



Influence of Treated POME Sludge Vermicomposting on Soil Physicochemical Properties and Maize Growth Performances

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ABSTRACT

Background: Transforming the abundance of palm oil mill effluent (POME) sludge into beneficial substances such as an organic amendments is vital in the recycling of waste. Vermicomposting from treated POME sludge (TPS) was evaluated on the effect of soil physicochemical properties, crop performances and to determine the best treatment effect on the biomass of the hybrid grain maize (*Zea mays* L.).

Methods: The experimental layout was designed in a randomized complete block design (RCBD). The grain maize cultivated in Bungor series soil (Ultisol) comprising of (T1) control (NPK fertilizer), (T2) 1 kg of vermicompost, (T3) 2 kg vermicompost, (T4) 1 kg TPS and T5 (2 kg TPS) with six replications, for a period of 100 days from June to September 2019. Half of the NPK fertilizer dosage applied from the recommended practices.

Result: The treatments with 50% reduction of NPK rate significantly ($p < 0.05$) affected soil physicochemical properties. The dry matter production, crop performance analysis (net photosynthesis, stomata conductance and transpiration rate) and root weight density were also increased significantly using 2 kg of vermicompost treatment. Vermicompost application demonstrated the best treatment effect on soil properties and grain maize productivity. Utilization of POME sludge waste into organic amendment through vermicomposting approach would become very crucial practices to be adopted in reducing the abundance waste.

Key words: Grain maize, Physicochemical, POME, Productivity, Vermicomposting.

INTRODUCTION

POME sludge is a residue commonly referred to as oil extraction by palm oil mills which is stored or discharged in disposal ponds, leading to the leaching of heavy metals to the groundwater and soil. POME was highlighted by palm oil mills operators as an expensive and difficult waste to manage (Madaki and Seng, 2013). Directly applied to the agricultural fields could cause soil-environmental problems like phytotoxicity (Breš and Politycka, 2016). Research from Khairuddin *et al.*, (2016), the treated POME sludge waste was safe for plant uptake (Association *et al.*, 1915). The waste had the potential to convert into an organic amendment for plant growth (Mohd Nizar *et al.*, 2018).

The emphasis of this study is to minimize the waste by converting it into vermicompost. Vermicomposting the treated POME sludge (TPS) is one of the most efficient means to mitigate and manage environmental pollution problems. The earthworm ingested TPS and yielded a peat-like material which called as vermicompost. This process is faster than traditional composting as the material passes through the earthworm gut, resulting in microbial activity and plant growth regulators (Pathma and Sakthivel, 2012).

A review by Rupani *et al.*, (2010), vermicomposting from POME sludge was one of the practical and effective practices. A technology in vermicomposting the TPS is expected to produce high grain maize (*Zea mays* L.) biomass yield production, highlighting comparable results with TPS and chemical fertilizer and also able to improve soil physicochemical conditions.

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MATERIALS AND METHODS

TPS was sampled at oil palm mills situated in Felda Jengka 8, Pahang, Malaysia. The selected dumping pond (DP) as a storage of POME sludge was initially treated with specific hydraulic retention time (HRT) method which using the standard methodologies of the wastewater that was compulsory to abide during the processes. Before applying it to the worms, the moisture content of TPS was maintained at the constant level in about 2 weeks to get better aeration and to speed up the degradation purposes.

The TPS was sieved to maintain its size <5.18 mm. The sieves substrate was placed in vermicomposters of 42 liter containers (length: 63 cm; width: 47 cm; depth: 38 cm). Five hundred grams substrates were kept in moist conditions using organic liquid that mixed with the distilled water (1:10) up to 40% in weight for a week in order to soften and accelerate the degradation processes. Hundred grams of earthworms (*Eudrilus eugeniae*) were added to the vermicomposter and the vermicast was collected at the top layer of the vermicomposter. The moisture content of the vermicompost was kept at 30%-40% throughout the experimental period and stored in a shady place at the temperature of 20°C-30°C. The substrate maintained at a depth of 25-30 cm and a new substrate was added. The earthworm stock maintained at the temperature of 25±1°C. The heavy metals content in TPS (Table 2) and preliminary nutrient properties in the vermicompost (Table 3) were determined using the standard methods.

Table 1: Soil characteristic of Bungor soil series (Ultisol) before experiment.

