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Growth Response of Abaca (Musa textilis Nee) in Abandoned Mine Soil Amended with Oil Palm Residues

Mechelle R. Mangmang and Katherine L. Cozo

Abstract

The mining industry is one of the leading sectors providing economic benefit to the community. However, mining minerals inevitably affect the ecosystem function of the land, thereby reducing ecological services provided to mankind. Soil remediation is done to restore ecological integrity while mitigating degradation processes. Thus, this study was conducted to determine the chemical properties of abandoned mine soil and to determine the effects of oil palm residues on the growth performance of abaca (Hybrid 7) grown in mined soil under nursery conditions. This study was arranged in a completely randomized design (CRD) with five treatments and four replications, namely, T1 - Mined Soil Alone, T2 - Garden Soil Alone, T3 - Mined soil + Oil Palm Sludge, T4 - Mined Soil + Oil Palm Empty Fruit Bunch (EFB) Biochar, T5 – Mined Soil + Oil Palm Vermicast. Chemical analysis of mined soil revealed extreme acidic soil condition, low organic matter, CEC, N, K, and high P content relative to soil nutrient sufficiency criteria. Mined soil contained 0.347 mg/kg Cd and 0.230 mg/kg Pb which are within the tolerable limit of 2.00 mg/kg for Cd and 300 mg/kg (Pb), respectively. Application of oil palm residues in mined soil can significantly improve the morphology and dry matter yield performance of hybrid 7 abaca seedlings. Plants grown in mined soil amended with oil palm residues were taller, larger pseudostem girth with more and bigger functional leaves, and had a higher survival rate compared to those grown in soil derived from the abandoned mining area. Abaca plants grown with amendments had accumulated higher dry matter. Oil palm residues particularly vermicast has greater potential as soil amendment under degraded mined in Mawab, Davao de Oro.

Keywords: degraded soil, organic amendments, oil palm residues, soil rehabilitation, recycling

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The mining sector worldwide is greatly important for income generation, employment, economic activities, and development. Mining, however, poses major health threats and hazards that lead to significant environmental impacts, such as soil degradation and mass movements (Carvalho, 2017). Mining operations completely alter a site's ecosystems by disrupting the ecological balance, natural landscapes including forest and agricultural productions. Generally, it reduces soil's ecosystem function and services.

As claimed by de Barros et al. (2013), the environmental effects of mining activities can be mitigated using appropriate environmental controls and ecological restoration techniques. In other countries like Indonesia, integrated spatial planning of mined land was found to be potentially effective in providing environmental benefits, economic sustainability, and social acceptability (Kodir et al., 2017). Nevertheless, the restoration of soil as the basic foundation for any bioremediation is inevitable. Among others, organic soil amendments (OSA) are often used to improve the soil's physical, chemical, and biological properties. The use of OSA enables sites' remediation, revegetation and revitalization, and reuse (Brown et al., 2005). Organic by-products produce organic fertilizers that can provide nutrients through biochemical processes, stimulating plant growth through the synthesis of growth-promoting substances.

Caraga Administrative Region (Region XIII) in the Philippines is home to the pioneering large-scale oil palm plantation that started in the early '80s. It covers 35% of the total oil palm production area in the country. In the year 2016, the CARAGA region produced approximately 168,818 metric tonnes of fresh fruit bunch (PSA, 2018), and about 80% of biomass are discarded as waste (Pleanjai et al., 2004). The massive volume of the waste by-product can be potentially recycled as a source of organic amendments to improve the soil properties and thereby considered as an option to rehabilitate abandoned mine soils (Srinivasarao et al., 2021).

Aside from using OSA, revegetation plays an important facet in the overall sustainable rehabilitation strategy. Nevertheless, planting edible crops in contaminated soil is unsafe for food consumption due to heavy metals toxicity. Thus, the introduction of other plant types could be used as another alternative like abaca which is known for its industrial purposes. Abaca is grown commercially for its fibers which are used as raw material for pulp, cordage, aesthetics, and handicrafts. Planting abaca could also be a potential source of income to the farmers at the same time reducing the ongoing soil degradation and threat to human health.

Abaca (*Musa textilis* Nee) is closely related to edible banana (*Musa acuminate* and *M. balbisiana*) that is indigenous to the understory of the Philippines tropical lowland rainforests. For many years, the Philippines is the leading producer of abaca in the world market. It constitutes about 87% of the total production in the world followed by Ecuador (12%) and Costa Rica (0.06%), respectively (PhilFIDA, 2016). Among the top five (5) abaca producing regions in the Philippines, three of them namely, Davao Region, Caraga Administrative Region, and the Autonomous Region in Muslim Mindanao (ARMM) are situated in the island of Mindanao. In fact, in the year 2015, the biggest increment in production was recorded in Region XIII by 19% (PSA, 2018). At the moment, the Philippine government focuses on the expansion and rehabilitation of abaca to catch up with the increasing demand for abaca's by-products in the world market. These urge the grower to produce more good quality abaca by-products to accommodate the domestic and global demand. One of the strategies to increase production aside from expansion is the use of mechanization and the use of abandoned land areas like abandoned mines. Thus, this research could serve as an alternative way to solve the ongoing soil degradation at the same time increasing the production of abaca to meet the global market demand. Specifically, it aims to determine the chemical properties of abandoned mine soil from Mawab, Davao de Oro, Philippines and to determine the effects of oil palm residues on the growth performance of abaca (Hybrid 7) grown in abandoned mine soil under nursery conditions.

