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Study on the Effect of Organic Amendments in Abandoned Mine Soil

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သတ္တုတူးဖော်ထားရှိခဲ့သည့်မြေများတွင် အော်ဂဲနစ်ပစ္စည်းများအသုံးပြု၍ မြေပြုပြင်ခြင်း၏ အကျိုးသက်ရောက်မှုအား လေ့လာခြင်း

ဆွေဆွေထွန်း၊ လက်ထောက်သုတေသနအရာရှိ
ဖြူဖြူဆွေ၊ လက်ထောက်သုတေသနအရာရှိ
ချမ်းမြေ့အောင်၊ တောအုပ်ကြီး

စာတမ်းအကျဉ်း

ဤသုတေသနစာတမ်းသည် သတ္တုတူးဖော်ထားရှိခဲ့သည့် မြေရှိ သတ္တုအဆိပ်အတောက်များအား အော်ဂဲနစ်ပစ္စည်းများအသုံးပြု၍ မြေပြုပြင်နည်းများဖြင့် လျော့ချပေးနိုင်သည့် အခြေအနေအား စမ်းသပ်ဆောင်ရွက်ခြင်း ဖြစ်ပါသည်။ ဤစမ်းသပ်မှုတွင် သတ္တုတူးဖော်ထားရှိခဲ့သည့် စွန့်ပြစ်မြေ၏ အပေါ်ယံမြေဆီလွှာများ (ရွှေသတ္တု၊ ကြေးနီ သတ္တုနှင့် နီကယ်သတ္တု) အား ဇီဝမီးသွေးနှင့် မြေဆွေးမြေဩဇာအချိုးအမျိုးမျိုး(၀၊ ၅၊ ၁၀၊၂၀ ရာခိုင်နှုန်း) ဖြင့် ရောစပ်သည့် မြေပြုပြင်နည်း(၆)မျိုးဖြင့် ပြုပြင်ထားရှိပြီး၊ ရွေးချယ်ထားသည့် သစ်မျိုး၅မျိုးတို့အား စမ်းသပ်စိုက်ပျိုးခဲ့ခြင်း ဖြစ်ပါသည်။ တစ်လခွဲသားအရွယ် ပျိုးပင်ဖြင့် စတင်စမ်းသပ်စိုက်ပျိုးခဲ့သော ကျွန်း၊ တမာ၊ မယ်ဇလီ၊ အော်ရီရှားနှင့် မန်ဂျန်ရှားပင်များကို ရေငွေ့ထိန်းခန်းတွင် ထိန်းသိမ်းထားရှိပြီး၊ စိုက်ပျိုးပြီး ၅လတွင် ပျိုးပင်အမြင့်တိုင်းတာခြင်းနှင့် စမ်းသပ်မြေတွင် ပျော်ဝင်နေသည့် ဒြပ်စင်အချို့နှင့် ၎င်းနှင့်ဆက်စပ်လျှက်ရှိသည့် မြေဆီလွှာဂုဏ်သတ္တိများကို စမ်းသပ်ခဲ့ပါသည်။ စမ်းသပ်တွေ့ချက်အရ ဇီဝမီးသွေး နှင့် မြေဆွေးတို့ အသီးသီးရောစပ်၍ မြေပြုပြင်ခြင်းနည်းများသည် မူလမြေနှင့် နှိုင်းယှဉ်ပါက အပင်အမြင့်နှင့် မြေဆီလွှာ အရည်အသွေးတို့ တိုးတက်ကောင်းမွန်စေသည်ကိုတွေ့ရှိရပြီး ဇီဝမီးသွေး ၂၀ ရာခိုင်နှုန်း (သို့မဟုတ်) မြေဆွေး ၂၀ ရာခိုင်နှုန်း ရောစပ် ပြုပြင်သည့် မြေတို့မှာ အကောင်းဆုံးဖြစ်ကြောင်း တွေ့ရှိရပါသည်။ အော်ဂဲနစ်ပစ္စည်းများဖြင့် မြေပြုပြင်သည့် နည်းလမ်းများသည် မြေဆီလွှာထဲရှိ သတ္တုအဆိပ်အတောက်များကိုလည်း လျော့ချပေးနိုင်ပြီး စမ်းသပ်ဆောင်ရွက်သော မြေပြုပြင်ခြင်းနည်း(၆)မျိုးအနက် ဇီဝမီးသွေး ၂၀ရာခိုင်နှုန်း ရောစပ် ပါဝင်သော မြေပြုပြင်နည်းသည် အဆိပ်အတောက်များအား အထိရောက်ဆုံး လျော့ချပေးနိုင်ကြောင်း ပြသခဲ့ပါသည်။ ထို့ကြောင့် ဇီဝမီးသွေး ၂၀ရာခိုင်နှုန်းပါဝင်သည့် မြေပြုပြင်နည်းသည် မြေဆီလွှာ အတန်း အစား ကျဆင်းနေသည့် သတ္တုမြေနေရာများတွင် သစ်တော ပြန်လည်ထူထောင်ရာတွင် မြေဆီဩဇာပြန်လည်ဖြည့်တင်းစေသည့် အလားအလာကောင်းများ ပြသနေပါသည်။ ယခု သုတေသနလုပ်ငန်းသည် မြေပြင်မှုနည်းလမ်းအချို့သာ ဆောင်ရွက်ခဲ့ခြင်းဖြစ်ပြီး သတ္တုအဆိပ်အတောက်များ၏ ရေရှည်အကျိုးသက်ရောက်မှုအား တစ်ပြိုင်နက်လျော့ချနိုင်ပြီး သဘာဝပတ်ဝန်းကျင်အား ဘေးကင်းပြီး ကုန်ကျစရိတ်အရ သက်သာသည့် ဆန်းသစ်ကောင်းမွန်သော မြေပြုပြင်နည်းလမ်းများ ဆောင်ရွက်သင့်ကြောင်း အကြံပြုပါသည်။