Parameter	Value
Series	Bungor (Ultisol)
pH before liming	4.19
pH after liming	5.4
Texture	Sandy clay loam
Clay (%)	27.67
Silt (%)	8.75
Sand (%)	63.59
Total N (%)	0.09
P (ppm)	0.05
K (ppm)	40.15
CEC (cmol kg ⁻¹)	9.98

Field arrangement

The experiment was conducted at Agrotech farm, Universiti Putra Malaysia (2°58'55.0"N 101°42'55.1"E) (Fig 5A). The vermicompost and TPS with different rates of application mixed with 20 kg of Bungor series soil (Ultisol) as the planting medium filled in a polybag of 20' × 20'. Treatments evaluated were: (T1) NPK fertilizer as a control, (T2) 1 kg vermicompost + NPK, (T3) 2 kg vermicompost + NPK, (T4) 1 kg TPS + NPK and (T5) 2 kg TPS + NPK with six replications. 13 g of chemical fertilizer (NPK: 15:15:15) added to all the treatments for each plant 14 days after sowing and 10 g of chemical fertilizer (NPK: 12:12:17) after 7 days after flowering phase occurred. The experimental layout was set up in a randomized complete block design (RCBD) (Fig 5B) and the maize variety planted was the hybrid grain maize (*Zea mays* L.). The rate of NPK fertilizer used was half of the recommended rate as suggested by MARDI (Onn, 2005).

Soil analysis

The Bungor soil series (Ultisols) was collected from topsoil (0-10 cm) for preliminary data analysis. The soil samples were placed in a container and immediately transported to the laboratory for analysis. The soil characteristics of Bungor soil series before experiment showed in Table 1. After harvesting, the soil samples were collected to analyse the selected physicochemical properties using the standard methods. Aggregate stability of the soil was analysed using a wet sieving apparatus procedure (Eijkkelkamp, Netherlands) adapted from Kemper and Rosenau (Kemper and Rosenau, 2018). Bulk density was conducted using the core ring method (Klute, 1986; Singh, 2016). Soil porosity was measured by the ratio of the bulk density to the particle density. Hydraulic conductivity also measured by placing the soil samples in the core ring and measured using the constant head method (Klute and Dirksen, 1986) derived

Table 2: Content of heavy metal of POME anaerobic sludge and treated POME sludge (Khairuddin *et al.*, 2016).

WHO standard	POME anaerobic sludge (Baharuddin <i>et al.</i> , 2010)	Treated POME sludge (Khairuddin <i>et al.</i> , 2016)	WHO-ML Standard
Composition of heavy metal elements			
Copper (mg/kg)	70.40+21.60	45.05+2.87	75.00
Chromium (mg/kg)	9.30+0.20	27.86+0.55	150.00
Cadmium (mg/kg)	n.d	0.41+0.01	1.90
Zinc (mg/kg)	151.00+14.50	130.11+3.49	140.00
Lead (mg/kg)	0.5+0.60	0.38+0.10	0.30
Nickel (mg/kg)	14.0+2.2	10.77+0.15	67.00
Manganese (mg/kg)	495.24+48.3	422.56+12.04	500.00
Composition of nutrient elements			
Boron (mg/kg)	n.d	n.d	-
Iron (%)	1.09+0.40	2.24+0.02	-
Potassium (%)	5.16+2.20	0.03+0.01	-
Calcium (%)	2.55+0.10	1.67+0.04	-
Magnesium (%)	1.41+0.20	0.55+0.02	-
Phosphorus (%)	1.25+0.10	0.08+ 0.01	-
Sulphur (%)	1.21+0.30	0.30+0.01	-

Table 3: Characteristics of selected chemical composition in vermicomposting, TPS and standard organic fertilizer.

Selected chemical characteristics	Vermicompost	TPS organic fertilizer	Organic fertilizer (Kala <i>et al.</i> 2011)
Carbon (%)	12.1	25.53	≥12
Total N (%)	0.7	4.21	0.70 -4.40
Phosphorus (%)	0.4	0.08	0.04-8.85
Potassium (%)	1.0	0.03	1.29-6.94
Magnesium (%)	0.4	0.55	0.3-3.3
Calcium oxide (%)	0.12	1.67	0.12-12.00
C/N ratio	17.3	6.1	3.8-42.7
Moisture content (%)	57.9	68.4	50-70
pH value	8.9	6.2	4.5-9.8

from the Darcy's law. (O'neal, 1949) proposed ranges in classifying the hydraulic conductivity of soils into seven classes (Table 4).

