

Research Article

The effect of ameliorants on improvement of soil fertility in post gold mining land at West Kalimantan

Sulakhudin^{1*}, Denah Suswati¹, Muhammad Hatta²

¹ Department of Soil Science, Faculty of Agriculture, Tanjungpura University, Indonesia

² West Kalimantan Assessment Institute for Agricultural Technology, Indonesia

* corresponding author: sulakhudin@gmail.com

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Abstract : The application of ameliorant has been suggested to improve soil fertility and crop growth in post illegal gold mining (PIGM) lands. This study evaluated the effect of ameliorant types and semi-permeable layer on properties of soil in PIGM lands and growth of sorghum. A field experiment employed two treatments, i.e. type of ameliorant and semi-permeable layer. There were four ameliorant types applied i.e., without ameliorant (M0); coastal sediment at a dose of 40 t/ha (M1); biochar at a dose of 4 t/ha (M2), and coastal sediment at a dose of 30 t/ha + 4 t biochar/ha (M3). The second treatment consisted of two levels, namely: without a semi-permeable layer (S0) and the semi-permeable layer of 20 cm depth from the soil surface (S1). The results showed that types of ameliorant gave different effect to soil properties. Application of coastal sediment at a dose of 40 t/ha significantly increased the contents of Ca and Mg, whereas application of biochar at a doses of 4 t/ha increased soil CEC. The semi-permeable layer did not significantly affect plant height and stem diameter of sorghum. The highest of sorghum growth was reached by application of coastal sediment at a dose of 30 t/h + biochar at a dose of 4 t/ha. The combination of coastal sediment and biochar from banana peels could complement each other to improve soil fertility in PIGM land.

Keywords: *ameliorant, biochar, coastal sediment, post gold mining land, sorghum*

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Introduction

Illegal gold mining has been going on since before the 17th century. Mining was done traditionally in the river, but the last decade it moved to the land because of the gold reserves in the Kapuas River had been reduced. Mining which has been operated for many years resulted in environmental pollution and land degradation. The land of PIGM reached 6,613 ha that spread across 267 locations in eleven districts in West Kalimantan (Department of Mines and Energy, 2012). The PIGM lands have been damaged in physically, chemically, biologically and contain Hg (Neneng et al., 2012). The results of the study conducted by Ferianto et al. (2013) showed that Hg levels in PIGM land in West Kalimantan were

low. In 10-15 years after mining activities the Hg content was an average of 0.037 ppm. When compared to the quality standard of mercury abundance in the soil of 10 ppm (Stwertka, 1998), then the PIGM land can be utilized for cultivation of food crops. Once of food crops that can be cultivated in the PIGM is sorghum. It can be grown well in infertile soil conditions (Irawan and Sutrisna, 2011). Additionally, sorghum is drought resistant, needs low input, high yield and can be accumulator metal elements (Jamali et al., 2007).

Development of food crops in the PIGM land requires the right technology because the soil in the area had been degraded. Application of a specific amelioration technology is expected to optimize the soil in the area of PIGM to support the growth of food crops. This technology uses

local resources such as coastal sediment and biochar from banana peels, so the production cost can be reduced. Coastal sediment that is the result of sea deposition is widespread on the coast of West Kalimantan. According to Suswati (2009), the coastal sediment ameliorant could replace the role of lime in increasing pH and base saturation (BS). Results of the study of Suswati et al. (2015) showed that the addition of coastal sediment on PIGM land reduced soil acidity, and improved CEC, BS, and availability of soil nutrients (K^+ , Ca^{2+} , Mg^{2+} and Na^+). Application of coastal sediment at a dose of 40 t/ha on peat could increase the yield of hybrid maize that reached 12 t/ha (Suswati et al., 2014).

In addition to the use of coastal sediment, soil fertility of PIGM land can be improved by applying biochar. It can improve the soil chemical, physical, and biological properties contain functional groups and amorphous as well as resistant in soil (Sohi et al., 2010; Tammeorg et al., 2016). Biochar generally has high pH, C-organic and CEC (Lehmann, 2007). Biochar has high water absorption and is resistant to microbial decomposition (Lehmann and Joseph, 2009). The properties make biochar has a high nutrient retention, thereby reducing nutrient leaching and increasing nutrient use efficiency (Laird et al., 2010; Hussain et al., 2016). According to Novak et al. (2010), biochar addition increases retention of water containing N, P, and K nutrients that can be absorbed by plants. The results of the study of Hairani et al. (2016), biochar application of 35 t/ha was able to increase the yield of sorghum 1.48 times higher than without biochar. Once of good substance for making biochar is banana peel because it is an ordinary biological waste with a high content of cellulose and minerals (Zhou et al., 2017).