Materials and Methods

Soil Collection and Preparation

Mining is one of the important economic activities in the province of Davao de Oro, Philippines. This province is considered as the Gold District of Davao Region, due to the rich deposit of metallic (Gold, Silver, Copper, and Iron) and non-metallic resources. The prevalent small-scale mining operations in the area are concentrating on gold and silver extraction. Bulk soil samples used in the study were collected randomly at 20-30 cm depth using spade at the abandoned mine soil in Mawab, Davao de Oro. Soil samples were mixed thoroughly to obtain one composite sample. This was placed in a clean and properly labeled sack and brought to USeP Mabini for processing. The collected soil sample was air-dried for two weeks, pulverized, sieved through a 10 mm wire screen to remove small stones, gravel, and other fragments. About 1kg composite soil sample was set aside from the bulk sample and brought to the Davao Trade Exponents, Inc., Guianga, Tugbok Dist., Davao City Soil Analytical Laboratory, for the determination of its initial soil chemical properties such as soil pH, soil electrical conductivity (EC), Mehlich 3 (M3) Phosphorous (P), exchangeable Potassium (K), Nitrogen (N) and heavy metals (Cadmium (Cd), and Lead (Pb).

Ordinary garden soil was collected at the upper 0-20cm from USeP experimental area which was previously planted with root crops. About 1 kg composite soil sample was set aside from the bulk sample for the chemical analysis.

Experimental Design and Treatments

The study was conducted at the greenhouse of the University of Southeastern Philippines (USeP), Tagum-Mabini Campus, Mabini Unit, Mabini, Davao de Oro from December 2019 to May 2020. The experiment was laid out in a completely randomized design (CRD) with five (5) treatments replicated four (4) times having 10 sample plants per treatment combined with a total of 200 samples (Figure 1).

The treatment combinations were as follows:

T_1- Mined soil alone

T_2- Garden soil alone

T_3- Mined Soil + Oil palm sludge (1:1 ratio)

T_4- Mined Soil + Oil palm empty fruit bunch (EFB) biochar (3:1 ratio)

T_5- Mined Soil + Oil palm vermicast (1:1 ratio)

Figure 1. Standing crop inside the greenhouse, 30 days after transplanting (DAT).

Preparation of treatments - Oil Palm Residues (OPR)

The oil palm vermicast (OPV) was sourced from the Vermiculture Project of the College of Agriculture, Agusan Del Sur State College of Agriculture and Technology, Bunawan, Agusan Del Sur. Before vermicomposting, the oil palm waste was allowed to decompose for a couple of months. From there, the earthworms (*Eudrilus eugeniae*) consumed the pre-decomposed organic materials through their gut to produce a cast. Vermicast was harvested approximately one and half months from the start of vermicomposting. Oil palm sludge (OPS) and Oil Palm EFB (OP-EFB) were collected at Rosario, Agusan del Sur. These materials were chopped, shredded, and heated for two hours using an improvised gasifier stove to produce biochar.

Chemical analysis of oil palm waste product organic amendments

The collected samples of OPR were air-dried for two weeks, pulverized, sieved to remove other fragments. Then, about 1kg of organic amendments such as OPS, OP- EFB biochar, and OPV were submitted to the Davao trade exponent, Inc., Guianga, Tugbok Dist., Davao City Soil analytical laboratory for the determination of its chemical properties such as pH, OM, CEC, and total N, P and K following the methods of Rayment and Lyons (2011).

Cultural Management and Practices

All weeds present inside the greenhouse were removed to prevent pests and diseases from harboring. The area was sprayed with disinfectant to eliminate the disease-carrying bacteria or viruses inside the greenhouse. The greenhouse was covered with a layer of the black net to minimize direct sunlight exposure. Two (2) weeks before transplanting, a mixture of mined soil and organic amendments was placed in a clay pot (32 x 35 cm) and incubated for 3 weeks before the transplanting of the abaca seedlings (abaca, Hybrid 7 variety). Three kilograms of collected soil per pot was used for treatment 1 (mined soil alone) and treatment 2 (garden soil alone). The application of organic amendments in T3, T4, and T5 was based on the designed treatments. For treatment 3, 1:1 ratio of mined soil and oil palm sludge was used (1.5kg of mined soil + 1.5kg of OPS), T4 had 2.25kg of mined soil + 750g of OP-EFB biochar, and T5 had 1.5kg of mined soil + 1.5kg of OPV/pot. Before transplanting, seedlings were carefully evaluated and classified according to their plant height to guarantee uniformity in terms of morphological characteristics of planting materials. The selected abaca seedlings were planted individually in each prepared pot.