Soil pH was determined using the soil to water ratio of 1:2.5 and calibrated pH meter (Rayment and Higginson, 1992). Total nitrogen content was measured using Perkin-Elmer 2400 (CNS analyzer). Soil samples were analysed using Bray's method (Bray and Kurtz, 1945) and measurement by the Auto Analyzer (AA) and the exchangeable potassium using ammonium acetate (Simard, 1993). The measurement was done using the flame atomic absorption spectrophotometer (AAS).

Crop performance analysis

The total dry matter yield (leaves, stem, cobs and roots) after harvesting was recorded. The plant samples were placed in the oven and left to dry at 60°C for 75 hours or until the constant weight achieved. The root sample was calculated to determine the root weight density (Yang *et al.*, 2010). Mass of root (g) was divided with the volume of polybags (m³). The measurements of the photosynthesis system were calculated using the LI-COR, LI-6400XT Portable Photosynthesis System (Lincoln Nebraska USA). These measurements were done before the harvesting processes at the 100 DAS.

Statistically analysis

One-way ANOVA design was adopted and the data analysed using the Statistical Analysis System (SAS 9.4) to observe the significant difference between the treatments and Pearson's coefficient correlation to observe the relationship of some selected parameters in this study. Means separation was carried out using LSD and Tukey test at $p < 0.05$.

RESULTS AND DISCUSSION

Preliminary of nutrients properties

The comparison of the nutrients content in vermicompost, treated POME sludge and other organic fertilizers properties were shown in Table 3. The pH value in vermicompost was quite high or alkaline compared to the TPS and the other organic fertilizers. A few nutrients did not show too much differences such as total N, P, K and Mg content in the vermicompost and TPS organic fertilizer.

Table 4: Soil hydraulic conductivity classes (O'Neal, 1949).

Class	Hydraulic conductivity, K (cm/h)
Very slow	< 0.125
Slow	0.125-0.5
Moderately slow	0.5-2
Moderate	2-6.25
Moderate rapid	6.25-12.5
Rapid	12.5-25
Very rapid	> 25

Selected soil physicochemical properties

The addition of vermicompost and treated POME sludge showed that there was a significant effect ($p < 0.05$) on (A) total porosity, (B) bulk density and (C) aggregate stability and (D) hydraulic conductivity (Fig 1). In Fig 1A shows that vermicompost, T3 (68.08%) had the highest mean value of total porosity compared to the control (47.25%). Organic matter is lighter and more porous than an equivalent amount of solid soil which indicated low bulk density. Soil treated with 2 kg (0.85 g/cm³) of vermicompost showed the lowest value of bulk density (Fig 1B). The same result exhibited by Zainal, (2014). Low bulk density strengthened the soil aggregate formation (Odey, 2018). This statement proved that after treated with T3 (76.86%) the soil aggregate formation showed the highest value in Fig 1C compared to the control (53.24%).

In Fig 1D, the increased of hydraulic conductivity at 8.79 cm/h after application of treatment with T3. High values indicated that the soil treated with vermicompost became more permeable to water to pass through the pore spaces. According to Table 4, vermicompost treatment was categorized in the moderate rapid class. Hence, the addition of vermicompost explained the increased of Ks due to the total soil porosity and soil aggregates stability (Fig 1A and 1C). Soil structure played a vital role in the hydraulic conductivity, either high or low (Mohd Nizar *et al.*, 2018).

Fig 2 shows that vermicompost and TPS was significantly different ($p < 0.05$) in (A) pH, (B) total nitrogen, (C) available phosphorus and (D) exchangeable potassium. Soil mixed with vermicompost treatment indicated the pH value was 6.5 compared to T1 (5.05) (Fig 2A). The difference

in pH compared with the different treatments explained by the chemical content of the wastes, which contributed to the effect on mineralization processes and other intermediate compounds during the vermicomposting (Lim *et al.*, 2015). The organic treatment improved the soil pH within the range of nutrients availability for plant uptake. Remaining macronutrients in the soil achieved the highest amount of nitrogen (0.3%) after being treated with 2 kg of vermicompost (Fig 2B). Fig 2C and 2D showed that there was no difference of available phosphorus and potassium in vermicompost and TPS at all rates of application. Vermicompost and TPS were able to retain adequate water and nutrients. Similar results highlighted that

high rate of macronutrients produced high production of grain maize (Tajul *et al.*, 2013).

