine tailings ponds (locally known as TP1, TP2, TP3 and TP4) located in Barangay Paco. Barangay in the Philippines is a term used to denote a small village. Cuevas and Balangcod (2014) traced its history. TP4 is an abandoned tailings pond which was amended by the intentional addition of soil and accidental inputs of municipal wastes. It is currently being utilized as a pasture land. TP3 is an abandoned mine tailing pond with no added amendments. Mine tailings that are contained in these ponds have a high concentration of copper, low organic matter content and a strongly acidic pH. These poor physical and chemical properties of mine tailings inhibit plant growth resulting to low or sparse vegetation cover.

There is a need to rehabilitate these mine tailings so that it will be able to support plant growth. The study identified (i) plant species that are potential phytoremediation agents and; (ii) the differences of physical and chemical properties of the surface horizon of the soil materials (a. agricultural soil obtained from an area close to the site, b) TP4, and; c) TP3). This study was conducted from November 2013 to June 2014.

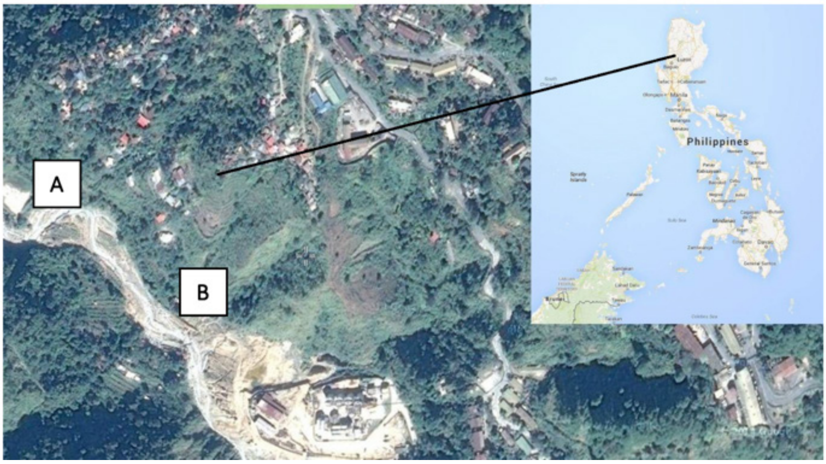

Figure 1. Photo showing Brgy. Paco, Mankayan, Benguet showing relative positions of A) Tailing pond 4 (TP4) and B) Tailing pond 3 (TP3).

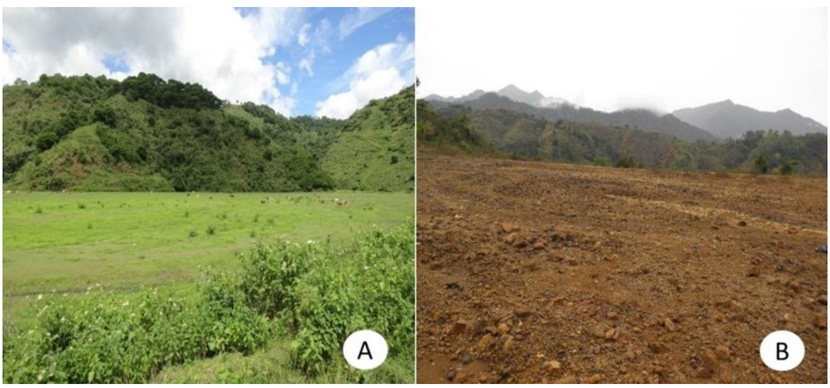

Figure 2. A) Tailing pond 4 (TP4) and B) Tailing pond 3 (TP3) containing copper-contaminated soil and municipal wastes.

2. Materials and Methods

2.1 Study Area and Establishment of Sampling Sites

A reconnaissance survey was conducted to establish sampling points within the area of Mankayan (Figure 1). Soil material samples were obtained from TP4 (Figure 2.A) and TP3 (Figure 2.B) of Lepanto Consolidated Mining Company (LCMC) in Barangay. Paco, Mankayan, Benguet. The agricultural soil that was used for the control set-up was obtained from an abandoned agricultural field 1km away from TP4. The barangay is located at around 860 m elevation. The experimental plots were established in an abandoned agricultural field located in Barangay. Paco, Mankayan, Benguet which was abandoned for five (5) years and has now become a scrub land.