Transplanting was done inside the shaded area to avoid seedling damage and dehydration. Thereafter, the newly transplanted seedlings were placed and arranged randomly inside the greenhouse until termination. Seedlings were irrigated with enough water to help seedlings recover from transplanting shock.

Application of inorganic fertilizer was done to supplement the nutrients for their growth and development particularly in harsh soil conditions. Inorganic fertilizers such as urea and muriate of potash (MOP) were applied at planting, 30 and 60 days after transplanting (DAT). The fertilizer was applied at a distance of 2 cm from the base of the plant to avoid damage. Urea (46-0-0) was applied at a rate of 4.5g/pot while MOP (0-0-60) was applied at 4g/pot. These fertilizers were applied across all treatments. The occurrence of pests and diseases was closely monitored from planting until termination. Immediate hand-picking of insect pests and removing infected plant parts were done to ensure treatment effects are not altered by pests and diseases. Watering was done twice a day (morning and afternoon) using a hand sprinkler. This was done to ensure that the soil was at field capacity to avoid water stress.

Growth Response of Abaca (Hybrid 7 variety)

The growth responses of Abaca plants were collected from 10 sample plants in each treatment throughout the study. The collection of data was done at 15 days intervals until termination. The following growth parameters such as plant height (cm), pseudostem girth (mm), number of functional leaves, leaf area index (cm^2), and percentage of survival were measured. Morphological characteristics of abaca at termination were also determined such as length of adventitious roots (cm), fresh weight of plants (grams/plant), and dry matter yield (gram/plant).

Statistical Analysis

Data were analyzed through the analysis of variance (ANOVA) of Completely Randomized Design (CRD). The difference among treatments means was compared using Tukey's Range Test (TRT). All data gathered were analyzed statistically using Assistat version 7.7.

Results and Discussion

General Observation

In the first week after transplanting, morphological differences of abaca plants were not yet manifested. Plants grew at a uniform rate regardless of the treatment applied. However, at 15 DAT, some plants particularly those planted in mined soil alone started to turn yellow and eventually did not survive (Figure 2, a and b). Plants treated with OPS also showed symptoms of Nitrogen deficiency or possibly Iron (Fe) and Aluminum (Al) toxicity as the pH level of mined soil is extremely low (2.08). Among those other symptoms are stunted growth, yellowing of older leaves, and overall paleness of the plant (Figure 2, c and d).

Figure 2. Observable symptoms of deficiency/toxicity (a - stunted growth, b – the death of plant tissue, c – yellowing of leaves, d – paleness of the entire plant) of abaca grown in mined soil applied with various organic amendments weeks after transplanting.

Among the treatments mentioned, plants applied with OPV (T_5) exhibited superior growth as manifested by plant height, stem diameter, production of leaf area index, and better plant survival (Figure 3). According to Mahmud et al., (2018) vermicompost enriches the soil with essential plant nutrients, thereby improving soil quality.

Figure 3. Growth of abaca (hybrid 7) seedlings a month (a) and 3 months after transplanting (b), respectively.

Important Soil Properties of Mined Soil and Garden Soil

The result of the soil analysis of abandoned mine and ordinary garden soil is presented in Table 1. Heavy metals such as Cadmium (Cd) and Lead (Pb) are extremely toxic in values greater than 3.0 mg/kg and 100-300 mg/kg, respectively (Fageria et al., 2011 & Landon, 1991). The significant amount released into the environment is alarming as a result of natural and anthropogenic processes (Morkunas et al., 2018). Cadmium can alter the uptake of minerals by plants through its effects on the availability of minerals from the soil (Moreno-Grau et al., 2002).

Results revealed that mined soil contained 0.347 mg/kg Cd and 0.230 mg/kg Pb which are within the tolerable limit (2.00 mg/kg for Cd and 300 mg/kg for Pb) (Landon, 1991). According to Nas and Ali, (2018) considerable concentration of heavy metals like Lead can cause the same symptoms as observed in the abaca plants such as stunted growth, chlorosis, and darkening of roots. Moreover, the symptoms manifested by the crop are closely related to organic matter present and Nitrogen content in mined soil which is very low according to the sufficiency levels of Benton Jones (2012). This is likely to occur because organic materials are an important source of nutrients particularly Nitrogen in the soil. Organic matter for instance provides nutrients to the plant as well as maintaining soil biology and desirable soil physical property. Hence, organic matter is beneficial in sustaining plant growth and development while improving the overall soil properties. The result further elucidates the undesirable effect of the mining process on soil quality.

Table 1. Chemical properties of an abandoned mine and garden soil used in the study.