Crop growth performance

Photosynthesis rate showed the highest photosynthesis rate, $25.33 \mu\text{mol m}^{-2}\text{s}^{-1}$ in T3 while control ($15.57 \mu\text{mol m}^{-2}\text{s}^{-1}$) with the lowest rate (Fig 3A). From the findings of Mahmud *et al.* (2019), the application of vermicompost presented positive effects on the total chlorophyll content. As the plant production in vermicompost treatment increased, the total chlorophyll content also increased and led to a higher rate of photosynthesis.

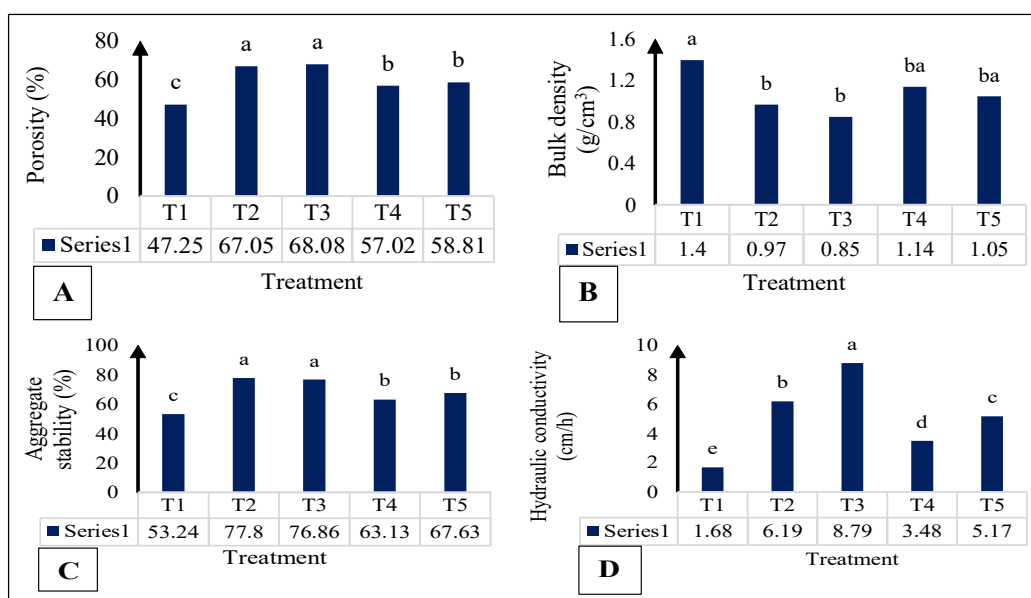


Fig 1: (A) Total porosity, (B) Bulk density, (C) Aggregate stability and (D) Hydraulic conductivity. Mean with the same letter is not significantly different at ($p < 0.05$).