Studies on the effects of the addition of coastal sediment and biochar to improve soil fertility in PIGM are limited. Many studies have been carried out on the use of biochar and coastal sediment to increase soil fertility in some soil in an individual manner. The hypothesis was that application of coastal sediment and biochars can improve soil fertility and growth of sorghum in PIGM land by favorable changes in soil physicochemical properties. This study extends knowledge related to the use of coastal sediment and biochar as soil amendments to the reclamation of PIGM land, so it can play a role in supporting sustainable food security program nationally.

Materials and Methods

A field experiment was carried out at the PIGM land in Simpang Monterado Village, Monterado

Sub-District, Bengkayang District of West Kalimantan Province. The experiment was conducted from July to October 2016. Coastal sediment was derived from Kijing beach and applied in wet condition. Biochar was obtained by hydrolysis of banana peels at a temperature of 350 °C. The study was a factorial randomized complete block design with two treatments and five replicates. The first treatment was the amelioration of top soil (M) that consisted of four levels, namely: without amelioration (M0), coastal sediment at a dose of 40 t/ha (M1), biochar at a dose of 4 t/ha (M2), and coastal sediment at a dose of 30 t/ha + biochar 4 t/ha. The second treatment was a semi-permeable layer thickness (S) that consisted of two levels, namely: without a semi-permeable layer (S0), and semi-permeable layer as deep as 20 cm of the soil surface, semi-permeable 3 cm thick layer (S1). The semi-permeable layer made from a mixture of 5% of coastal sediment and 95% sandy soil from PIGM areas. The study comprised 40 plots (each of 3 m x 1.5 m size) with a 1 m protection zone framing the experimental field. The sorghum was planted at a spacing of 60 cm x 40 cm, resulting in 21 plants per plot. Six plant samples were taken randomly for measurements of height plant and stem diameter per weeks. Fertilizers applied as basal fertilizers were manure 5 t/ha, Urea 200 kg/ha, SP-36 100 kg/ha and KCl 50 kg/ha. Plant growth variables measured were plant height and stem diameter.

The measurements were made every week until the end of vegetative growth. Soil analysis was performed after the treatment. Some properties of soil analyzed were pH (H_2O), electrical conductivity (EC), cation exchange capacity (CEC), base saturation (BS), contents of N, P, K Ca, Mg and Na in the soil. The analysis of soil properties was conducted at the Laboratory of Soil Chemistry and Fertility, Faculty of Agriculture, Tanjungpura University. Data obtained were subjected to analysis of variance (two-way ANOVA) using the Microsoft Excel software and R statistic version 3.3.2. The differences between treatments were analyzed with Duncan's test at the 0.05 level.

Results and Discussion

Characteristics of coastal sediment, biochar, and soil in PIGM land

The characterization of coastal sediment and biochar is shown in Table 1. Coastal sediment was the result of sedimentation materials result of erosion from the upland area through watershed deposited around the coast. The content of

nutrients in the coastal sediment varies greatly depending on soil type and conditions of the origin of these sediments. The coastal sediment for this study was alkaline with a pH of 8, due to the presence of base cations mainly Ca and Mg with concentrations of 9.75 and 5.82 cmol(+)/ kg, respectively. The content of Mg in coastal sediment was higher than that used by Suswati et al. (2015), amounting to 1.73 cmol(+)/kg, while the Ca content was lower. The coastal sediment that was used by Suswati et al. (2015) has Ca content of 14.62 cmol(+)/kg. It had high BS (82.87%) and consisted of 3.57% sand, 46.90% silt, and 49.53% clay. The high clay content will increase soil CEC because clay is a source of soil negative charge (Bergaya and Lagaly, 2006).

Table 1. The characteristics of coastal sediment and biochar.