Soil chemical characteristics	Unit	Threshold levels for sufficiency and toxicity	Mined Soil	Garden Soil
pH (1:1 water)		6.5 – 7.0*	2.08	5.450
Organic matter, OM (Wakley Black)	%	4*	0.140	1.331
Nitrogen, N (Kjeldahl)	%	2*	0.029	0.100
Phosphorous, P (Mehlich)	mg/kg	20*	63.19	11.57
Potassium, K (Ammonium Acetate pH 7)	mg/kg	100*	32.80	91.10
Cation Exchange Capacity, CEC (Ammonium Acetate pH 7)	meq/ 100g	5-15**	5.475	9.126
Electrical Conductivity, EC (1:1 water)	dS/m	0-2.0**	2.630	0.107
Cadmium, Cd (Mehlich)	mg/kg	0.01-2.0**	0.347	nd
Lead, Pb (Mehlich)	mg/kg	2.00-300**	0.230	nd
nd – not detected				

**soil nutrient sufficiency (Benton Jones, 2012)*

***for Cd and Pb, values greater than the higher values are contaminated soil (Landon 1991)*

Soil pH is important to plant growth because it determines the availability of almost all essential plant nutrients. Presented in Table 1, the soil pH values in mined and garden soil were 2.08 and 5.45, respectively. Both pH values found for both soils are quite low compared to the nutrient sufficiency level for plants as suggested by Benton Jones (2012). The extreme acidic level of mined soil is probably brought by pyritic minerals that were oxidized due to exposure of this parent material to the environment. Accordingly, mined soil that contains a considerable amount of pyritic materials will cause a rapid drop of soil pH to a range of 2.2-3.5 at oxidizing soil conditions (Sheoran et al., 2010). Also, extreme soil pH can affect the population and survival of microbes thereby hindering the decomposition process.

Nitrogen (N) is by far the most important element along with Phosphorus and Potassium that is fundamental for plant growth and development affecting biochemical and physiological functions (Leghari et al., 2016). As depicted in Table 1, the total Nitrogen content of mined soil was 0.029% while garden soil had 0.100%. Both soils have low Nitrogen value compared to the nutrient sufficiency level suggested by Benton Jones (2012). The amount of Nitrogen present in mined soil can be attributed to a low level of organic matter content. Organic matter content in soil is a major source of Nitrogen that is a significant source of nutrients to the plants. In most rehabilitation studies, nutrient inputs such as Nitrogen are essential in the establishment and maintenance of any plant community (Sheoran et al., 2010).

Phosphorous (P) is responsible for several functions in plants, particularly root development. Surprisingly, P content in mined soil is higher (63.19%) compared to garden soil (11.57%) (Table 1). The result of the analysis found in this study contradicts the data in literature wherein if not all, P is deficient in a disturbed soil environment. Similarly, Buta et al. (2019) mentioned that this element is a limiting nutrient next to Nitrogen particularly in mine spoil, and likely to increase P fixation over time. Nevertheless, when soil is subjected to the mining process, oxidation of pyrite results in low pH levels and high concentrations of Sulphates, Fe, and Al that are known to fix P into compounds unavailable to plants (Evangelou, 1995). The contradicting result could be explained by the presence of P-rich minerals like apatite and fluorapatite in the parent material. During, the metal extraction process, these insoluble minerals are exposed to drastic physical and chemical changes that could produce P soluble products. For instance, apatite minerals are subjected to strong acids such as Sulfuric acid and Nitric acid to produce readily available P products (Reta et al, 2018).

Potassium (K) is classified as a macronutrient because plants take up large quantities of K during their life cycle. Mined soil contained 32.8 mg/kg K while garden soil had 91.1 mg/kg (Table 1). The value of K in mined soil was very low compared to the nutrient sufficiency level suggested by Benton Jones (2012). This implies that if the soil has low in K may defect K deficiency which caused leaves to become smaller and slower to grow with rapid yellowing starting from the tip of older leaves.

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH, and soil's reaction to fertilizers and other ameliorants. Table 1 shows that mined soil had 5.47 meq/100g while garden soil had 9.12 meq/100g. Soils with a low CEC value (<5) can be associated with low fertility because they cannot hold many cations that are important to maintaining the buffering capacity against changes in nutrient concentration and availability. Also, low CEC soils have a low resistance to variations in soil chemistry brought by land use (Hazelton and Murphy, 2007). While, soils with a high CEC (>25) tend to be more fertile and are capable of providing and retaining more nutrients to crops thereby, enhancing plant growth (CUCE, 2007). High CEC corresponds to the high surface area responsible for the adsorption of positively charged ions in the soil solution.