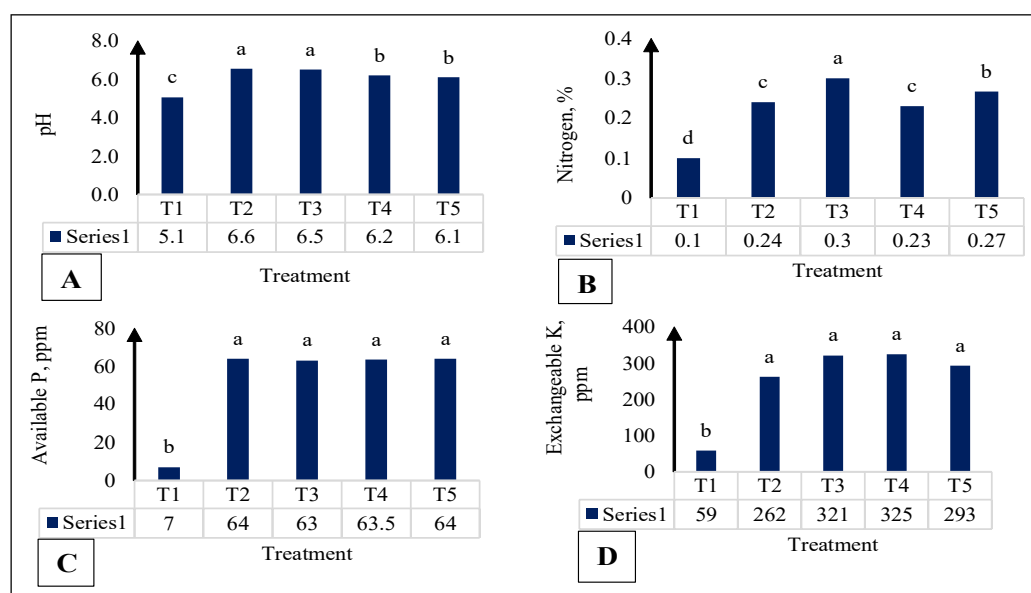


Fig 2: (A) pH value, (B) Total nitrogen content, (C) Available phosphorus and (D) Exchangeable potassium. Mean with the same letter is not significantly different at ($p < 0.05$).

Referring to Fig 3B, stomata conductance highlighted significantly different ($p < 0.05$) in T3 ($1.31 \text{ mol m}^{-2}\text{s}^{-1}$) than T1 as the control ($0.5 \text{ mol m}^{-2}\text{s}^{-1}$) due to the water content was sufficient in the soil, the guard cell turgor increased, leading to a rise in the stomata pore openings. The physiological maturity phase of the maize showed that vermicompost and TPS performed more effectively than the control because of a complete mineralization processes and

the incorporation of the organic amendments that already occurred (Dolorima *et al.*, 2018).

Transpiration occurred while the stomata opened for the CO_2 and O_2 passage to enable the process of photosynthesis. In Fig 3C, T2 showed that the transpiration rate was low in vermicompost ($1.11 \text{ m}^2\text{s}^{-1}$) compared to the TPS and control treatment which might reflect to the photosynthesis effect of the maize. The high stomata

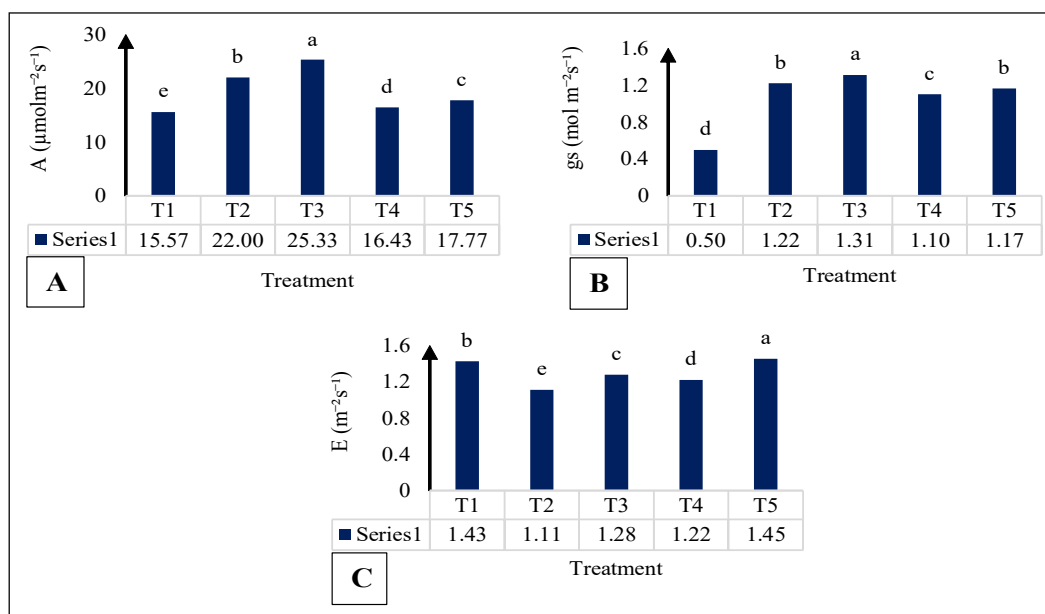


Fig 3: (A) Photosynthesis rate, (B) Stomatal conductance and (C) Transpiration rate of maize. Mean with the same letter is not significantly different at ($p < 0.05$).