Study on the Effect of Organic Amendments in Abandoned Mine Soil

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Abstract

The study examines the effect of organic amendments as measure to reduce the content of heavy metals in contaminated abandoned mine soil. In this experiment, six amendments composed of biochar and compost (0%,5%, 10% & 20%) were applied to abandoned mine soil (gold, copper, and nickel), and tested the effect on soil amendment with five selected tree seedlings. For the experiment, 1.5 month-old seedlings of 5 tree species; *Tectona grandis*, *Azadirachta indica*, *Senna siamea*, *Acacia auriculiformis*, and *Acacia mangium* were planted on each soil types and raised in a mist chamber. After five months, tree growth and soil properties associated with trace element solubility were measured and analyzed. The result indicated that, compared with the unamended soil, applications of different ratios of compost and biochar enhanced plant height and soil quality. Among the tested six soil types, soil amendment with application of 20% biochar or 20% compost exhibited superiority. Soil amendments, on the other hand also decreased the bioavailability of heavy metals, and 20% biochar showed the most effective immobilization effects. Thus, the application of 20% biochar has potential to recover soil fertility for reforestation in degraded mine land. This research was conducted with few soil amendments. Further study should be conducted on new and novel amendments that are cost-effective, environmentally safe, and capable of simultaneously affecting multiple contaminants with long-term performance.

Key words: compost and biochar, heavy metal, mine soil, organic amendments

Study on the Effect of Organic Amendments in Abandoned Mine Soil

1. Introduction

Myanmar, endowed with world-class mineral resources has long history of mining and to date mining sector has played a significant role in the country economic. To ensure the long-term sustainable production of mineral resources and minimize the environmental impact, Mine law, the law amending to the Myanmar Mine law and the Myanmar mining Rules are prescribed as a core pieces of mining regulations together with other related laws including Environmental Conservation Law and Rules, Environmental Impact Assessment Procedures,Forest Law. Importantly, the mining policy of the Myanmar Government aims, among other, and rehabilitation of abandoned mines.

From forestry sector, Myanmar Reforestation and Rehabilitation Program (MRRP) has been implemented in States and Regions since 2017, and the program is underway to rehabilitate degraded lands, including abandoned mines.

Mining activities negatively impact the environment due to the deposition of huge waste materials. Soils on mine tailings usually present unfavorable conditions for the survival of living organisms (Vega et al., 2005; Asensio et al., 2013a).

Mine rehabilitation can facilitate, accelerate, and immediate natural successional processes to increase biological productivity, reduce soil erosion rates, and increase soil fertility, including soil organic matter (ITTO, 2002). Various soil remediation techniques have been successfully employed to reduce the risks associated with heavy metals (HMs) efflux into the soil. Among these, the use of low-cost and environmentally safe inorganic and organic amendments for the in-situ immobilization of HMs has become increasingly popular.

Soil amendments can be a source of nutrients. They can also act as a soil conditioner, improving the soil's physico-chemical properties and fertility, resulting in enhanced plant establishment in metal contaminated soils. The application of organic amendments to mine sites improves the quality of their soils and allows the establishment of vegetation (Asensio et al., 2013).

Organic amendments such as biochar and compost are the most feasible method for reusing waste products, recycling essential nutrients, stabilizing the organic matter present in such materials, and restoring degraded areas (Camps Arbestain et al. 2008; Karami et al. 2011; Yang et al. 2013).

However, few studies on the soil reclamation report in the mine rehabilitation process have been carried out and still exist on the soil quality information by adding organic materials to reforestation in the abandoned mine area.

This paper focuses on the soil properties only with methods of soil reclamation of mine soils .

2. Objectives

- To assess the effectiveness of compost and biochar amendment on some chemical characteristics and bioavailability of heavy metals in abandoned mine soil.
- To propose the optimal soil amendment method for abandoned mine areas

3. Literature Review

Young, poorly developed soils characterize mining areas are often with scarce or absent vegetation cover due to extreme pH values, poor fertility conditions, low organic matter contents, and degraded soil structures, usually with high metals and other potentially hazardous elements (Mench et al. 2010). The mobility and bioavailability of metals such as Cu, Pb, and Zn in contaminated soils are of global concern (Uchimiya et al. 2010)

Most existing technologies to remove the pollutants are often ineffective, uneconomical, or technically complicated. The addition of organic and inorganic soil amendments can promote the fixation of the metal and can thus enhance the effect of stable plant restoration. Contaminated soils can be modified using organic/inorganic amendments depending on the optimal growth conditions of the plant. Mo-Ming Lan et al. 2020

In this respect, organic materials are paid consideration for the remediation of mine soils because organic amendments can increase the pH of acidic soils and bind metals (Agnieszka et al. 2020). Organic materials, such as waste compost and biochar, have been used as soil amendments to enhance the condition of degraded soils (Peña et al., 2015; Zhang et al., 2014; Zong et al., 2016). Organic amendments prepared from soil reclamation waste can be dominated by human-made materials and contain many artefacts (FAO 2014).

The use of compost as an amendment can improve the physical, chemical, and biological properties of degraded soils by supplying organic matter and can be used in soil reclamation. Compost improves soil fertility, provides organic matter, increases aggregate stability, aeration, water infiltration, and retention, and decreases soil erosion. (Mo-Ming Lan et al. 2020)

Biochar is an organic material produced by burning biomass under low temperatures and minimal oxygen conditions. The multiple benefits of using biochar as an amendment include improving soil properties, reducing environmental pollution, and mitigating climate change. Biochar is reported to increase pH, cation exchange capacity, electrical conductivity, water retention capacity, and the retaining of toxic metals in the soil (Mo-Ming Lan et al. 2020).