Chemical Characteristics of Organic Amendments from Oil Palm Residues

Palm oil sludge commonly referred to as palm oil mill effluent (POME) is a high-strength wastewater produced from the extraction of palm fruit (Iwuagwu & Ugwuanyi, 2014). It causes harmful impacts to the environment once discharged directly to water bodies (Rupani et al, 2017). The chemical properties of OPR used in this study are reflected in Table 2. The pH of the OPS was at 6.02 which is much higher compared to the recorded value of 3.9 from fresh POME (Rupani et al., 2017). Oil palm sludge also contains a higher amount of organic matter (17.62%) relative to the result found by Abdurahman et al. (2011). In addition, OPS had higher N (1.69 %) and P (1.05%) content but low in K (0.20) compared to OPV and OP-EFB biochar. The high level of N and P content of OPS supports the findings of other studies wherein sludge contains readily available N and P hence it is considered a threat to the water ecosystem once disposed directly to water bodies. Further, the results obtained in this study were relatively higher compared to the chemical properties found in olive oil mill wastewater containing 0.15% N, 0.089% P, and 0.52% K (Macci et al., 2010).

Table 2. Chemical analysis of various organic amendments derived from oil palm residue.

Chemical Characteristics of Organic amendments	Unit	OP Vermicast	OP Sludge	OP EFB Biochar
pH (1:1 water)		6.490	6.020	10.630
Organic matter (Walkley Black)	%	20.199	17.620	23.094
Nitrogen (Kjeldahl)	%	0.927	1.698	0.243
Phosphorous (Aqua-regia: ICP-OES)	%	0.116	1.056	0.230

P_2O_5 (Aqua-regia: ICP-OES)	%	0.266	2.424	0.528
Potassium (Aqua-regia: ICP-OES)	%	0.399	0.208	2.794
K_2O (Aqua-regia: ICP-OES)	%	0.481	0.251	3.366
CEC (Ammonium Acetate pH 7)	Meq/100g	19.671	31.231	40.762

Oil palm-EFB biochar is carbonaceous material produced from the conversion process of biomass with the absent or limited supply of oxygen (Lehmann & Joseph, 2015). Many organic by-products from the processing of various agricultural commodities are often left in the field with no economic value. Nevertheless, the physicochemical characteristics of this biomass can be improved through biochar production or vermicomposting. These products were found to sequester a considerable amount of carbon, improve soil properties, and increased crop productivity (Rehrah et al., 2014). The soil pH value of OP-EFB biochar was 10.63 (Table 2), the highest among the organic amendments. The increase in pH levels of biochar is due to the relative concentration of non-pyrolyzed inorganic elements and the formation of basic surface oxides under high pyrolysis temperatures (Rehrah et al., 2014). Also, it contained the highest organic matter content (23.09%), K (2.79%), and CEC (40.76). However, OP-EFB biochar has the lowest N (0.24%) and a P-value of 0.23%.

Vermicomposting technology is known to effectively reduced biodegradable waste materials through the process of composting (Fantonalgo and Salubre, 2019). It is recognized as one of the most efficient and eco-friendly methods for converting massive organic waste into a valuable product. According to Rupani et al. (2017), the conversion of organic waste material into vermicompost can significantly improve the N, P, and K content of the organic materials. Results revealed that the OPV had a pH value of 6.49, riched in organic matter (20.19%), and lower amounts of N (0.92%), P (0.11%), and K (0.39%). Further, the OPV had a CEC of 19.67 meq/100g. The chemical properties of vermicast from OPR are neutral, rich in organic matter, and a considerable amount of CEC. These attributes are vital to the plants and in maintaining a good soil environment.

Growth Response and Dry Matter Yield of Abaca

a. Plant Height Increment (cm)

The growth response of hybrid abaca in terms of plant height is significantly affected by various amendments from OPR (Figure. 4). Results revealed that application of oil palm by-products in mined soil improved the height of abaca plants particularly at 30, 45, 60, 75, and 90 days after transplanting.

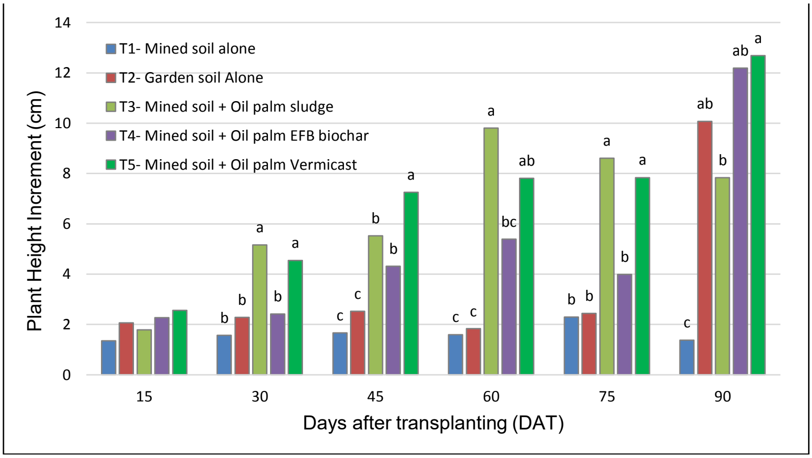

Figure 4. Plant height increment (cm) of abaca grown in an abandoned mine soil amended with oil palm residues. (Bars in every observation with the same letters and those without letters are not significantly different at 5% TRT and ANOVA, respectively).