2.2 Establishment of experimental plots with varying levels of compost

1x1 m^2 plots replicated three times were established. The plots were buried 15 cm. deep to the level of top soil to keep soil temperature and amount of moisture constant in all set-ups. The role of organic matter in phytoremediation was examined and verified by adding various concentrations of copper to the plots. Compost was then mixed based on the treatments as follows: for agricultural soil (i) 0% (0 kg/m^2), (ii) 4% (5 kg m^{-2}), (iii) 8% (10 kg/m^2) and (iv) 16% (20 kg/m^2); for soil materials from tailing ponds (i) t0% (0 kg/m^2), (ii) 4% (6.6 kg/m^2), (iii) 8% (13.2 kg/m^2) and (iv) 16% (26.4 kg/m^2). The growth media materials were mixed properly to ensure homogeneity were then labeled.

There were 24 treatments consisting of a combination of three factors, namely: a) soil copper levels; b) compost with 4 levels (0, 4%, 8%, and 16%), and; c) the plant factor. Table 1 shows the amount of soil and compost added to the different treatments. The weight of soil and soil materials needed to fill up the wooden frame varied due to the compactness of the materials as compared to the soil. The surface levels of the various media were the same for all treatments. Compost was bought from the Benguet State University (BSU). The amount of compost added was based on a w/w dry basis.

Table 1. Amount of materials and amendments (compost) added to each treatment replicated three times (Agric. Soil=Agricultural soil, TP3=TP3 soil materials, TP4=TP4 soil materials).

TREATMENTS	MEDIUM	MEDIUM (%)	AMOUNT OF MEDIUM (kg)	COMPOST (%)	AMOUNT OF COMPOST (kg)
1	Agric. soil	100	125	0	0
2	Agric. soil	96	120	4	5
3	Agric. soil	92	115	8	10
4	Agric. soil	84	105	16	20
5	TP3	100	165	0	0
6	TP3	96	158.4	4	6.6
7	TP3	92	151.8	8	13.2
8	TP3	84	138.6	16	26.4
9	TP4	100	165	0	0
10	TP4	96	158.4	4	6.6
11	TP4	92	151.8	8	13.2
12	TP4	84	138.6	16	26.4

2.3 Plant Inventory and Vegetation Analyses

Plants were allowed to freely colonize the plots. The different plant species growing were identified and inventoried. The following data were gathered a) name of plant; b) plant cover and; c) frequency. Plant samples were also collected and brought to experts for identification. Taxonomic information regarding the plant samples were verified from references authored by Moody, Munroe, Lubigan and Paller (1984). On-line data bases and literature were also consulted. The dominant plant species per plot were determined based on Importance Value (IV) (Mueller-Dombois, 1974). The relative frequency, relative cover and the species diversity were obtained from the different species growing in soil, TP4 and TP3.

2.4 Copper Concentration

Dry matter production was determined. The roots and the leaves of the top two dominant plants per media used were analyzed for total copper concentration. The plant materials were submitted to the University of the Philippines-Los Baños' National Institute of Molecular Biology and Biotechnology (BIOTECH). Soil samples from the plots were analyzed for % OM and pH. The soil samples were analyzed at the Soil Analytical Chemistry Laboratory in the University of the Philippines Los Baños, College, Laguna. Exchangeable soil copper concentration was determined at BIOTECH.

2.5 Biological Accumulation Coefficient (BAC), Biological Concentration Factor (BCF) and Translocation Factor (TF)

TF, BCF, and BAC values were used to evaluate the potential of plant species for phytoextraction and phytostabilisation (Yoon *et.al*., 2006; Li *et al*, 2007). Biological Concentration Factor (BCF) was calculated as metal concentration ratio of plant roots to soil (Yoon *et al*., 2006). Translocation Factor (TF) was described as ratio of heavy metals in plant shoot to that in plant root (Cui *et al*., 2007; Li e*t al*., 2007). Biological Accumulation Coefficient (BAC) was calculated as ratio of heavy metal in shoots to that in soil (Li *et al*., 2007; Cui *et al*., 2007). The Biological Accumulation Coefficient (BAC) of a plant in relation to certain heavy metals is the metal concentration of its aboveground part (mainly leaf or leaf plus stem) divided by the same metal content in soil (Kumar, *et al*., 2009). Equations are as follows:¬

$$BCF = [Metals]_{root}/[Metals]_{soil}$$
$$TF = [Metals]_{shoot}/[Metals]_{root}$$
$$BAC = [Metals]_{shoot}/[Metals]_{soil}$$

