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Effect of Premium Compost on Soil Carbon Microbial Biomass in Pineapple Plants on Marginal Land Central Lampung

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ABSTRACT

Acidic soil reactions, low nutrient content, low organic carbon levels, and low soil biodiversity characterize marginal land. Adding organic matter, such as compost, is expected to rehabilitate these lands. One key biological indicator of successful land rehabilitation by adding organic matter or compost is soil carbon microbial biomass (SCMB). This study aimed to assess the effect of compost on SCMB in pineapple plants. It was designed using a Randomized Completely Block Design with four treatments: Control (P_0) = Without compost (Pineapple Cultivation Standard at GGPC), P_1 = Cow dung compost (50 Mg ha^{-1}), P_2 = Premium compost A (50 Mg ha^{-1}) and P_3 = Premium compost B (50 Mg ha^{-1}). Each treatment was replicated four times. The data were analyzed using ANOVA at the 5% significance level, following testing for homogeneity of variance using the Bartlett test and additivity with the Tukey test. Different treatment means were examined using contrast orthogonal tests, and correlation tests were performed to explore relationships among key variables. Results indicated that cow dung and premium compost (A and B) increased SCMB by 89.31% and 84.06%, respectively, at 15 and 16 MAP observations. At 16 MAP observations, soil organic carbon and soil pH were correlated with SCMB; in contrast, at observations 13, 14, and 15 MAP, soil organic carbon, soil pH, soil moisture, and soil temperature did not correlate with SCMB.

Keywords: Cow manure compost, marginal land, premium compost, pineapple plants

INTRODUCTION

GGPC is one of the largest companies in Indonesia that cultivates pineapples in Ultisol soil (Pujawan et al., 2016). Ultisol-type soil is marginal land with low productivity caused by low nutrients and soil organic matter contents, low soil pH, and low CEC (Suprapto, 2002). The problem that often occurs on marginal land is land degradation. Land degradation can occur physically, chemically, and biologically. Biological soil degradation includes decreased organic carbon, biodiversity, and soil carbon microbial biomass (SCMB) (Wahyunto and Dariah, 2014).

Fertilization, both inorganic and organic, is essential to increasing soil productivity. However, long-term use of inorganic fertilizers can have negative impacts, such as the decreasing of soil organisms due to low soil organic matter (Punuindoong et al., 2017) and a negative effect on soil microbial biomass due to soil acidification (Treseder, 2008; Malý et al., 2009).

In contrast to inorganic fertilizers, organic amendments such as manure and compost can increase soil carbon availability for soil microbes (Punuindoong et al., 2017). The addition of soil organic matter is expected to be an adequate and optimal source of nutrients and energy for soil biological life (Dariah et al., 2015), which can be beneficial for enhancing microbial biomass compared to inorganic fertilizer application only (Jangid et al., 2008; Neufeld et al., 2017). It is suggested that applying organic fertilizer acts as a soil remediation. However, organic fertilizers such as cow dung manure have low macro and micronutrient content, which impacts the amount of compost added to the soil. Therefore, adding other organic materials can improve the compost quality. Young charcoal (bituminous/sub-bituminous) has a high content of carbon, nitrogen, and potassium (Hairul et al., 2014; Minwal and Syafrullah (2018), low sulfur (Said and Herawati, 2021) and a high humic acid content in lignite can increase the negative charge originating from the humic acid functional group so that it can improve chemical, pH and microbial properties in the soil (Herviyanti et al., 2012; Said and Herawati, 2021; Aliyanta et al., 2021; Zhou et al., 2019). Another alternative is vermicompost. Several researchers have demonstrated that vermicompost (earthworm castings) have excellent aeration, porosity, structure, drainage, and moisture-holding capacity. Moreover, earthworms promoted the retention of nitrogen and gradual release of P, as well as reduced electrical conductivity, resulting in improved substrates for agricultural use. Instead of adding nutrients, it can also improve soil properties and increase carbon in the soil, which will be a source of energy for developing soil microorganisms (Margolang et al., 2015; Riniarti et al., 2017).

Adding organic material is expected to increase the SMBC. The SMBC is the total carbon from soil related to soil fertility and could indicate soil fertility. The SMBC is affected by several factors, such as soil organic carbon, water retention capacity, and pH (Adekiya et al., 2020; Agbede et al., 2020; Toková et al., 2020; Susanti et al., 2014). Pan et al. (2009) stated that organic fertilizer could increase SMBC by 13% compared to inorganic fertilizer.