4. Materials and Method

4.1 Soil Sampling

Three types of abandoned mine soils (gold, nickel, and copper) were selected for this study and made for the combination of soil amendments. The first one (gold site - GM) is situated at Ma Gi Gone close to an abandoned gold mine in Bamauk Township. The second (copper site - CM) is situated at Kyae Sin Taung area in Salingyi Township, where there is an old copper mine, and The last (nickel site-NM) is at Ta gaung Taung nickel mine areas in Tabaik Kyin Township. This soil samples were collected from the top 20 cm during the dry season in 2019 with the help of staff from a mining company ltd and local Forest Department.

4.2 Pot Experiment

The materials used as amendments for the pot experiment were biochar and compost. The biochar (B) was made from rice husk submitted to a pyrolysis temperature of 400 °C for 8 hours (Karami et al. 2011). The compost (CP) was a commercial material marketed for soil amendment, cow manure.

In preparation of soil mixture, the soil samples collected from the abandoned mine sites were mixed with organic materials as follows

T1 = B 10% amendment + 90% mine soil;

T2 = B 20% amendment + 80% mine soil;

T3 = CP 10% amendment + 90% mine soil,

T4 = CP 20% amendment + 80% mine soil;

T5 = B 5%& CP 5% amendment + 80% mine soil and

T6 = un-amended (0 % amendment)

For this study, one and half months old seedling of five tree species mentioned below were used: *Tectona grandis*, *Azadirachta indica*, *Senna siamea*, *Acacia auriculiformis*, and *Acacia mangium.* The seedlings were planted in a 3 L plastic pot filled with amendment mixture. This 3 x 6 x 5 factorial design was replicated three times for 270 pots, and conserve at mist chamber. Throughout the experiment period, seedlings were watered with tap water (approximately three times a week, as required) to maintain a proper moisture level but were not apply fertilized, and seedlings were harvested 180 days after transplanting. The mist chamber was maintained at a temperature of 25 ± 3 ºC and 75 ± 5% relative air humidity.

4.3 Soil Analysis

Composite soil samples were made for each treatment for the low cost of soil analyses by randomly selecting two or three pots and combining and mixing the soils. It provided five replications of each treatment combination for statistical analysis. Soil pH, soil texture, organic matter content, and total N were determined using soil laboratory methods (Pritchett & Tin Tin Ohn, 1981). Metal concentrations of Cu, Pb, Zn, and Ni were extracted with aqua regia by acidic digestion (1:3 v/v) in a hot plate and determined by GFAAS in a water laboratory on FRI.

4.4 Measurement of Plant Height

At the end of the experiment, plant heights were measured in each pot and washed with deionized water, and dry biomass was weighed on a laboratory scale after oven drying at 70 °C for 48 h and cooling at room temperature and store plant samples for further analysis.

4.5 Data Analysis

The recorded data of the experiment was expressed as the mean data. Analysis of variance was prepared by using SPSS 20.0. The significant difference between treatments was differentiated by the statistical test known as Least Significant Difference (LSD), with a p-value less than 0.05.

5. Results

5.1 Mining soil properties

The physical and chemical properties of soil samples from abandoned mine sites are presented in Table 2. The pH range of the study area was found to be slightly acidic 4.68–5.86. The average levels of organic carbon and total nitrogen in the mined soil were generally low, which have resulted in the removal of vegetation and, consequently, loss of plant nutrients. The results of this study reveal that the heavy metals/metalloid contents of the study soils were within and above the recommended limits as set up in WHO (1996) guidelines.

Table1. Mining soil properties in all soil

*

Particular	pH	Total N %	OM%	Metal concentration (mgkg-^{1})					Texture
				Cu	Pb	Zn	Ni	Cd	
Gold mine soil	5.86	0.030	2.0	42.10	20.00	12.96	58.24	1.24	Sandy-Loam
Copper mine soil	4.68	0.028	3.0	50.00	35.30	15.53	35.30	1.89	Sandy-Loam
Nickel mine soil	5.48	0.016	3.0	18.02	30.68	18.92	118.45	3.6	Clay Loam
soil standard*	5.5-6.5	0.07-1.00	3-7	-	-	-	-	-	Sandy Clay-Loam
WHO**	-	-	-	36	85	50	35	0.8	-

** WHO(1996) permissible limit for heavy metal plant and soil

Tin Tin Ohn, (2007) ITTO Teak project PD 270/04 Rev. 2(F)

5.2 Effect of amendments on soil properties

The Result of the experiment showed that soil amended treatments had significant effects on physicochemical properties in different mine soils and almost significant interactions between the two factors (pH < .005). See in Appendix1 and table 2.

Table 2. Mean comparison of amendments on soil properties in mine soils

Soil type	Treatment	pH	Total N%	OM%
Gold soil	T1	6.38 c	0.09 b	3.20 b
GM	T2	6.77 a	1.21 a	4.34 a
	T3	6.70 b	0.07 c	3.23 b
	T4	6.74 a	1.18 a	4.42 a
	T5	6.35 c	0.09 c	3.21 b
	T6	5.83 d	0.03d	2.02 c
Copper soil	T1	6.87 b	0.08 b	5.18 c
CM	T2	7.23 a	1.29a	7.72 a
	T3	6.84 b	0.08b	3.24 b
	T4	7.08 a	1.29 a	8.34 a
	T5	6.82 b	0.09 b	5.36 c
	T6	5.84 c	0.04 c	3.04 d
Nickel soil	T1	6.08 b	0.08 b	5.26 c
NM	T2	6.27 a	1.18 a	7.98 a
	T3	6.06 c	0.08 b	5.58 b
	T4	6.16a	1.18 a	8.04 a
	T5	6.04 c	0.08 b	5.36 c
	T6	5.45 d	0.04 c	3.04 d

The amended soils showed significantly higher pH values than the untreated soils. Soil pH was increased depending on the initial pH of mine soil type. The observed soil pH ranged from 5.48 to 7.23. Among different soil mixtures, 20% biochar and 20% compost amended soil significantly increased pH unit compared to others, but no significant differences were observed between these amendments (Figure 1).

