IMPROVEMENT OF VERMICOMPOST PRODUCED FROM POME SLUDGE ON SELECTED SOIL PHYSICOCHEMICAL PROPERTIES AND THE PHYSIOLOGICAL PERFORMANCE OF MAIZE

By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Mohd Rizal Ariffin, PhD
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Palm oil industries is one of the world's leading producer in Malaysia which is contribute to the Malaysian agricultural sector. However, palm oil production generates abundance of Palm Oil Mill Effluent (POME) sludge wastes eventually pollute the environment. Sludge waste from the palm oil were treated to produce treated POME sludge (TPS). The waste sludge were treated with specific hydraulic retention time and the standard methodologies of the wastewater that use as raw material for vermicomposting. Vermicomposting is one of the methods to treat the waste with minimal cost. A research was conducted in an open field at Agrotech farm, Universiti Putra Malaysia from June to September 2019. The treatments were: (T1) control (NPK fertilizer), (T2) 1 kg of vermicompost + NPK, (T3) 2 kg vermicompost + NPK, (T4) 1 kg TPS + NPK and (T5) 2 kg TPS + NPK with 5 replications. Vermicompost used in this experiment were produced from treated POME sludge (TPS). Half recommendation rate of NPK fertilizer were applied. The experimental design were laid in a randomized completely block design (RCBD). The first objective of the research was to examine how TPS and vermicompost affect the physicochemical characteristics of the soil. The results showed that 2 kg vermicompost + NPK influence the soil physicochemical properties significantly ($p < 0.05$) while control treatment showed least effect to the soil physicochemical properties. This was due to the improved of soil texture and structure thus enhanced soil shear strength which were resulted in the increased angle of internal friction and low cohesion value. Vermicompost have higher total N, P, K Ca and Mg compared to chemical fertilizer and TPS. The ability of vermicompost to retains adequate nutrients supply due to the movement of water through its effect on the physical characteristic of soils. The second objective aimed to evaluate physiological performance of maize after application of vermicompost and treated POME sludge (TPS). The 2 kg vermicompost had higher chlorophyll content which contributed to the increased rate of photosynthesis. Maize applied with vermicompost showed increase the maize growth compared to maize applied with NPK fertilizer due to the dry matter production, crop performance analysis and root weight density increased significantly using 2 kg of vermicompost treatment. In conclusion, the research showed that the influence of vermicompost giving highest growth parameters and improved the soil physicochemical properties. The treated POME sludge (TPS) are capable to use for production of vermicompost.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENAMBAHBAIKAN VERMIKOMPOS YANG DIHASILKAN DARIPADA ENAP POME PADA SIFAT FIZIKOKIMIA TANAH TERPILIH DAN PRESTASI FISIOLOGI JAGUNG

Oleh

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Industri kelapa sawit adalah salah satu pengeluar terkemuka dunia di Malaysia yang menyumbang kepada sektor pertanian Malaysia. Walau bagaimanapun, pengeluaran minyak sawit menjana banyak sisa enapcemar Efluen Kilang Minyak Sawit (POME) akhirnya mencemarkan alam sekitar. Sisa enap cemar daripada minyak sawit telah dirawat untuk menghasilkan enap cemar POME (TPS) yang dirawat. Enap cemar sisa telah dirawat dengan masa pengekalan hidraulik khusus dan metodologi standard air sisa yang digunakan sebagai bahan mentah untuk vermikompos. Vermikompos merupakan salah satu kaedah untuk merawat sisa dengan kos yang minimum. Satu kajian telah dijalankan di kawasan lapang di ladang Agrotech, Universiti Putra Malaysia dari Jun hingga September 2019. Rawatan tersebut adalah: (T1) kawalan (baja NPK), (T2) 1 kg bihun + NPK, (T3) 2 kg bihun. + NPK, (T4) 1 kg TPS + NPK dan (T5) 2 kg TPS + NPK dengan 5 ulangan. Vermikompos yang digunakan dalam eksperimen ini dihasilkan daripada enap cemar POME (TPS) yang dirawat. Kadar syor separuh baja NPK telah digunakan. Reka bentuk eksperimen diletakkan dalam reka bentuk blok sepenuhnya rawak (RCBD). Objektif pertama penyelidikan adalah untuk mengkaji bagaimana TPS dan vermikompos mempengaruhi ciri fizikokimia tanah. Keputusan menunjukkan bahawa 2 kg vermikompos + NPK mempengaruhi sifat fizikokimia tanah dengan ketara ($p < 0.05$) manakala rawatan kawalan menunjukkan paling sedikit kesan kepada sifat fizikokimia tanah. Ini adalah disebabkan oleh tekstur dan struktur tanah yang bertambah baik sekali gus meningkatkan kekuatan ricih tanah yang mengakibatkan sudut geseran dalaman meningkat dan nilai kohesi yang rendah. Vermikompos mempunyai jumlah N, P, K Ca dan Mg yang lebih tinggi berbanding baja kimia dan TPS. Keupayaan vermikompos untuk mengekalkan bekalan nutrien yang mencukupi disebabkan oleh pergerakan air melalui kesannya terhadap ciri fizikal tanah. Objektif kedua bertujuan untuk menilai prestasi fisiologi jagung selepas penggunaan vermikompos dan enap cemar POME (TPS). Vermikompos 2 kg mempunyai kandungan klorofil yang lebih tinggi yang menyumbang kepada