2.6 Physical and Chemical Characteristics of Media

The physical and chemical characteristics at the root zone level were measured. Different physical soil parameters influencing plant growth was determined which included water holding capacity (WHC), soil texture, and bulk density. Chemical analysis included soil pH, organic matter content (OM), and determination of available Copper concentration. Composite samples from the surface soil at a depth of 0-20 cm were obtained from each sampling site. Geographic positioning system (GPS) was used to obtain the geographical reference site of the selected sampling sites. Soil analysis was done at the Soil Analytical Chemistry Laboratory, Agricultural System Cluster, College of Agriculture, University of the Philippines Los Baños (UPLB). Soil copper concentration was determined at the Central Analytical Services Laboratory of the National Institute of Molecular Biology and Biotechnology (BIOTECH), UPLB Science Park.

2.7 Statistical Analysis

The data obtained from the plant analysis was subjected to Analysis of Variance (ANOVA) and Tukey's test.

3. Results and Discussion

3.1 Plant Diversity

Plant Species Present in Plots Using Soil as a Major Component of Growth Media

The dominant species in the plot where soil was used as medium for growth were determined (Table 2). The plant species with the highest importance value was *Cynodon dactylon* (L.) Pers. (40.76) followed by *Bidens pilosa* L. (38.01), *Crassocephalum crepidioides* (Benth.) S. Moore (20.47), *Ageratum conyzoides* L. (17.92) and 5th in rank is *Solanum nigrum* (13.92). The high importance value of *Cynodon dactylon* (L.) Pers. can be attributed to its high relative cover (88.26), high relative density (18.63) and high relative frequency (15.38).

Plant Species Present in Plots Using Soil Materials from TP3 as a Major Component of Growth Media

The materials from TP3 had a very restrictive environment for root establishment as well as plant growth and development. It has a high bulk density, low CEC values, very acidic media, low OM and high mean exchangeable copper content (delos Angeles and Cuevas, 2018). The site is nutrient-stressed making it a harsh environment for plants to thrive in. Despite the unforgiving soil environment, there was a total of 15 plant species at the end of the experiment. The dominant species in the plot where tailings from TP3 was used as medium for growth were determined (Table 3). The plant species with the highest importance value was *Cynodon dactylon* (L.) Pers. (IV=54.30) followed by *Axonopus compressus* (IV = 23.80), *Portulaca oleracea* L. (IV = 12.95), *Mimosa pudica* L. (17.62) and 5th in rank is *Paspalum* sp. (IV = 11.09). The high importance value of *Cynodon dactylon* (L.) Pers. can be attributed by its high relative cover (114.85), high relative density (26.19) and high relative frequency (21.88). These plants are considered pioneers due to its ability to tolerate such stressful conditions.

Table 2. Importance values of recorded plant species from the plots where soil was used as growth medium established at Barangay Paco, Mankayan, Benguet (RC=Relative Cover, RD=Relative Density, RF=Relative frequency).

RANK	SCIENTIFIC NAME	RC	RD	RF	IV
1	*Cynodon dactylon* (L.) Pers.	88.26	18.63	15.38	40.76
2	*Bidens pilosa* L.	80.02	18.63	15.38	38.01
3	*Crassocephalum crepidioides* (Benth.) S. Moore	38.1	11.76	11.54	20.47
4	*Ageratum conyzoides* L.	30.41	13.73	9.62	17.92
5	*Solanum nigrum*	24.31	7.84	9.62	13.92

Table 3. Importance value and rank of species in the set-up where tailings from TP3 was used as the growth medium established atBrgy. Paco, Mankayan, Benguet (RC=Relative Cover, RD=Relative Density, RF=Relative frequency).