In several treatments, the organic matter content increased in all soil types (Figure 1). The organic matter content varied from 2.03-2.3% to 5-8% in the soil amendments. The soils treated with 20% compost and 20% biochar exhibited a higher organic content than the other treatments, but no significant difference between these amendments.

The results showed that the total N concentration was significantly affected by soil amendments. Total N also varied significantly among the treatments, ranging from ~0.028-1.294% in GM, CM, and NM soil type (Figure 1). High amounts of the amendments resulted in statistically significant differences compared with other soil amendments.

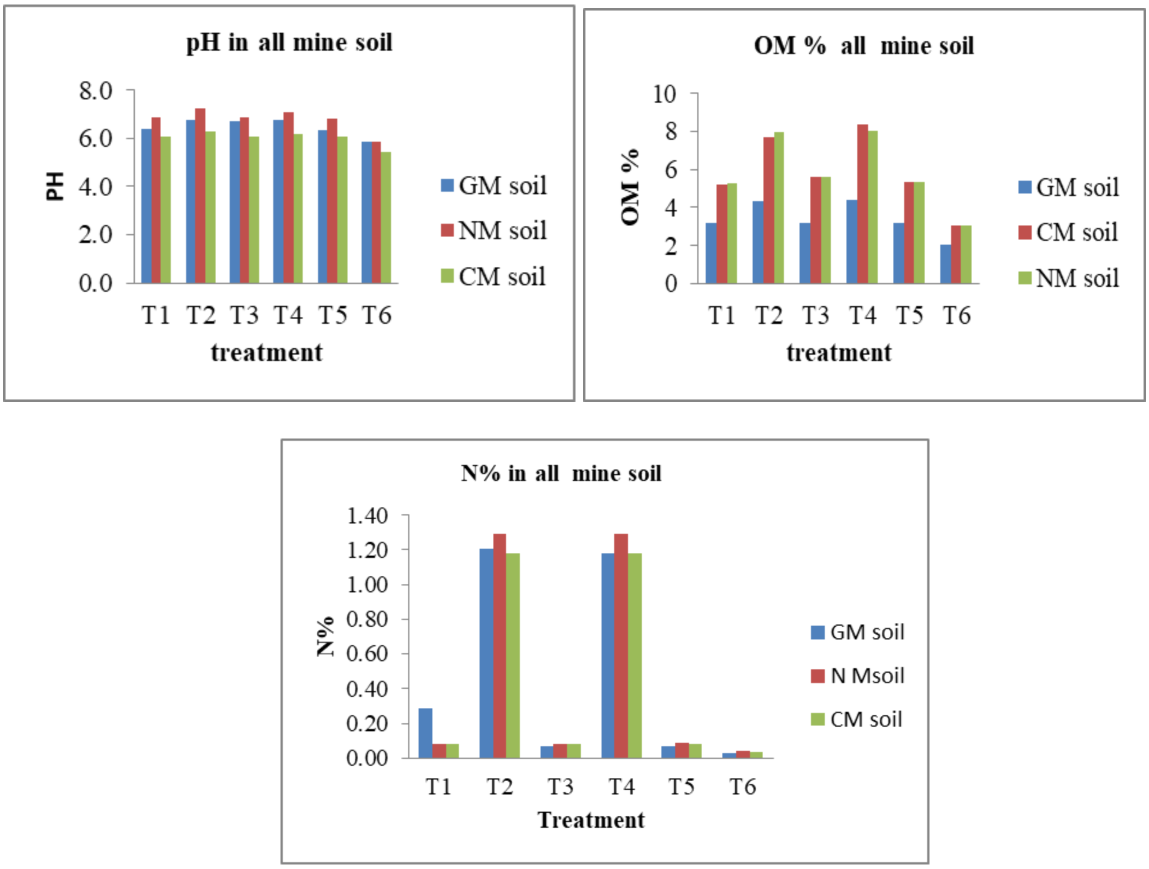


Fig: 1 Treatments effect on soil properties

5.3 Effect of amendments on heavy metal concentration

The effect of different biochar and compost applications on heavy metal conditions in all mine soils significantly reduced the availability of Pb, Cu, Zn, Ni, and Cd compared to control (Table 3 and appendix 2). The results show general reductions in the metal levels from their initial concentrations to the end of the study in all treatments as shown in figure 2.

Soil amendment reduced Cu, and Pb concentration in all soil types varies from 3.11 to 29.01 mgkg^{-1} and 0.86 to 6.63 mgkg^{-1} after application. The concentration of Zn and Ni decreased in the range of 1.10 - 49.20 mgkg^{-1} and 4.33 – 49.20 mgkg^{-1}, respectively. Trace element reduction efficiency of bioavailable Cd in the treatment compared to the control was in the range of 0.01–0.96 and 0.49-1.97 % mgkg^{-1}, respectively.