The combined organic material (cow dung manure, vermicompost, bituminous) was the most effective stabilizing agent for cattle manure. Moreover, earthworms promoted the retention of nitrogen and gradual release of P and electrical conductivity, resulting in improved substrates for agricultural use. Therefore, premium fertilizer containing various mixed compositions of organic and inorganic materials is expected to improve compost quality.

Thus, in the present research, we study the effect of premium compost amendments in Pineapple Plants on Marginal Land in Central Lampung on soil carbon microbial biomass.

MATERIALS AND METHODS

Experimental site and treatment

The experiment was conducted from December 2021 until July 2022 on Pineapple Plantation at Great Giant Pineapple Company (GGPC), District Central Lampung, Indonesia. Compost treatment and four replications established a randomized complete block design (RCBD). The compost treatments included P_0 = without compost, P_1 = cow manure compost 50 Mg ha^{-1}, P_2 = Premium Compost A 50 Mg ha^{-1}, and P_3 = Premium Compost B 50 Mg ha^{-1} Premium compost was made with several organic materials such as cow manure, young charcoal (bituminous), vermicompost, LOB (liquid organic biofertilizer), and zeolite. Each of these materials was chosen for its specific properties and potential benefits to the soil and plant growth. The composition of premium compost A and B are shown in Table 1.

Soil Tillage and Compost application

Soil tillage was used to prepare pineapple cultivation. Standard tillage GGPC was applied, which included a chopper, moldboard, harrow (disc plow), ridge, and excavator. Then, 3 Mg ha^{-1} dolomite was applied and left for one month. Furthermore, a planting path or bund was made using a ridge. The compost treatment (cow dung compost, premium compost A, and premium compost B) was applied at 50 Mg ha^{-1}.

Table 1. The composition of organic and inorganic material of compost, premium A and Premium B .

	Treatment (Mg ha^{-1})		
Composition	Compost	Compost Premium A	Compost Premium B
Cow dung	50	37	39.5
Young charcoal/Bituminous		7.5	5
Vermicompost		0.5	0.5
Zeolite		5	5
LOB (Liquid Organic Biofertilizer)		900 L	900 L
Total application	50	50	50

The ultimately scheduled pineapple plantation can be seen in Figure 1.

Soil Sampling and Soil Carbon Microbial Biomass Determination

Soil samples were taken after the pineapple forcing phase at the 13th, 14th, 15th, and 16th months after planting (MAP). Soil samples were taken using a shovel to a depth of 0-10 cm, put in a plastic bag, and labeled. Then, the sample was taken to the laboratory for analysis.

Determination of soil carbon microbial biomass was carried out using the general chloroform fumigation extraction method (Franzluebbers et al., 1999; Widodo et al., 2016; Smith et al., 1995). The 100 g of moist soil was placed in a 50 ml beaker and then fumigated using 30 ml of chloroform in a desiccator, which had been pressurized at 50 cm Hg for 120 minutes and then incubated for 48 hours. After that, the chloroform was removed. Then, the soil was put into a 1 L jar with two film bottles containing 10 ml of 0.5 N KOH and another film bottle containing 10 ml of distilled water. Then, 10 g of fertile soil as an inoculum source was put into a jar containing 100 g of soil, closed tightly and incubated at 25 °C in a dark place for 10 days. The quantity of CO_2 absorbed by KOH was determined by titration using HCl, with phenolphthalin and methyl orange indicators. The same method was also carried out on non-fumigation soil as a control. The HCl used for the titration was related directly to the amount of CO_2 bound. The same thing was done for the control. The research also measured soil organic-C (Walkley and Black method), soil pH (Electrometric method), soil temperature (Soil thermometer), and soil water content (Gravimetric method).