RANK	SCIENTIFIC NAME	RC	RD	RF	IV
1	*Cynodon dactylon* (L.) Pers.	114.85	26.19	21.88	54.31
2	*Axonopus compressus*	49.38	9.52	12.50	23.80
3	*Portulaca oleracea* L.	33.33	2.38	3.13	12.95
4	*Mimosa pudica* L.	17.68	11.90	6.25	11.94
5	*Paspalum* sp.	19.89	7.14	6.25	11.09

Plant Species Present in Plots Using Soil Materials from TP4 as a Major Component of Growth Media

There is a richer plant community in the TP4 set-up as compared to TP3. The total number of plant species recorded by the end of the experiment was 18. The dominant species for this type of media in the absence of grazers were determined (Table 4). The plant species with the highest importance value was *Amaranthus spinosus* L. (45.53) followed by *Cynodon dactylon* (L.) Pers. (44.45), *Cuphea carthagensis* (20.39), *Portulaca oleracea* L. (17.62) and 5th in rank is *Crassocephalum crepidioides* (Benth.) S. Moore (8.19). The high importance value of *Amaranthus spinosus* L. can be attributed by its high relative cover (109.17) and high relative frequency (14.47). *Cynodon dactylon* (L.) Pers. had the highest relative density (16.47). In a study conducted by Cuevas and Balangcod (2014), the dominant species of TP4 in the presence of grazers were *Cynodon dactylon*, *Cuphea carthagensis* and *Paspalum conjugatum*. In this study where grazers are absent, *Cynodon dactylon* and *Cuphea carthagensis* were still the dominating plants. However, P. *conjugatum* was no longer a dominant species. In the absence of grazing pressure, other plant species were allowed to colonize the area which resulted to the displacement of P. *conjugatum* as the dominant species. *Cynodon dactylon* was able to dominate different growth media with highly variable soil physical and chemical characteristics. This plant species is capable of tolerating and colonizing areas which are contaminated with copper.

Bioaccumulation Factors for the Two Dominant Species Per Growth Media in the Free Colonization Plots

Total copper concentration was determined from the top two dominant species per type of growth media in the free colonization plots. In plots which utilized agricultural soil, the BCF values were calculated to be more than 1 for both *Cynodon dactylon* and *Bidens pilosa* (Table 5). In plots which utilized soil materials from TP4 *Cynodon dactylon* had a BCF value of 1.52. *Amaranthus spinosus* on the other hand had a BCF value less than 1 (Table 5). In the plots which utilized soil materials from TP3, both *Cynodon dactylon* and *Axonopus compressus* had BCF values greater than 1 (Table 5). The dominant species in each growth media has the potential to be utilized as a phytostabilising agent except for *Amaranthus spinosus*. *Cynodon dactylon* is capable of dominating different types of growth media with highly varied physical and chemical properties. This plant can be utilized as a phytostabilizing agent in different media types contaminated with copper.

Table 4. Importance value and rank of species in the plots where soil materials from TP4 were used as the growth media (RC=Relative Cover, RD=Relative Density, RF=Relative frequency).

RANK	SCIENTIFIC NAME	RC	RD	RF	IV
1	*Amaranthus spinosus* L.	109.17	12.94	14.47	45.53
2	*Cynodon dactylon* (L.) Pers.	102.40	16.47	14.47	44.45
3	*Cuphea carthagensis*	36.40	12.94	11.84	20.39
4	*Portulaca oleracea* L.	29.38	12.94	10.53	17.62
5	*Axonopus compressus*	24.77	3.53	3.95	10.75

Table 5. Biological Concentration Factor (BCF) of the top two dominant plants in plots grown in agricultural soil, soil materials with TP4, and soil materials with TP3 all applied with 4% compost application.