Properties	Coastal sediment	Banana Peel Biochar
pH H ₂ O 1:2	8.0	9.7
Organic-C (%)	4.81	33.93
Total N (%)	0.88	1.82
P Bray I (ppm)	0.51	0.37
Extract NH ₄ OAc 1N pH 7		
K (cmol(+)/kg)	0.18	10.13
Ca (cmol(+)/kg)	9.75	0.82
Mg (cmol(+)/kg)	5.82	0.54
Na (cmol(+)/kg)	3.24	
CEC (cmol(+)/kg)	22.94	
Base Saturation (%)	82.87	
Texture		
Sand (%)	3.57	
Silt (%)	46.90	
Clay (%)	49.53	

As indicated in Table 1, the banana peel biochar was more alkaline and had a high K concentration. The high pH value of banana peel biochar may be due to hydrolysis that was undergone by carbonates and bicarbonates of base cations such as K, Ca and Mg. Biochar from banana peels had 10.13 cmol(+)/kg of K, 0.82 cmol(+)/ kg of Ca and 0.54 cmol(+)/ kg of Mg. In line with the study of Butnan et al. (2015) which reported that among the nutrients in ash that are sources of plant nutrients, Ca and K constituted the two highest contents, whereas Mg and P were the two lowest in the biochars. A number of biochars have high quantities of ash, which are enriched with several plant nutrients, particularly cationic elements, such as K, Ca, and Mg

(Rajkovich et al., 2012). The Ca content in coastal sediment was 9.76 cmol(+)/kg. Other than as a nutrient source, it can maintain the balance of nutrients in the soil in PIGM. Table 2 shows that the BS of the soil in the PIGM was only 26.37%, while the coastal sediment was more than 82.87%, so application coastal sediment was expected to increase soil pH and BS in PIGM land. Besides coastal sediment had a high Mg content, as many as 5.82 cmol(+)/kg, it could raise the availability of Mg in the soil. Mg contents in the soil in PIGM land was very low, only 0.31 cmol(+)/ kg.

The positive effect of coastal sediment can be improved by adding the biochar, especially those made from banana peels. Biochar is made by pyrolysis to obtain biochar with good quality. The content of total N in biochar was 1.82% while the total N content in coastal sediment that was only 0.89%. Additionally, the biochar also contained 10.13 cmol(+) K/kg, while the coastal sediment only contained 0.18 cmol(+) K/kg. Thus, the use of two ameliorants was expected to improve some properties of soil in PIGM land at District Monterado, Bengkayang. The soil of the study site has suffered severe physical, chemical and biological damages that make the soil was not able to support optimal plant growth.

Table 2. The characteristics of soil in the PIGM land in the sub-district of Monterado.

Soil properties	Value	Level
pH H ₂ O 1:2	5.94	slightly acid
pH KCl 1:2	5.10	acid
Organic-C (%)	0.21	very low
Total N (%)	0.03	very low
P Bray I (ppm)	15.21	very high
Extract NH ₄ OAc 1N pH 7		
K (cmol(+)/kg)	0.02	very low
Ca (cmol(+)/kg)	0.88	very low
Mg (cmol(+)/kg)	0.31	very low
Na (cmol(+)/kg)	0.04	very low
Hg (ppm)	nd	nd
CEC (cmol(+)/kg)	4.74	very low
Base Saturation (%)	26.37	low
Texture		
Sand (%)	95.00	sandy
Silt (%)	5.00	
Clay (%)	0.00	

Source: Leveling according to the Soil Research Institute (2005), nd = not detected

The results of the analysis of some soil physical and chemical properties showed that the soil in the PIGM land has low fertility. It is shown that

the binding ability of soil nutrients and water are very low. The ability of soil to retain water and soil nutrients can be seen from the value of the CEC that was very low at 4.74 cmol(+)/kg (Table 2). In addition, the low fertility rate can also be seen from the sandy soil texture. The content of the sand particle in the PIGM land was 95%. This value was higher than in the soil of PIGM land in the District Mandor that amounted to 91.53% (Sagiman et al., 2015). Soil mineral fraction that is dominated by sand will lead to the low ability to store water and nutrients because the sand has low sorption sites (negative charge) (Schoonover and Crim, 2015). Soil particles that are dominated by sand fraction have high permeability. This will cause the very high rate of leaching of nutrients in the soil (Jalali and Merrikhpour, 2008). As a result, the availability of nutrients is low to very low.