As depicted in Figure 4, the growth of abaca at 30 DAT was superior in mined soil amended with OPS and OPV, while comparable effects were observed in plants grown in mined soil (T_1) and garden soil alone (T_2), and mined soil amended with biochar (T_4). At 45 DAT, application of OPV in mined soil (T_5) got the highest plant height with an average of 7.25 cm. This was followed by the comparable effects of OPS and OP-EFB biochar and the shortest increment was observed in plants grown in mined soil alone and garden soil alone.

A drastic increase in plant height was recorded in plants grown in mined soil amended with OPS at 60 DAT with an average increase of 9.80 cm. This was followed by T_5- mined soil + OPV (7.81 cm) and T_4- mined soil + OP-EFB biochar. The same trend was noted 75 DAT such that the application of OPS and OPV had a superior effect in improving the plant height of the Hybrid 7

Abaca variety. In addition, plants grown in soil amended with OP-EFB biochar had comparable height increments to those plants grown without amendments.

Further at 90 DAT, the highest increment was recorded with biochar, followed by other amendments, and lowest with mined soil alone. The extremely high pH value (10.6), organic matter content (23.0 %), and CEC (40.7 meq/100g soil) of biochar amendment used in this study could possibly improve the soil quality of mined soil. The addition of biochar in contaminated soil had promising results in terms of improving the growth of *Lolium perenne* in the study conducted by Rees and Germain (2015). Enhancement of the chemical properties of mine tailings and improvement of the growth of *Cassia alata* L with the incorporation of biochar was also observed by Huang et al., (2018). This result further elucidates the significance of the application of organic amendments in improving the growth performance of the plants under harsh soil conditions (Figure 5).

Figure 5. The growth response of hybrid abaca at 90 days after transplanting (DAT).

b. Pseudostem Girth (mm)

The effect of different amendments from oil palm residue in terms of pseudostem girth is presented in Figure 6. At an early stage of growth and development (15 DAT) the analysis of variance revealed no significant difference among treatments. Variation of the pseudostem girth started to become evident at 30, up to 90 DAT. It can be viewed that bigger pseudostem was manifested in those plants amended with organic amendments while smaller stem with mined soil alone. However, variations among the amendments used including the garden soil alone were noticeable. For instance, at 45 DAT significant increase of pseudostem girth was observed in plants amended with OPV with the highest pseudostem girth (7.25 mm) and OPS (5.52 mm). Moreover, it was noted that abaca had the same response in terms of girth when planted to garden soil and OP-EFB biochar.

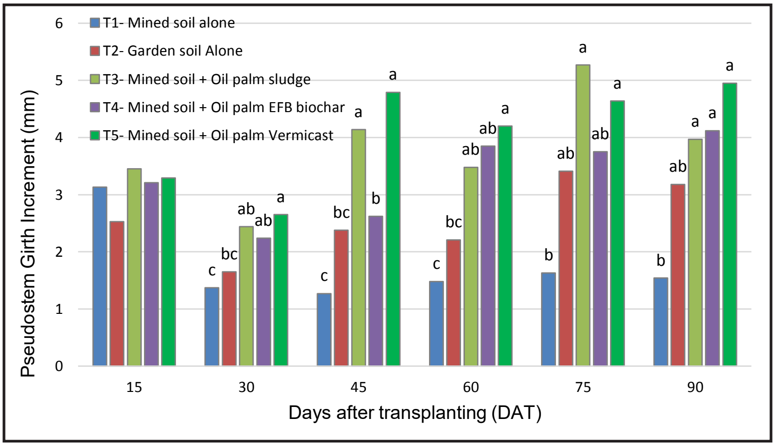

Figure 6. Pseudostem girth increment (mm) of abaca (Hybrid) grown in mined soil amended with oil palm residues. (Bars in every observation with the same letters and those without letters are not significantly different at 5% TRT and ANOVA, respectively).

The same trend was recorded at 60 DAT wherein the highest pseudostem girth was observed in plants amended with OPV which was comparable with those in plants applied with OPS (9.80 mm) and OP-EFB biochar. Among all observations, the highest girth increment was observed at 75 DAT. Finally, at 90 DAT, plants from all treatments produced comparable girth increments except those grown in mined soil alone which consistently had poor growth of pseudostem.

c. Number of Functional Leaves Increment

Improvement in the number of leaves was observed at 45,60, 75, and 90 days after transplanting. Treatment 3 - OPS produced a greater number of leaves at 45, 60, 75, and 90 DAT which is comparable to the rest of the treatment except for mined soil alone. Application of sludge from oil palm residues consistently produces more functional leaves (Figure 7).