SOIL MATERIALS	PLANT SPECIES	TOTAL ROOT COPPER CONCENTRATION (PPM)	EXCHANGEABLE COPPER CONCENTRATION AT 4% COMPOST APPLICATION (PPM)	BCF
AGRICULTURAL SOIL	*Cynodon dactylon*	125.03	55.5	2.25
	Bidens pilosa	1569.95	55.5	28.29
TP4	*Amaranthus spinosus*	20.84	36.3	0.57
	Cynodon dactylon	55.02	36.3	1.52
TP3	*Cynodon dactylon*	139.77	54.27	2.58
	Axonopus compressus	32.92	54.27	0.61

3.2 Differences of Physical and Chemical Properties of the Surface Horizon of the Soil Materials

Changes in Soil Properties with Soil Materials from TP3 as Component of Growth Media with Compost Amendment

Initial physical and chemical characteristics used in the study has been discussed thoroughly in the study of delos Angeles and Cuevas (2018). Treatments with TP3 soil materials amended with various levels of compost revealed that the mean final bulk density in all treatments were not significantly different from that of the control (Figure 3.A). The sample size was small to effect significant changes. However, results showed a trend was established that as the amount of compost application was increased, the mean final bulk density decreased. Bulk density is an important soil parameter since it changes based on the structural condition of the soil (Tafangenyasha, *et al.*, 2011). One of the important functions of organic matter is the formation of stable aggregates and in soil protection (Craswell and Lefroy, 2001). The change in bulk density in plots allowed more space for water and air to penetrate the media which allowed soil biota to proliferate.

The mean final (CEC) of growth media using soil materials from TP3 increased from 3.79 cmol/kg in the control to 14.79 cmol/kg at 13.2 kg/m^2 (Figure 3.B). However, this increase was not determined to be statistically significant because no statistical analysis was done due to the small sample size. In an experiment conducted by Cuevas (2009) in an acidic grassland soil amended with 16% compost significantly improved the CEC values from a mean of 15 cmol/kg to 41 cmol/ kg. In this same study 30% and 46% compost application had no significant difference with 16%. Mean final pH 2.5 of the control plots rapidly increased to 5.0 with addition of 6.6 kg/ m^2 (4%) (Figure 3.C). Addition of more compost also increased pH to 6.2 but the increases were no longer significantly different from each other. Change in the pH may have been influenced by the presence of plants. Rapid elevation of pH in the plots is mainly due to the presence of more plant species. Plant root activities at the rhizosphere may have elevated soil pH to neutrality (Neumann and Romheld, 2002). Plants release exudates into the soil which alters the soil pH (Karthikeyan and Kulakow, 2002). According to Nye (1981), plant roots release HCO^{3-} to the soil in order to maintain electrical neutrality in the rhizosphere resulting to a more alkaline pH. In the soil, nitrification or conversion of NH^{4+} to NO^{3-} is an aerobic process facilitated by nitrifying bacteria. An increase in uptake of NO^{3-} primarily results in a net release of HCO^{3-} with a corresponding increase in rhizospheric pH (Nye 1981). The final mean OM content under different rates of compost application in the plots did not have any significant differences. Insignificant differences can be attributed to only two replicates and high variation in data obtained (Table 6). Results also showed that there were no significant mean differences of exchangeable copper concentration among treatments where soil materials from TP3 was treated with varying levels of compost (Table 7).