Table 2 shows the low nutrient contents of total N (0.03%), K (0.02 cmol(+)/kg), Ca (0.88 cmol(+)/kg), Mg- (0.31 cmol(+)/kg) and Na (0.04 cmol(+)/kg). Only P content that was exceptionally high reaching 15.21 ppm. The very low CEC value (4.47 cmol(+)/kg) might be caused by several factors, among others: (1) the soil does not contain clay fraction (0.00%) which is a source of soil negative charge; (2) the soil organic matter content is very low as indicated by the low value of organic C was 0.21% (Kleber et al., 2015). The very low soil organic matter content could be due to the rapid rate of decomposition of organic matter in sandy soil because the temperature was quite high and aerobic atmosphere (Zechmeister et al., 2015). The results of the analysis presented in Table 2 show that the organic material was decomposed further (C/N = 7). The pH value of the soil at PIGM land amounted 5.94 was slight acid. The pH value of the soil will be a limiting factor because some nutrients became less available, e.g. nutrient K, Ca and Mg so that less can provide the optimal nutrients for plant growth (Fageria, 2016). One of the alternatives to increase pH was by giving coastal sediment and biochar. Besides being able to increase the pH and availability of some nutrients, coastal sediment and biochar can improve some properties of soil in the PIGM land.

Effect of ameliorant and semi-permeable layer on soil chemical properties in PIGM Land

Data presented in Table 3 show that the application of ameliorants significantly improved some chemical properties of the soil in the PIGM land. All treatments were able to increase the pH significantly compared with no ameliorant (control). The highest increase of soil pH was

caused by application of 30 t coastal sediment/ ha + 4 t biochar/ha (M3). This was because of both materials had high pH (Table 1). The coastal sediment had pH of 8.0; the banana peel biochar had pH of 9.7 so that a combination of both materials could increase the pH exceeding other treatments. The M3 treatment raised soil pH from pH 5.94 to 7.03. Suswati et al. (2015) reported that application of coastal sediment at doses of 14-100 t/ha raised significantly soil pH because it contained high alkaline cations. Whereas biochar raised soil pH because biochar has negatively charged from phenolic, carboxyl and hydroxyl groups on biochar surfaces that bind H⁺ ions in the soil solution, so reducing its concentration in the soil solution and raising the soil pH value (Gul et al., 2015). Table 3 shows that application of coastal sediment and biochar alone or combined did not significantly improve the content of soil C-organic and CEC. All treatments were able to increase the content of organic C and CEC, but the increase was too small when compared with those without ameliorant having C-organic content and CEC respectively by 0.30% and amounted to 5.37 cmol(+)/kg. This was because of the very low content of organic C and CEC on the soil in PIGM land (Table 2).

Application of biochar increased soil CEC by 27.93% that was higher than that of other treatments. This was similar to that reported by Laghari et al. (2015), who observed that application of 45 t biochar ha⁻¹ slightly increased the CEC of soil by 20% as compared to the control in the sandy desert soil. The Ca content of the soil applied with 30 t coastal sediment/ha + 4 t biochar/ha (M3) was significantly higher than no ameliorant (M0) and application of biochar treatment (M2). This was because of the high Ca content of the coastal sediment (9.75 cmol(+)/kg), while biochar had only very low Ca content (Table 1). The same phenomenon was also observed in the content of soil Mg, which indicated significant differences of Mg soil at M1 and M3 treatments compared to M0 and M2 treatments. Coastal sediment had Mg content of 5.82 cmol(+)/kg, whereas biochar had only 0.54 cmol(+) Mg/kg (Table 1).

The increased Ca content due to the addition of coastal sediment was in line with the study of Suswati et al. (2015) showing that provision of coastal sediment raised the contents of Ca and Mg in the soil. Table 4 shows that there were interactions between applications of ameliorant and semi-permeable layer on some soil chemical properties in PIGM land. On the parameter of EC, it appeared that all treatments were significantly different from control (no ameliorant).

Table 3. Effect of ameliorant on some soil chemical properties

Treatments *)	Soil chemical properties					
	pH	Organic C (%)	Ca	Mg (cmol(+)/kg)	Na	CEC
M0	5.68 b	0.30 a	0.59 b	0.33 b	0.84 b	5.37 a
M1	6.72 a	0.56 a	1.25 a	0.64 a	0.78 b	5.95 a
M2	6.57 a	0.57 a	0.69 b	0.39 b	1.44 a	6.87 a
M3	7.03 a	0.48 a	0.96 a	0.54 a	1.17 ab	5.45 a

Description: Numbers followed by the same letters in the same column indicate no significant differences at the Duncan test at 5% level of significance. *) M0 = without amelioration, M1 = coastal sediment at a dose of 40 t/ha, M2 =biochar at a dose of 4 t/ha, M3 = coastal sediment at doses 30 t/ha + biochar 4 t/ha.