Statistical Analysis

Data were analyzed with an analysis of variance (ANOVA) using a statistical package for the social

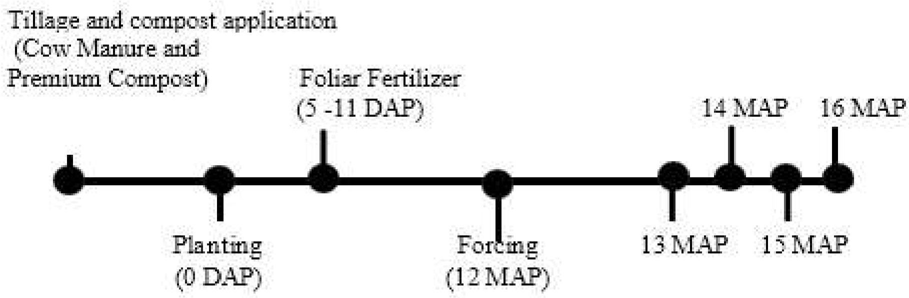

Figure 1. Time was scheduled for the pineapple plantation during the study. DAP = Day After Planting; MAP= Month After Planting.

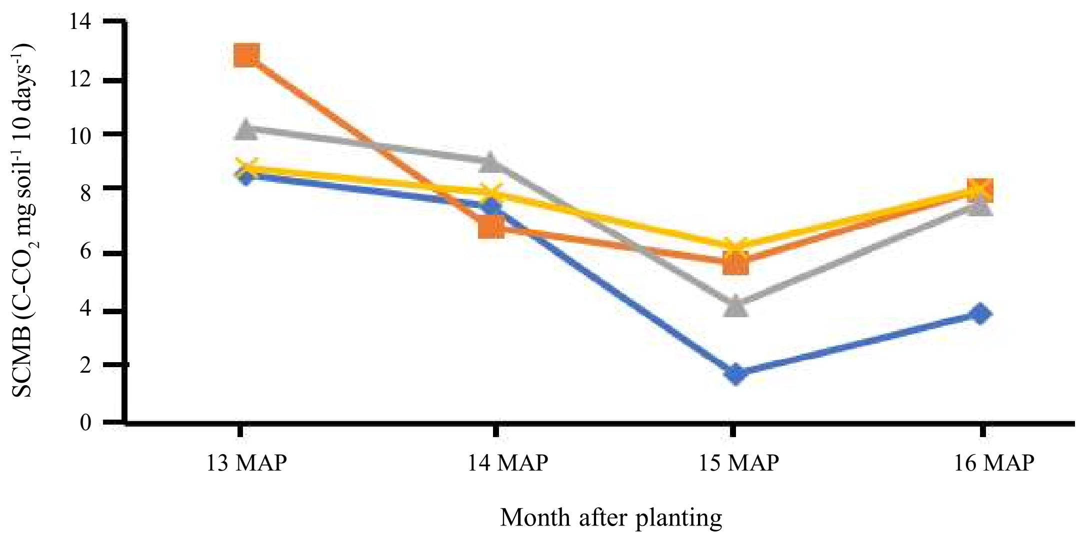

Figure 2. Soil Carbon Microbial Biomass dynamic caused by compost application during pineapple growth (P_0 =control, P_1= cow dung manure compost, P_2= Premium Compos A, P3=Premium Compos B).

sciences (SPSS) Statistics v27 (2020) for a complete randomized block design followed by a contrast orthogonal at a probability level of 5% for means data comparison. Correlation analysis was used to analyze the relationship between soil temperature, moisture content, pH, organic carbon, and SCMB.

RESULTS AND DISCUSSION

Soil carbon microbial biomass (SCMB) at pineapple cultivation

Figure 2 presents the Soil Carbon Microbial Biomass dynamic caused by compost application during pineapple growth. The highest SCMB reached 12.80 mg C-CO_2 kg soil^{-1} ten days^{-1} in the cow dung compost treatment (P_1) at 13 MAP observations. Then, SCMB decreased until 15 MAP and increased again until 16 MAP observation.

According to Setiawati et al. (2021), microorganisms will go through the slow phase (lag phase) in the earlier application of compost because microorganisms have to adapt to the new environment. The rising phase (exponential phase) is the growth phase of microorganisms, which depends on the new environmental conditions. The balanced phase (stationary phase) is when nutrients in the environment become increasingly depleted or other by-products accumulate that inhibit the growth of microorganisms. It can be seen in the application of premium fertilizer containing young coal, which slowly releases nutrients (Zhou et al., 2019), so premium compost needs to stabilize environmental conditions with microorganisms. In the cow dung compost treatment, SCMB is higher because the energy source is more readily available and ready to be utilized by microorganisms than premium compost (Setiawati et al., 2021).