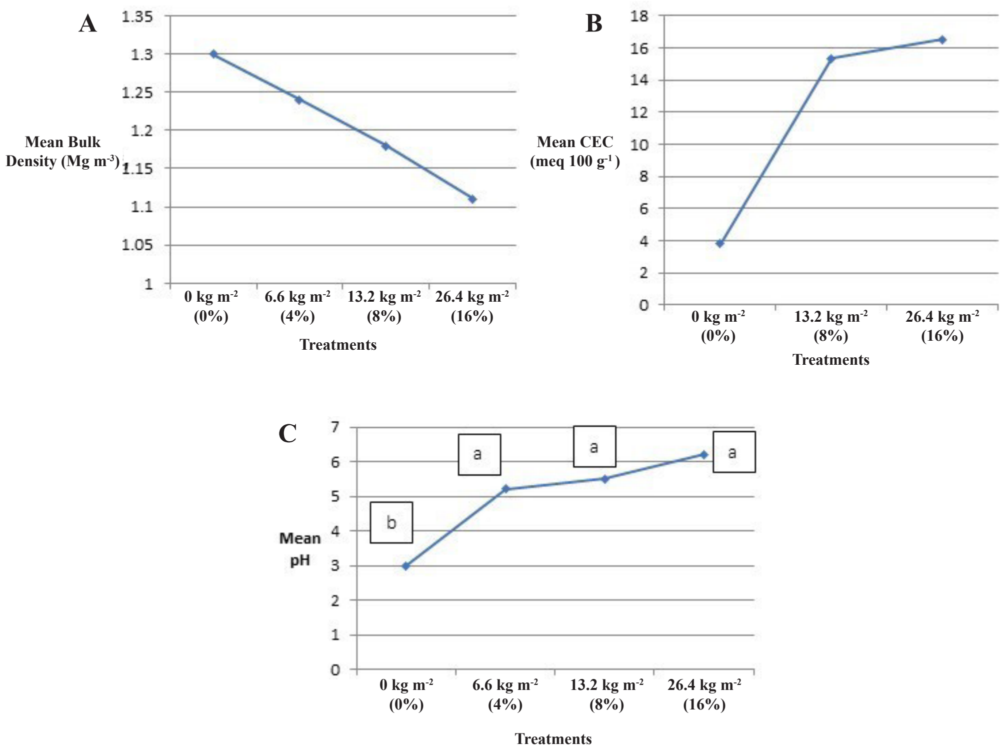

Figure 3. Changes in f A) Final bulk density, B) Mean final CEC and C) Mean final pH in treatments where materials from TP3 was used as growth medium.

Table 6. Mean values of organic matter (%) in the set-ups where soil materials from TP3 was used as growth medium for set-ups which allowed free colonization and in set-ups where Paspalum conjugatum was the main colonizer. MEAN + SD.

COMPOST APPLICATION	FREE COLONIZATION*
0 kg m^{-2} (0%)	$0.32^{a} \pm 0.06$
6.6 kg m^{-2} (4%)	$2^{a} \pm 1.07$
13.2 kg m^{-2} (8%)	$2.87^{a} \pm 0.50$
26.4 kg m^{-2} (16%)	$5.67^{a} \pm 2.05$

*Mean values with the same letters within a column are not significantly different.

Table 7. Mean final exchangeable copper concentration (ppm) in the set-ups where materials from TP3 was used as growth medium for the plots. MEAN + SD.

COMPOST APPLICATION	FREE COLONIZATION*
0 kg m^{-2} (0%)	$64.88^{a} \pm 8.20$
6.6 kg m^{-2} (4%)	$54.27^{a} \pm 1.80$
13.2 kg m^{-2} (8%)	$48.81^{a} \pm 5.12$
26.4 kg m^{-2} (16%)	$61.65^{a} \pm 5.50$

*Mean values with the same letters within a column are not significantly different.

The addition of organic amendments is a practical in situ immobilization technique in remediating metal-contaminated soils where it hastens the attenuation of metal mobility and toxicity in soils (Wuana and Okieimen, 2011). However, in this experiment this only holds true to 4% compost application at 6.6 kg/m^2 application. A challenge frequently encountered in field studies is uneven distribution of contaminants including “hot spots” across a site (Ferro, *et.al.*, 1999; Van Dillewijn, *et.al*., 2007; Nedunuri, *et.al.*, 2000; U.S. Environmental Protection Agency). In laboratory and greenhouse experiments, soils are generally mixed, to achieve a uniform matrix. This may not be possible in the field, even if the site is extensively tilled prior to planting. The spatial heterogeneity of initial contaminant levels results in data scatter, which can make it difficult to statistically show significant treatment effects for field trials. Pearson Correlation analysis showed that mean pH was significantly correlated with final OM content in the plots where materials from TP3 was used as a growth medium with varying levels of compost applied for both free colonization ($r = 0.864$, $p < 0.006$). In a study conducted by Valarini, *et al*. (2009), the addition of compost equivalent to 20 and Mg/ha to agricultural fields grown with wheat significantly increased the pH from 5.5 to 6.1. pH increased with increasing compost application due to the presence of plant roots wherein its growth is promoted by the application of compost. Plant roots release HCO^{-3} which corresponds to an increase in pH making it more alkaline. In addition, the increase in pH could be due to the higher initial pH value of the compost (7.2) as compared to that of the soil materials from TP3 (2.5).