The increase EC of soil in the PIGM land due to the addition coastal sediment was greater than the semi-permeable layer. It can be seen that the increase of soil EC caused by provision of coastal sediment without a semi-permeable layer (S0M1) was 16.92% less than the application of coastal sediment with a semi-permeable layer (S1M1) of 18.91%. Suswati et al. (2015) reported that addition of 60 t coastal sediment/ha could increase soil EC. The soil EC due to the application of banana peel biochar, either with a layer of semi-permeable (S1M2) or not (S0M2) was higher than the value of EC at control. Table 4 shows the value of EC in the S1M2 treatments was 1217 μ S/cm and in the S0M2 treatment was 1138 μ S/cm, whereas in the control was only 1052 μ S/cm. The increase of soil EC after biochar additions might be largely due to the high

contents of K, Ca, Mg and Na in the soil (Hossain et al., 2011). The content of soil total N after treatment showed that the effect was not significantly different among all treatments. The content of total N ranged from 0.31 to 0.32% and they were all very low. This was caused by the sandy soil texture of PIGM land, so N leaching was very high. Thereby application of ameliorant in the form of coastal sediment and biochar, as well as the semi-permeable layer had not been able to increase soil total N content. The main nitrogen form in the agricultural field is nitrate, which is very mobile in the soil due to the poor absorption by soil colloidal particles because it has a negative charge. Therefore, the N cannot be adsorbed to cation exchange sites, so it is highly susceptible to loss by the way of surface water runoff (Yu et al., 2014).

Table 4. Effect of ameliorant and semi-permeable layer on some soil chemical properties

Treatments	Electric Conductivity (μ S/cm)	Total N (%)	Base Saturation (%)	Available P (ppm)	Exchangeable K (cmol(+)/kg)
S0M0	1052 d	0.31 a	31.96 bc	1.02 d	0.34 d
S0M1	1230 ab	0.31 a	65.91 a	1.10 d	0.43 cd
S0M2	1138 c	0.32 a	44.58 b	1.44 bc	0.77 ab
S0M3	1174 bc	0.31 a	59.60 a	1.50 b	0.86 a
S1M0	1072 d	0.31 a	28.90 c	1.29 c	0.40 cd
S1M1	1254 a	0.31 a	39.60 bc	1.12 d	0.42 cd
S1M2	1217 ab	0.32 a	63.94 a	1.81 a	0.67 abc
S1M3	1243 a	0.31 a	73.00 a	1.58 b	0.53 bcd

Description: Numbers followed by the same letters in the same column indicate no significant differences at the Duncan test at 5% level of significance. M0 = without amelioration, M1 = coastal sediment at a dose of 40 t/ha, M2 =biochar at a dose of 4 t/ha, M3 = coastal sediment at doses 30 t/ha + biochar 4 t/ha, S0 = without a semi-permeable layer, S1 = semi-permeable layer as deep as 20 cm of the soil surface, semi-permeable 3 cm thick layer.

Base saturation (BS) is a parameter that indicates the dominance of nutrients in the form of nutrient cations. Table 4 shows the treatments using coastal sediment (S0M1, S0M3, and S1M3) had higher BS than without application of ameliorant (S0M0 and S1M0). This was due to coastal

sediment had very high BS of 82.98%. According to Suswati et al. (2014), coastal sediment contained high alkaline cations, which increased BS and availability of cations Ca^{2+} , Mg^{2+} , Na^+ , and K^+ . Moreover, the increase of these cations might form a ligand complex with organic acids,

and therefore improved soil fertility (Husen et al., 2013). Data presented in Table 4 show that the content of available P in the treatment of semi-permeable layer (S1) was higher than the treatment without semi-permeable layer (S0). In the treatment without a semi-permeable layer, each treatment of ameliorant (M0, M1, M2 and M3) had available P of 1.02, 1.10, 1.44 and 1.50 ppm, while the treatment with a semi-permeable layer each had available of 1.29, 1.12, 1.81 and 1.58 ppm. This indicates that semi-permeable layer can lower P loss due to leaching. The semi-permeable layer is a layer that is capable of decreasing the flow rate of water in the sandy soil, so water will accumulate on top of the semi-permeable layer. Inhibition of water flow will

reduce leaching of P nutrient because P easily migrates along the water that dissolves it.

Effect of ameliorant and semi-permeable layer on sorghum growth at PIGM land

Ameliorant influenced the improvement of soil properties (Tables 3 and 4). Improvement of soil properties stimulated the growth of plants that could be observed on the parameters of plant height and stem diameter. Effect of ameliorant on plant height can be seen in Figure 1. Application of 30 t coastal sediment/ha+ 4 t biochar/ha (M3) resulted in higher plant height than other treatments on all the observation periods. Even on the observation of the 7th weeks of the treatment looked significantly different between the control and M3 treatment.