Effect of Compost Treatments on Soil Carbon Microbial Biomass (SCMB)

Based on ANOVA and orthogonal contrast, compost treatment had no significant effect on the soil carbon microbial biomass at 13 MAP and 14 MAP; however, at 15 MAP observations, the compost application treatment significantly affected the soil carbon microbial biomass (Table 2). Compost application, cow dung, and premium compost A and B were higher than that control at the 15 and 16 MAP observations. Based on the orthogonal contrast test, at 15 MAP observations, cow dung compost, premium compost A, and premium compost B increased SCMB by 89.31% compared to without compost, and at 16 MAP observations, increased SCMB by 84.06%. However, the application of all kinds of compost, both cow dung compost or compos premium A and B, have the same effect on the SCMB. According to Setiawati et al. (2021), adding compost as an organic material is a good energy source for soil microorganisms so that soil carbon microbial biomass will increase.

Premium compost A (P_2) and premium compost B (P_3) are not significantly different from cow dung compost (P_1) in increasing SCMB, even though the composition of premium compost A and B contain humic acid from young charcoal (Smith et al., 1995; Ahmad et al., 2015; Syafrullah, 2016). It is caused

Table 2. Anova and contrast orthogonal for soil carbon microbial biomass caused by different compost application.

Treatment	Soil carbon microbial biomass			
	13 MAP	14 MAP	15 MAP	16 MAP
	mg C-CO_2 kg soil^{-1} 10 days^{-1}			
Control (P_0)	8.63	7.53	1.68	3.80
Cow dung compost (P_1)	12.80	6.80	5.56	8.12
Premium A (P_2)	10.24	9.07	4.09	7.60
Premium B (P_3)	8.85	7.97	6.07	8.12
	Significance			
	1.93 ^{ns}	0,44 ^{ns}	9.17*	3.00 ^{ns}
Contrast Orthogonal				
$C_1 = P_0$ vs P_1 P_2 P_3	1.58 ^{ns}	0.06 ^{ns}	22.55*	8.91*
$C_2 = P_1$ vs P_2 P_3	3.72 ^{ns}	0.98 ^{ns}	0.36 ^{ns}	0.03^{ns}
$C_3 = P_2$ vs P_3	0.51 ^{ns}	0.30 ^{ns}	4.63 ^{ns}	0.09^{ns}

Note: MAP = Month After Planting; ns = not significant at 5% level; * = significant at 5% level

Table 3. The effect of several compost treatments on the physical and chemical properties of the soil at observations 13, 14, 15, and 16 MAP.

Treatment	Organic-C (%)				Soil Temperature (°C)				Soil pH				Soil water Content (%)			
	MAP															
	13	14	15	16	13	14	15	16	13	14	15	16	13	14	15	16
P_0	1.16	1.06	1.00	0.95	26.88	27.00	27.00	27.63	4.38	4.40	4.29	4.24	17.26	13.05	14.78	15.59
P_1	1.35	1.26	1.23	1.18	27.13	27.25	27.13	27.75	4.42	4.33	4.85	4.76	19.03	13.20	15.73	16.63
P_2	1.30	1.34	1.31	1.26	27.13	27.38	27.75	27.38	4.45	4.51	4.42	4.55	16.95	12.97	16.42	16.78
P_3	1.21	1.48	1.23	1.20	27.25	27.38	27.38	27.75	4.28	4.52	4.70	4.80	17.50	13.88	15.41	16.39
	Significance															
Treatment	2.04^{ns}	4.19^{*}	1.08^{ns}	1.12^{ns}	1.16^{ns}	1.84^{ns}	1.62^{ns}	0.48^{ns}	7.64^{*}	0.68^{ns}	2.99^{ns}	1.67^{ns}	1.41^{ns}	0.55^{ns}	1.56^{ns}	1.31^{ns}
	Contrast orthogonal															
$C_1 = P_0$ vs $P_1P_2P_3$	3.24^{ns}	9.10^{*}	2.98^{ns}	3.14^{ns}	3.00^{ns}	4.26^{ns}	1.92^{ns}	0.10^{ns}	0.01^{ns}	0.14^{ns}	4.64^{ns}	4.11^{ns}	0.40^{tn}	0.21^{tn}	2.91^{tn}	3.56^{tn}
$C_2 = P_1$ vs P_2 P_3	1.75^{ns}	2.06^{ns}	0.08^{ns}	0.12^{ns}	0.12^{ns}	0.95^{ns}	1.88^{ns}	0.05^{ns}	2.83^{ns}	1.90^{ns}	2.51^{ns}	0.10^{tn}	3.60^{tn}	0.11^{tn}	0.08^{tn}	0.01^{tn}
$C_3 = P_2$ vs P_3	1.12^{ns}	1.39^{ns}	0.18^{ns}	0.10^{tn}	0.37^{tn}	0.32^{ns}	1.04^{ns}	1.31^{ns}	20.09^{*}	0.01^{ns}	1.83^{ns}	0.80^{tn}	0.25^{tn}	1.32^{tn}	1.69^{tn}	0.36^{tn}