Table 3. Mean comparison of treatments on heavy metal concentration

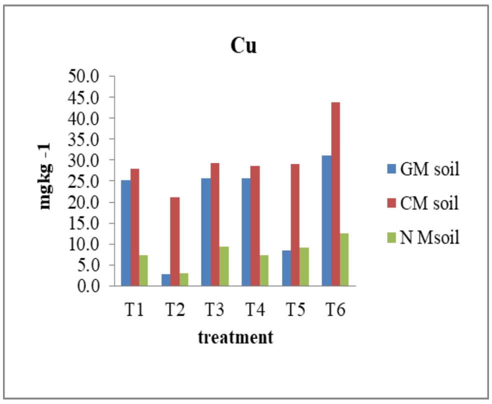
Soil type	Treatment	Cu mgkg^{-1}	Pb mgkg^{-1}	Zn mgkg^{-1}	Ni mgkg^{-1}	Cd mgkg^{-1}
GM	T1	25.19 c	4.68 b	4.24 b	12.13 c	0.32 b
	T2	12.86 a	3.27 a	1.10 a	4.33 a	0.08 a
	T3	25.72 c	4.19 b	3.56 b	11.08 c	0.38 b
	T4	25.60 c	4.88 b	1.63 a	7.024 b	0.14 a
	T5	18.46 b	6.63 c	3.50 b	12.04 c	0.35 b
	T6	31.00 d	8.26 d	6.73 c	45.12 d	0.49 c
CM	T1	27.960b	3.01 b	1.84 b	15.68 b	0.07 b
	T2	21.18 a	1.81 a	1.37a	9.452 a	0.01 a
	T3	29.36 b	2.49b	1.79 b	15.76 b	0.06 b
	T4	28.64 b	2.11 a	1.72 b	14.90 b	0.07 b
	T5	29.01b	3.23b	1.83 b	14.52 b	0.06 b
	T6	43.80 c	8.80 c	2.95c	23.50c	0.82 c
NM	T1	7.35c	2.39 b	9.70 b	49.20 b	1.18 c
	T2	3.11 a	0.86 a	4.52 a	21.28 a	0.48 a
	T3	9.29 c	2.09 b	9.318 b	45.28 b	1.23 c
	T4	7.25 b	2.22b	9.32 b	46.52 b	0.96 b
	T5	9.15 c	2.38 b	9.49 d	46.16 b	1.13 c
	T6	12.54 d	6.27 c	16.38 c	74.36 c	1.97 d

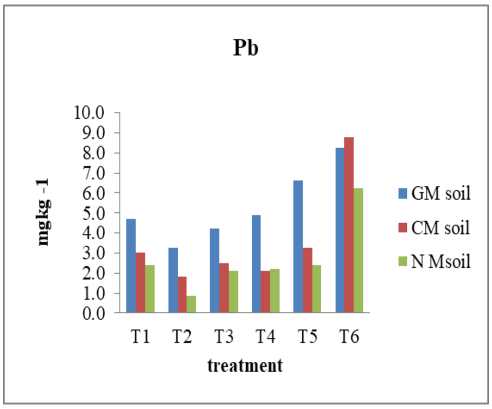
In all amendments, 20% biochar -T2 significantly decreased GM soil in Cu, Pb, and Ni concentrations. However, Zn and Cd decreased in 20% biochar -T2 and 20% compost-T4.

Soil amendments in CM soil, the lowest amount of Cu, Pb, Zn, Ni, and Cd were obtained in T2. Metal concentration in the T1, T3, T4, and T5 soil treatments was generally lower than T6, and there was no significant difference among treatments.

Soil amendments in NM soil, 20% biochar amended (T2) significantly reduced Cu, Pb, Zn, Ni, and Cd, followed by T4, T3, T1, T5, and T6.

In this experiment, the soil amendments effect is slightly different in all soils, but the effects were more pronounced at the higher dose of biochar.





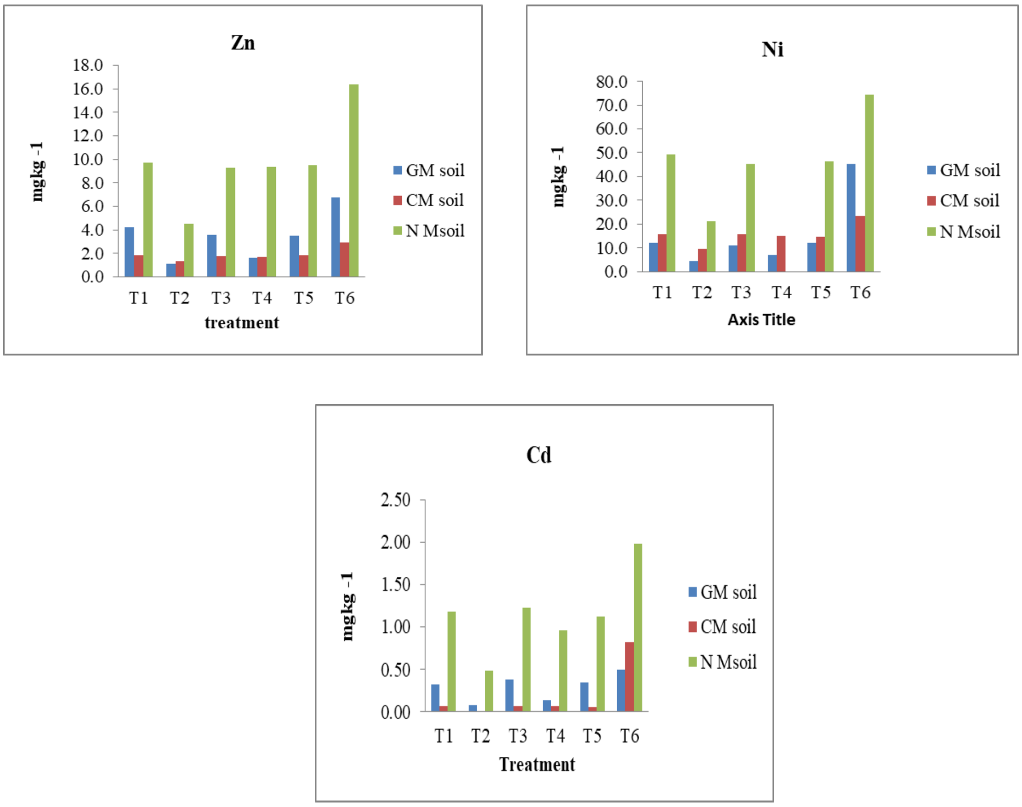


Fig: 2 treatments effect on heavy metal concentration in all soil

6. Discussion

6.1 Effect of amendments in soil fertility

Soil amendments can be a source of nutrients and thus can also act as a soil conditioner, improving the soil's physicochemical properties and fertility, resulting in enhanced plant establishment in metal contaminated soils. (Chaw Su Lwin et.al 2010)

The result showed that adding organic soil amendments improved some soil physical and chemical properties in all mine soils. The direction of the change in soil pH due to treatment application reflected the initial pH of the amendment material.