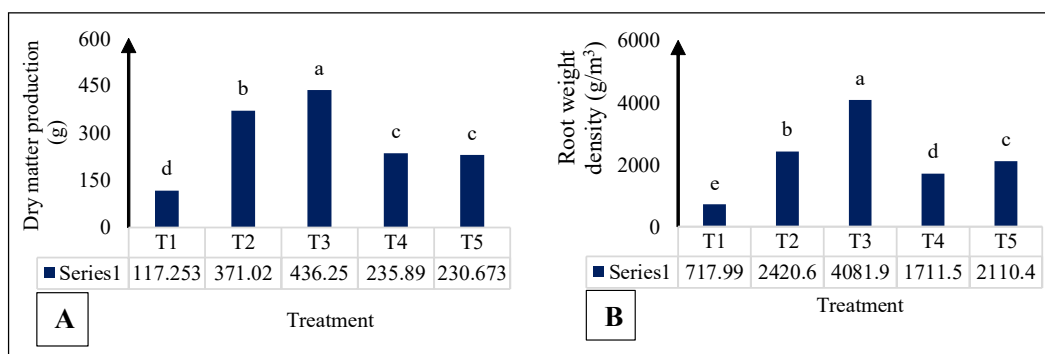


Fig 4: (A) Total dry matter production and (B) Root weight density. Mean with the same letter is not significantly different at ($p < 0.05$).

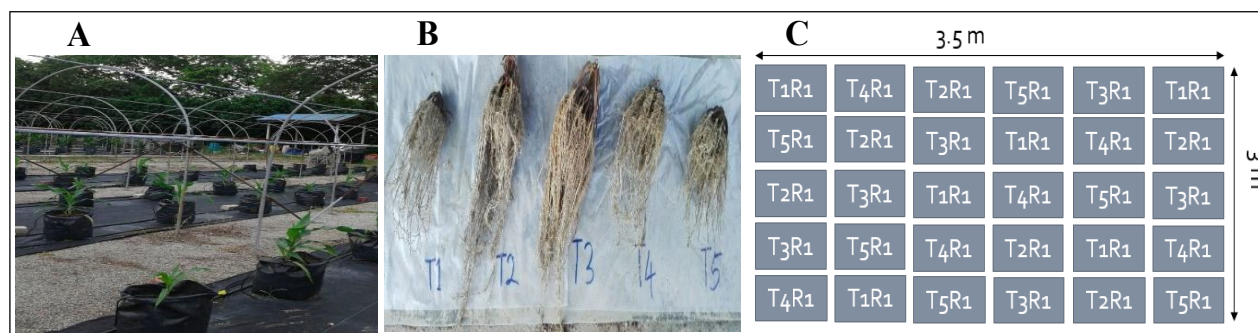


Fig 5: (A) Location of the experiment, (B) Root yield of maize in all treatment and (C) Layout of the experiment.

conductance of the maize plant in Fig 3B clearly explained its low transpiration rate.

Fig 4 showed that there was a significant difference ($p < 0.05$) in dry matter production (A) and root weight density (B) in T2 and T3 compared to the lowest value shown in T1. High values of macronutrients in vermicompost (Table 3) acts as a plant growth regulator that stimulated positive effects on crop performance (Canatoy, 2018). Hence, the application of vermicompost showed the highest root weight density. Fig 5C showed the root samples from all treatments after harvesting. The increased of root weight density in vermicompost was high compared to the TPS treatment, which due to the nutrients' availability. The application of organic amendments was one of the main reasons in providing nutrients to increase the plant vegetative growth and enhanced the condition of the kernel, loosen the soil and improved the passage of air entry for the root movement (Abaszadeh *et al.*, 2016).

CONCLUSION

The vermicomposting of TPS using the *E. eugeniae* was applied to observe the effect on the grain maize growth and soil physicochemical status. Hence, there were positive and significant achievement observed on crop performances and yield of the grain maize in this study. The 2 kg rate of vermicompost highlighted the best result of growth production, soil structure and physiological analysis of the hybrid grain maize (*Zea mays* L.). As a conclusion, vermicomposting from treated POME sludge (TPS) is practical and reliable to utilize the abundant POME sludge in the oil palm mills into organic amendment for plant uptake. In the future research, cost-benefit analysis is needed to analyse the effect on the 50% reduction of inorganic fertilizer application in combination with the vermicompost whether it is economically viable and able to produce a high production of grain maize due its nutrients availability comparing to the existing fertilizing program.

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