Changes in Soil Properties with Soil Materials from TP4 as Component of Growth Media with Compost Amendment

No significant differences were noted in the mean final bulk density, mean final OM content, mean final pH, and mean final exchangeable copper of growth media where soil materials from TP4 were used and applied with varying levels of compost (Figures 4.A, 10.B, 4.C and 4.D). The final mean CEC was observed to increase from 4.93 cmol/kg at 0% compost application to 11.07 cmo/ kg at 4% compost application to 16.01 cmol/kg at 8% compost application (Figure 4.E). No statistical analysis was done due to the few available data. This trend was also observed in TP3 as growth medium.

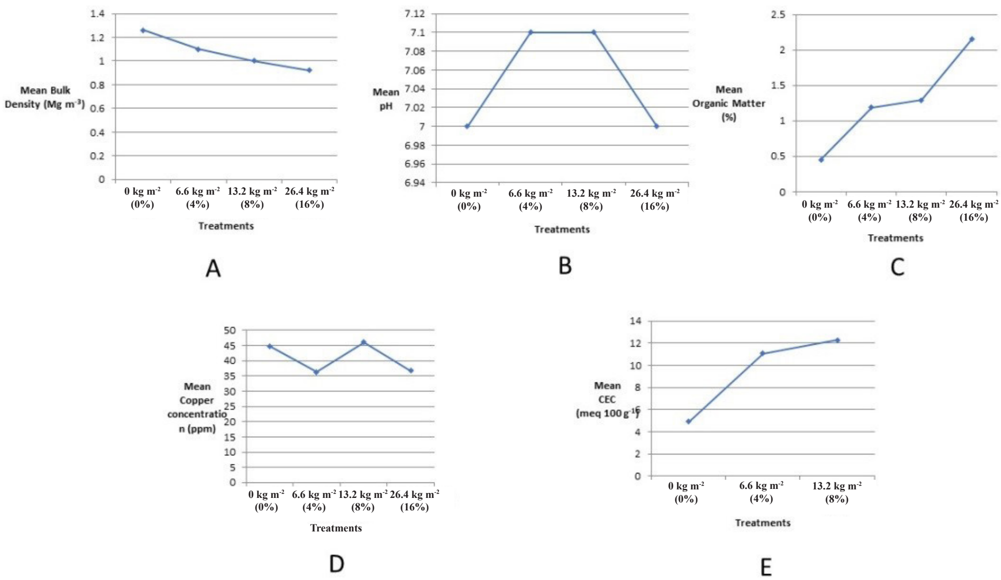

Figure 4. A) Mean bulk density, B) Mean final pH, C) Mean final organic matter (%), D) Mean exchangeable copper and E) Mean CEC in the treatments where materials from TP4 were used as growth medium for plots.

The addition of any levels of compost did not result in any significant changes and correlations among the physical and chemical properties using TP4 soil materials as base. The media may have reached stable physical and chemical properties due to the prior addition of amendments such as top soil and biowastes. The same observations were recorded in the study of delos Angeles and Cuevas (2018) wherein the same TP4 mine tailings were used as the potting medium with only *Paspalum conjugatum* Berg. as the plant colonizer. Physical and chemical properties of TP4 were not affected by organic matter (delos Angeles and Cuevas, 2018). There is also a more extensive vegetation cover in this site of about 70% as compared to TP3 of only about 10-24% (Cuevas and Balangcod, 2014). In addition, the presence of various grazing animals may have improved the soil physical and chemical properties through the continuous input of fecal matter which in time will eventually become additional organic matter. On the other hand, correlation analysis of the different parameters examined was done and results also showed that there were no significant correlations among the parameters monitored. There were minimal physical and chemical changes in the medium with compost application.