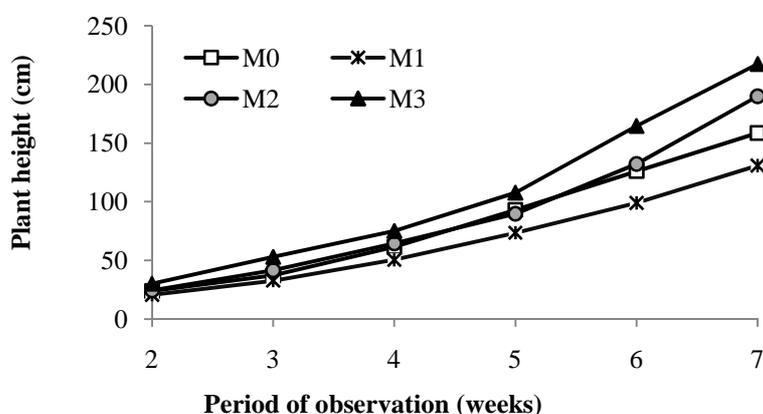


Figure 1. The effect of type of ameliorant to plant height of sorghum.

This may reflect the improved soil chemical properties, indeed a more available nutrients with 30 t coastal sediment/ha + 4 t biochar/ha had been supplied to sorghum growth. Suswati et al. (2014) reported that application of 40 t coastal sediment/ha could increase plant height of maize. Meanwhile biochar amendment at rates of 15 and 22 t/ha raised sorghum growth in sandy desert soil (Laghari et al., 2015).

The stem diameter was higher with addition of the coastal sediment and biochar mixture (M3) than other treatments (Figure 2). This treatment had highest stem diameter of 31 mm at 7 weeks observation period. The stem diameter was significantly different without application of ameliorant at 6 and 7 weeks. This indicates that application of 30 t coastal sediment/ha + 4 t biochar/ha were able to improve the condition of soil fertility in the PIGM land, so it could improve plant growth which was reflected in the stem diameter. In this study, application of 30 t coastal

sediment/ha and 4 biochar/ ha significantly improved sorghum growth. The possible explanation of the improved plant growth is that application of coastal sediment and biochar plant nutrients in the soil (P, K, Ca and Mg) and also improved soil EC, BS, pH (Tables 1 and 2). According to Albuquerque et al. (2014), biochar has high content of essential plant nutrients, hence, it raises supplied plant nutrients in soil and improved crop yield. In a study conducted by Schulz and Glaser (2012), biochar addition that increased plant growth in sandy soils was observed when biochar was combined with organic fertilizer. Suswati et al. (2014) reported the highest plant growth of maize under application of 40 t/ha^{of} coastal sediment and 1.5 t/ha of salted fish waste. Therefore, it can be concluded that the addition of coastal sediment and biochar enhanced sorghum growth in PIGM land.

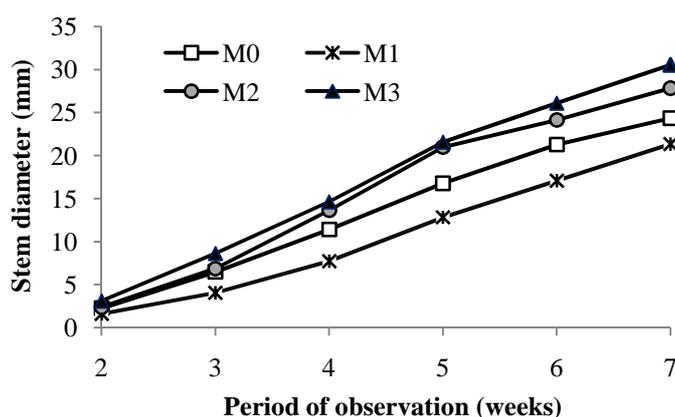


Figure 2. The effect of type of ameliorant to stem diameter of sorghum

Conclusion

Application of 30 t coastal sediment/ha + 4 t biochar/ha was able to improve some properties of the soil (pH, EC, and BS), and increase the nutrient contents of Ca and Mg. The combination of coastal sediment and biochar from banana peels can complement each other to improve some properties of soil so as to increase plant height and stem diameter of sorghum.

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