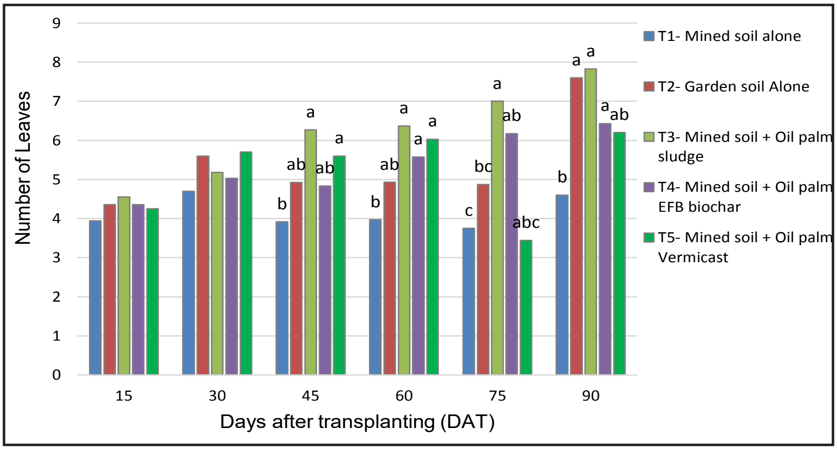

Figure 7. Number of Leaves of abaca grown in mined soil amended with oil palm residues. (Bars in every observation with the same letters and those without letters are not significantly different at 5% TRT and ANOVA, respectively).

d. Leaf Area Index (cm^2)

The result shows that amending soil with OPV and OPS can significantly improve the total leaf area index. According to Adebayo et al. (2011), the application of organic amendments tends to improve the chemical properties of the soil leading to improve plant organ development.

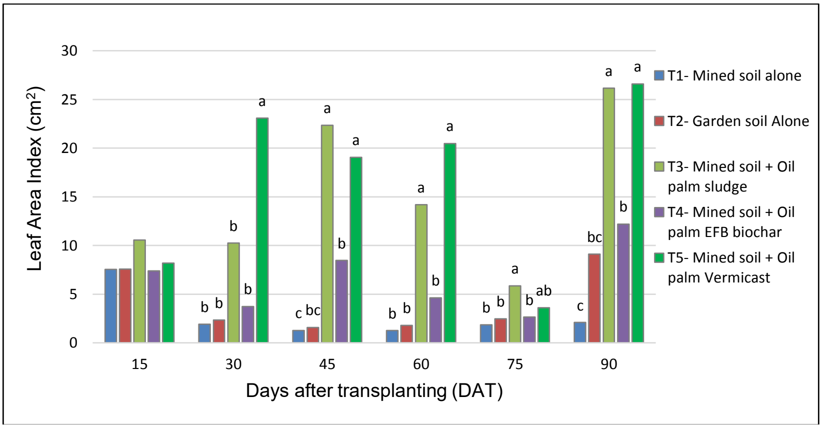

Figure 8. Leaf area index (cm^2) of abaca grown in mined soil amended with oil palm residues. (Bars in every observation with the same letters and those without letters are not significantly different at 5% TRT and ANOVA, respectively).

e. Percentage of Survival

Figure 9 presents the percentage of survival of Hybrid 7 abaca grown in mined soil amended with OPR. Among the amendments used, the highest survival was observed when plants were grown in mined soil and amended with OP-EFB-biochar and OPV. A similar percentage of plant survival was also manifested with garden soil, followed by the OPS, and the lowest survival rates were observed in mined soil.

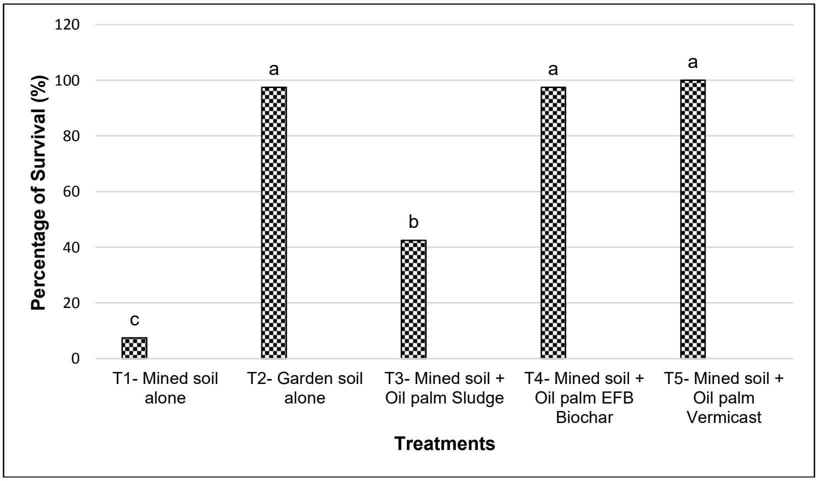

Figure 9. Percentage of survival of abaca grown in mined soil amended with oil palm residues. (Bars with the same letters are not significantly different at 5% TRT).