Changes in Soil Properties with Agricultural Soil as Component of Growth Media with Compost Amendment

In treatments where agricultural soil was used as growth media the mean values for bulk density were not significantly different from each other ($P > 0.05$). This may be due to the small sample size where variances among the data sets are minimal. However, it can be observed from the results that as the amount of compost added was increased bulk density decreased. As discussed earlier, a low value for bulk density is favorable soil biota to survive. As observed in TP4, when agricultural soil was used as base material final CEC (Figure 5.B), OM content (Figure 5.C) and exchangeable copper (Figure 5.D) were not significantly different with various rates of compost application. These findings show that the physical and chemical properties of the soil are stable that the addition of compost did not effect significant changes. However, mean final pH were significantly increased only with addition of 5 kg m^{-2} (4%) from 0% compost application (Figure 5.E). Adding various levels of compost to agricultural soil did not have significant effect on final bulk density, OM content, and exchangeable copper. However, pH was significantly raised from 4.9 (0%) to 6.1 (4%) in the treatments.

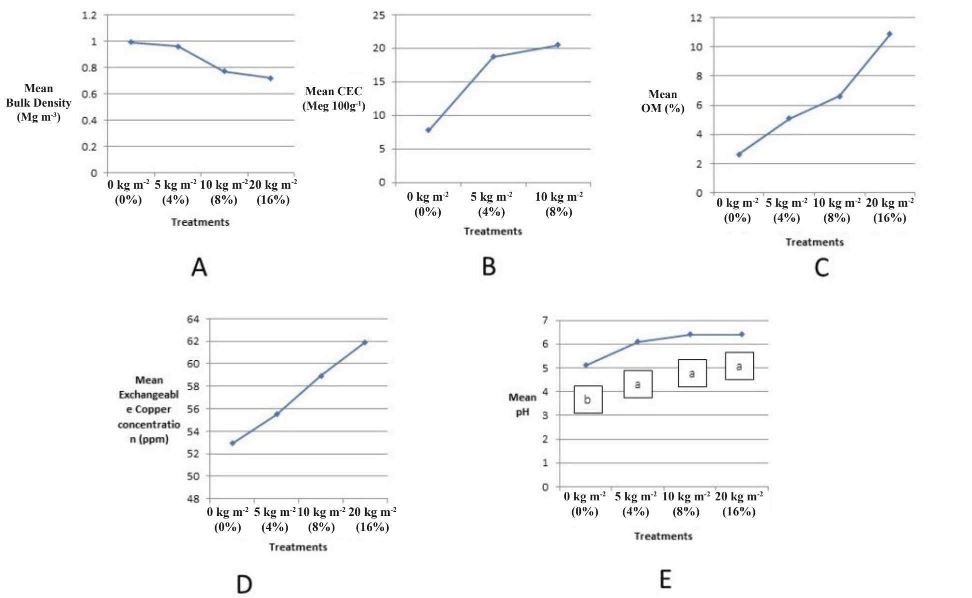

Figure 5. Changes in A) Mean bulk density B) Mean final CEC C) Mean final organic matter (%) D) Mean exchangeable copper concentration (ppm) E) Mean final pH in the treatments where amended soil was used as growth medium for plots

4. Conclusion

Fifteen species representing 12 genera and 8 families were potential phytoremediators. The most dominant species different growth media with highly variable soil physical and chemical characteristics, was *Cynodon dactylon* (L.) Pers. This plant can be utilized as a phytostabilizing agent in different media types contaminated with copper. The addition of 4% and 8% compost application increased cover to more than double from 18.33% of 0% compost application to 47.33% at 8% application by the end of the experiment. Increased application of compost resulted to the formation of soluble copper complexes which are available for plant uptake.

The agricultural soil had an initial acidic pH of 4.9 and the soil materials from TP4 had an initial acidic pH of 5. Materials from TP3 had a strongly acidic pH of 2.5 and had the densest media with a bulk density of 1.42Mg m^{-3} and the lowest CEC with 3.79 cmol kg^{-1}. TP3 has a very harsh environment making it difficult for plants to thrive in. This study also verified that addition of organic matter in phytoremediation illustrated a significant increase in pH. This study suggests to explore different plant species that are capable of tolerating copper-contaminated sites in the area. There will be a faster reclamation of these copper-contaminated sites once additional plant species as well as its phytoremediating mechanism are determined.

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