Soil amendments resulted in increased soil pH in all types of mine soil. Application of biochar significantly increases the soil pH compared to that of un-amendment (control), while application of compost significantly show positive trend. The sensitivity of soil pH to the organic amendments was likely due partly to the low buffering capacity (Neilsen et al., 1998).

As soil pH is increased, soluble fraction of heavy metals can make a complexation or bonding with ions and enable the immobilization of soluble heavy metals in (Young Kyu Hong etal.2020)

The application of organic amendments led to a significant increase in organic carbon content compared to its initial level. The addition of 20% compost and 20% biochar affected the soil organic matter content, and it demonstrated that the increased organic content was proportional to the application dose used.

The changes in the organic content in soils brought about changes in the total nitrogen content. The increased total nitrogen of the soil after amendments is closely related to the build-up of OM in the soil.

This study indicated that organic amendments beneficially improve soil characteristics and can be applied as effective amendments in contaminated soils.

6.2 Effect of amendments in bioavailability of trace elements

Our results showed that organic amendments added to the contaminated soil decreased the mobile fraction of trace elements (Pb, Cu, Zn, Ni, and Cd) compared with the untreated soil. The general reduction of metals observed indicates that plant species used for the study effectively extracted metals from the soil.

Heavy metals are related to various soil components differently, and these associations determine their mobility and availability. An important factor influencing the mobility of Pb, Cu, Cd, and Zn is the quantity of organic matter in the soil (Ross, 1994; McGrath et al., 1998, 2000). The sorption behaviour of Cd, Cr, Ni, and Zn in soils varied from soil to soil and was influenced by soil properties such as pH, organic matter, cation exchange capacity (CEC), and clay contents (McBride and Martinez, 1994)

Soil amendments significantly vary reduction efficiency among metal species in GM soil type. 20% biochar addition significantly reduces Pb, Cu, and Ni while Zn and Cd at 20% biochar and 20% compost. The variation of the metal species may be related to metals immobilization by humic-fluvic substances from compost and biochar application.

Increasing biochar application rates caused significant Pb, Cu, Ni, Zn, and Cd reductions in CM and NM soil types. Park et al. (2011) and Fellet et al. (2011, 2014) observed reductions in extractable and bioavailable Cd, Cu, Pb, and Zn when biochar was added to metal-laden soils. Yuan et al. (2011) suggested that reduction in metal bioavailability was due to the formation of metal carbonate species and reactions with surface functional groups, which may be a sequestration mechanism. The formation of metal oxyhydroxide species has also been shown to be a mechanism responsible for decreased metal bioavailability (Ippolito et al., 2012).

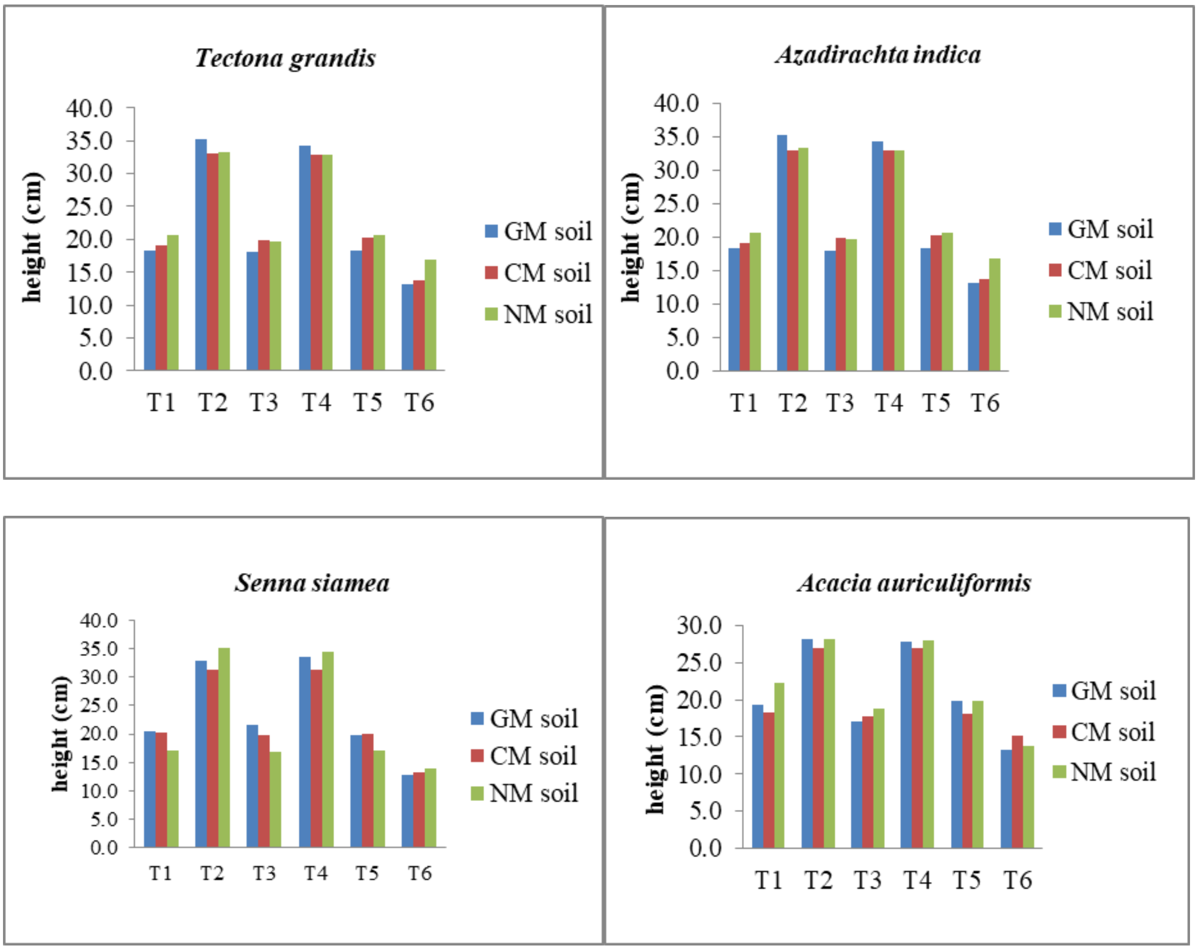
Although both 20% biochar and 20% compost similarly increased soil pH, OM, and Total N to a greater extent than the other 5 and 10% throughout the study. However, when bioavailable metal concentration differences were present, 20% biochar reduced metal bioavailability to a greater extent than 20% compost in most soil (data not shown). Thus, 20% biochar could be successfully used to create biochar that reduce heavy metal bioavailability in mine-affected soil.