Morphological Characteristics of Abaca at Termination

Length of Adventitious Roots (cm)

The length of the adventitious roots of abaca was significantly affected by various amendments from OPR (Figure 10). Plants amended with OP-EFB biochar produced the longest adventitious, followed by those applied with OPV, OPS, garden soil alone, and the shortest was observed in plants in mined soil alone. The result can be attributed to the beneficial effects of the amendments in improving the soil chemical properties, optimizing soil microbial population structure and richness that favored the growth and function of the plant roots (Lehmann et al., 2011). Moreover, the use of oil palm waste as soil amendments reduces soil compaction thereby increasing porosity.

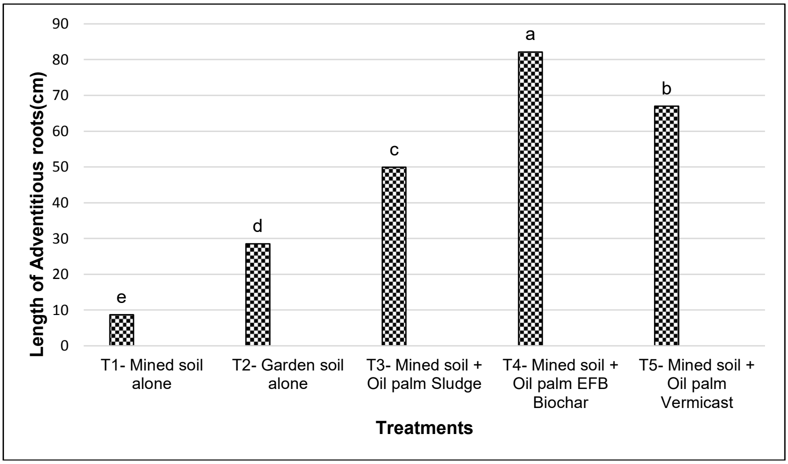

Figure 10. Average lengths of adventitious roots of abaca amended with oil palm residues. (Bars with the same letters are not significantly different at 5% TRT).

a. Fresh Biomass and Dry Matter Yield (g/plant)

Statistical analysis revealed significant differences among treatments on the fresh weight of abaca plants (Figure 11). The abaca plants grown in mined soil amended with organic residue from oil palm were heavier than those plants planted in mined and garden soil alone. This is expected since plants grown without amendments performed poorly in all the growth parameters evaluated. The result thus indicates that the application of OPR such as sludge, EFB biochar, and vermicast can significantly improve the fresh biomass of abaca under marginal soil conditions. The same result was obtained by Nada et al., (2011), wherein the application of vermicompost in coal spoil contaminated soil significantly increased the fresh weight and dry matter yield of the grass.

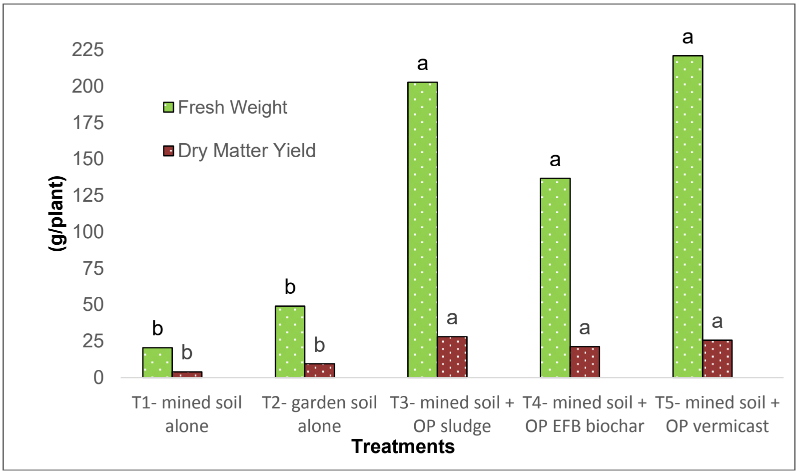

Figure 11. Fresh and dry weight biomass (g/plant) of abaca grown in mined soil amended with oil palm residues 3 months after transplanting. (Bars with the same letters are not significantly different at 5% TRT).

The improvement in the biomass was manifested by the plants when they are planted in harsh soil conditions with the application of organic amendments particularly OPS, OP- EFB biochar, and OPV. The application of OPR significantly improved the dry matter yield of abaca plants. A comparable effect was observed in plants grown in mined soil alone and garden soil alone.

Conclusion

The chemical properties of mined soil from Mawab, Davao de Oro, Philippines were classified as infertile soil, with extremely low soil pH value and considerable amounts of heavy metals such as Lead and Cadmium. Plants applied with sludge, biochar, and vermicast from oil palm residues were significantly taller, had bigger stems, with more functional leaves, and a higher percentage of survival, and consequently had higher dry matter biomass. The use of abaca is recommended for rehabilitation strategy in abandoned mine soil with the application of organic amendments from oil palm residues.

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