Note: MAP = month after planting; P_0 = control (no compost application); P_1 = cow dung compost; P_2 = premium compost A; P_3 = Premium Compost B; ^{ns} = not significant at 5% level; * = significant at 5% level.

by humic acid, which does not play a role in providing nutrients and energy for soil microorganisms (Smith, 2016). However, the negative charge of humic acid originating from the phenolic functional group will neutralize the H^+ ions in the soil so that the soil pH will increase. However, increasing soil pH has not been able to increase the carbon biomass of microorganisms significantly.

Effect of Compost Treatments on Soil Physical and Chemical Properties

Based on ANOVA and contrast orthogonal, compost only affected soil organic carbon at 14 MAP observations and soil pH at 13 MAP observations (Table 3). Furthermore, the treatment of cow dung compost, premium compost A, and

Table 4. Correlation between several characteristics of soil physic and soil chemistry with soil carbon microbial biomass (mg C-CO_2 kg soil^{-1} ten days^{-1}) in pineapple (*Ananas Comosus* L. Merr) plantations.

Soil Characteristic	Correlation coefficient (r) Soil Carbon Microbial Biomass			
	13 MAP	14 MAP	15 MAP	16 MAP
Soil Organic-C (%)	0.05^{ns}	0.23^{ns}	0.23^{ns}	0.51*
Soil temperature (°C)	0.44^{ns}	0.37^{ns}	0.28^{ns}	0.01^{ns}
Soil pH	0.3^{ns}	0.06^{ns}	0.11^{ns}	0.55*
Soil water content (%)	0.32^{ns}	0.4^{ns}	0.10^{ns}	0.10^{ns}

Note: MAP = Month After Planting; ^{ns} = no significant; * = significant at 5% level

premium compost B increased organic-C by 74.01% compared to the control. Tami and Handayani (2020) explained that adding organic material can increase the organic-C content of the soil. Carbon is an energy source for soil microorganisms, so the presence of organic C in the soil will stimulate the activity of microorganisms. Another result shows that premium compost A treatment significantly increased soil pH compared to premium compost B, which is caused by an increase in soil pH, which depends on the quality of the organic material used. Based on the orthogonal contrast test (Table 4), at observation 13 MAP, premium compost A treatment was able to increase soil pH by 0.17 or 3.82% compared to premium compost B. Karnilawati et al. (2015), and Syafrullah (2018), stated that humic acid compounds from young coal can improve the soil pH. Herviyanti et al. (2012) also stated that the increase in soil pH due to the application of humic acid was caused by the negative charge and the functional groups of humic (carboxyl groups (COO-) and phenolic groups (OH-).

Correlation between Physical and Chemical Properties and Soil carbon microbial Biomass (SCMB)

The correlation test between soil physical and chemical properties and soil carbon-carbon microbial biomass shows that organic-C and soil pH positively correlate with microorganism carbon biomass at 16 MAP observations. In contrast, soil water content and soil temperature are not correlated. It means that increasing soil organic carbon and soil pH could increase the SCMB.

CONCLUSIONS

Applying several composts (cow dung, premium A, and premium B) increased soil microbial biomass carbon by 89.31% at 15 MAP observations and 84.06 % at 16 MAP observations compared to without compost treatment. However, all the compost treatments had no different effect on SCMB. There is a positive correlation between soil organic carbon and pH with SCMB. Soil organic carbon and pH are the primary factors affecting SMBC.

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