6.3 Response of plant growth

The plant height significantly increased due to applying organic amendment in GM, CM, and NM (Appendix 3). The response of plants to the application of organic amendment was species-dependent (figure 3). The improved growth may be caused by improved plant health through the decomposition of OM, nutrient cycling, and the improvement of the soil structure. The application of 20% biochar and 20% compost caused remarkable increases in growth rate.

Many organic wastes represent an essential source of N, P, Ca, and others such as Zn, Cu, and Mg, essential to plant growth. Biochar and compost are rich with organic matter, which will encourage the growth of many beneficial microorganisms, and these organisms have an excellent ability to produce various organic acids compounds that help in nutrients availability or promote plant growth (Young Kyu Hong etal.2020)

The present Result confirmed that high dose applying the soil amendments could provide plants with nutrients and reduce the activity of Cd and Pb in the soil, thereby promoting plant growth and enhancing plant photosynthesis. (Mo-Ming Lan et al. 2020).



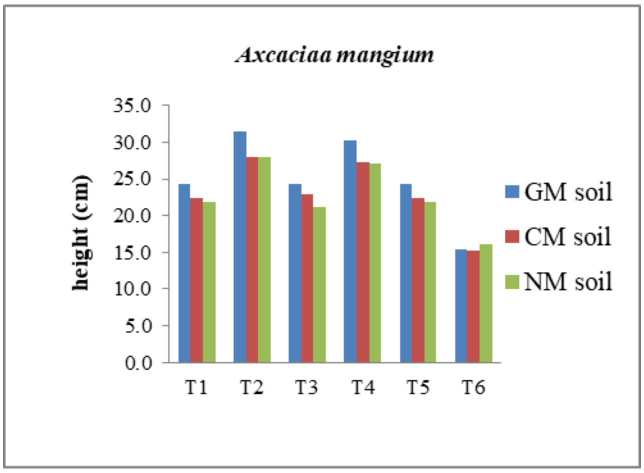


Figure 3. treatments effect on plant height in all soils

7. Conclusion and recommendation

This study evaluated the effect of organic amendments as measure to reduce the content of heavy metals in contaminated abandoned mine soil . The result indicated that, compared with the unamended soil, applications of different ratios of compost and biochar enhanced plant height and soil quality. Among the tested six soil types, soil amendment with application of 20% biochar or 20% compost exhibited superiority. Soil amendments, on the other hand also decreased the bioavailability of heavy metals, and 20% biochar showed the most effective immobilization effects. Thus, the application of 20% biochar has potential to recover soil fertility for reforestation in degraded mine land. This research was conducted with few soil amendments. Further study should be conducted on new and novel amendments that are cost-effective, environmentally safe, and capable of simultaneously affecting multiple contaminants with long-term performance.

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Appendix 1

Analysis of variances for soil properties

ANOVA

pH in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.327	5	1.265	574.354	.000
Within Groups	.053	24	.002		
Total	6.380	29			

ANOVA

pH in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.061	5	.412	303.860	.000
Within Groups	.033	24	.001		
Total	2.094	29			

ANOVA

pH in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.935	5	1.187	1356.498	.000
Within Groups	.021	24	.001		
Total	5.956	29			

Tests of Between-Subjects Effects

Dependent Variable: pH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25.433[a]	17	1.496	14.547	.000
Intercept	3752.615	1	3752.615	36489.638	.000
treatment	10.954	5	2.191	21.303	.000
site	11.794	2	5.897	57.340	.000
treatment * site	2.685	10	.268	2.611	.009
Error	7.405	72	.103		
Total	3785.452	90			
Corrected Total	32.837	89			

a. R Squared = .775 (Adjusted R Squared = .721)

ANOVA

Nitrogen in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.001	5	1.600	38.619	.000
Within Groups	.994	24	.041		
Total	8.995	29			

ANOVA

Nitrogen in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.942	5	1.988	1266.802	.000
Within Groups	.038	24	.002		
Total	9.980	29			

ANOVA

Nitrogen in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.193	5	1.639	1495.066	.000
Within Groups	.026	24	.001		
Total	8.219	29			

Tests of Between-Subjects Effects

Dependent Variable: N

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	26.162[a]	17	1.539	104.687	.000
Intercept	19.450	1	19.450	1323.119	.000
treatment	25.947	5	5.189	353.022	.000
site	.026	2	.013	.872	.422
treatment * site	.189	10	.019	1.283	.256
Error	1.058	72	.015		
Total	46.670	90			
Corrected Total	27.220	89			

a. R Squared = .961 (Adjusted R Squared = .952)

ANOVA

OM in Gm Soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	19.742	5	3.948	87.096	.000
Within Groups	1.088	24	.045		
Total	20.830	29			

ANOVA

OM in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91.763	5	18.353	17.246	.000
Within Groups	25.540	24	1.064		
Total	117.303	29			

ANOVA

OM in Nm soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	89.430	5	17.886	17.779	.000
Within Groups	24.144	24	1.006		
Total	113.574	29			

Tests of Between-Subjects Effects

Dependent Variable: OM

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	323.613[a]	17	19.036	26.995	.000
Intercept	2293.205	1	2293.205	3252.005	.000
treatment	183.257	5	36.651	51.975	.000
site	122.678	2	61.339	86.985	.000
treatment * site	17.678	10	1.768	2.507	.012
Error	50.772	72	.705		
Total	2667.590	90			
Corrected Total	374.385	89			

a. R Squared = .864 (Adjusted R Squared = .832)

Appendix 2

Analysis of variance for Heavy metal concentration in mine soils

ANOVA

Cu in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3192.448	5	638.490	346.750	.000
Within Groups	44.193	24	1.841		
Total	3236.641	29			

ANOVA

Cu in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1378.551	5	275.710	215.167	.000
Within Groups	30.753	24	1.281		
Total	1409.305	29			

ANOVA

Cu in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	242.311	5	48.462	66.852	.000
Within Groups	17.398	24	.725		
Total	259.709	29			

ANOVA

Pb in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	82.152	5	16.430	173.803	.000
Within Groups	2.269	24	.095		
Total	84.421	29			

ANOVA

Pb in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	169.892	5	33.978	339.795	.000
Within Groups	2.400	24	.100		
Total	172.292	29			

ANOVA

Pb in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	82.727	5	16.545	150.322	.000
Within Groups	2.642	24	.110		
Total	85.369	29			

ANOVA

Zn in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	101.130	5	20.226	253.395	.000
Within Groups	1.916	24	.080		
Total	103.046	29			

ANOVA

Zn in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.183	5	1.437	120.959	.000
Within Groups	.285	24	.012		
Total	7.468	29			

ANOVA

Zn in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	358.461	5	71.692	27.163	.000
Within Groups	63.343	24	2.639		
Total	421.804	29			

ANOVA

Ni in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5582.630	5	1116.526	749.390	.000
Within Groups	35.758	24	1.490		
Total	5618.388	29			

ANOVA

Ni in CM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	510.981	5	102.196	247.113	.000
Within Groups	9.925	24	.414		
Total	520.906	29			

ANOVA

Ni in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7092.000	5	1418.400	212.496	.000
Within Groups	160.199	24	6.675		
Total	7252.199	29			

ANOVA

Cd in GM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.600	5	.120	147.053	.000
Within Groups	.020	24	.001		
Total	.620	29			

ANOVA

Cd in CM soil Nm soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.540	5	.508	880.945	.000
Within Groups	.014	24	.001		
Total	2.554	29			

Cd in NM soil

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.841	5	1.168	109.034	.000
Within Groups	.257	24	.011		
Total	6.098	29			

Appendix 3

Analysis of variance for Av. Height (cm) in planted species

1.*Tectona grandis*

ANOVA

Av. Height of treatment effect in GM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1805.507	5	361.101	542.638	.000
Within Groups	15.971	24	.665		
Total	1821.478	29			

.Av. Height of treatment effect in CM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4015.255	5	803.051	9041.929	.000
Within Groups	2.132	24	.089		
Total	4017.387	29			

.

Av. Height of treatment effect in NM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2121.473	5	424.295	2544.129	.000
Within Groups	4.003	24	.167		
Total	2125.475	29			

2. *Senna siamea*

ANOVA

Ava .height of treatment effect in GM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1653.718	5	330.744	621.136	.000
Within Groups	12.780	24	.532		
Total	1666.498	29			

ANOVA

Ava .height of treatment effect in CM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1319.917	5	263.983	10189.790	.000
Within Groups	.622	24	.026		
Total	1320.539	29			

ANOVA

Ava .height of treatment effect in NM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2357.346	5	471.469	5166.785	.000
Within Groups	2.190	24	.091		
Total	2359.536	29			

3.*Azadirachta indica*

ANOVA

Ava .height of treatment effect in GM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2216.462	5	443.292	23252.853	.000
Within Groups	.458	24	.019		
Total	2216.919	29			

ANOVA

Ava .height of treatment effect in CM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1578.500	5	315.700	3427.692	.000
Within Groups	2.210	24	.092		
Total	1580.711	29			

ANOVA

Ava .height of treatment effect in NM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1294.089	5	258.818	7139.351	.000
Within Groups	.870	24	.036		
Total	1294.959	29			

4. *Acacia auriculiformis*

ANOVA

Ava .height of treatment in GM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	896.637	5	179.327	121685.212	.000
Within Groups	.035	24	.001		
Total	896.673	29			

ANOVA

Ava .height of treatment effect in CM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	655.349	5	131.070	39.053	.000
Within Groups	80.548	24	3.356		
Total	735.897	29			

ANOVA

Ava .height of treatment effect in NM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	786.350	5	157.270	119167.946	.000
Within Groups	.032	24	.001		
Total	786.381	29			

5. *Acacia mangium*

ANOVA

Ava .height of treatment effect in GM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	816.685	5	163.337	5586.686	.000
Within Groups	.702	24	.029		
Total	817.387	29			

ANOVA

Ava .height of treatment effect in CM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	517.107	5	103.421	52953.370	.000
Within Groups	.047	24	.002		
Total	517.154	29			

ANOVA

Ava .height of treatment effect in NM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	466.628	5	93.326	2751.737	.000
Within Groups	.814	24	.034		
Total	467.442	29			