peningkatan kadar fotosintesis. Jagung yang digunakan dengan vermikompos menunjukkan peningkatan pertumbuhan jagung berbanding jagung yang digunakan dengan baja NPK kerana pengeluaran bahan kering, analisis prestasi tanaman dan ketumpatan berat akar meningkat dengan ketara menggunakan 2 kg rawatan vermikompos. Kesimpulannya, kajian menunjukkan bahawa pengaruh vermikompos memberikan parameter pertumbuhan tertinggi dan meningkatkan sifat fizikokimia tanah. Enap cemar POME (TPS) yang dirawat mampu digunakan untuk pengeluaran vermikompos.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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I hereby confirm that:

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LIST OF ABBREVIATIONS

AA	Auto-Analyzer
AAS	Atomic Absorption Spectrophotometer
ABA	Abscisic Acid
ALP	Algae Pond
ANOVA	Analysis of Variance
AWC	Available Water Capacity
BOD	Biochemical Oxygen Demand
CEC	Carbon Exchange Capacity
COD	Chemical Oxygen Demand
DP	Dumping Pond
EFB	Empty Fruit Bunch
FC	Field Capacity
FP	Facultative Pond
HI	Harvest Index
HRT	Hydraulic Retention Time
LWR	Leaf Weight Ratio
NAR	Net Assimilation Rate
NUE	Nitrogen Use Efficiency
PAW	Plant-Available Water
POME	Palm Oil Mill Effluent
PWP	Permanent Wilting Point
RCBD	Randomized Complete Block Design
RGR	Relative Growth Rate
RWD	Root Weight Density

SLA	Specific Leaf Area
TPS	Treated Palm Oil Mill Effluent Sludge
VC	Vermicompost
WUE	Water Use Efficiency
AN	Net Photosynthesis
C	Cohesion
E	Transpiration Rate
K_s	Hydraulic Conductivity
Φ	Angle of Internal Friction

CHAPTER 1

INTRODUCTION

Palm oil mill effluent (POME) sludge is a residue from palm oil extraction that is stored or discharged in disposal ponds, causing heavy metals (contaminants) to leach into groundwater and soil. POME sludge causes serious environmental hazards if discharged directly to the environment, such as phytotoxicity (Bres and Politycka, 2016).The management of POME waste has been recognised as being expensive and challenging (Davies et al., 2020). Despite being organic, POME is difficult to decompose in the environment (Lee et al., 2019). In line with the concern above, the conversion of POME waste into usable form could be reused back to the environment as it contains organic matters that could improve root growth and sustain soil physicochemical properties. Because of that, a study was conducted to convert this effluent agro-waste to be more efficient and less polluting (Davies et al., 2020). For example, research from Khairuddin et al., (2016) study found that time retention (TR) methods and water retention curve (WRC) analysis were used to create treated POME sludge (TPS) that was safe for plant uptake (Walter, 1961). The TPS resulted in high supply of the nutrient content and changes in soil physicochemical characteristics.

The purpose of this study is to improvise the TPS by using the vermicomposting technique for better performance of plant growth. The waste could be transformed into an organic plant growth amendment (Khairuddin et al., 2016). The efficiency of treated POME sludge (TPS) produced from the previous study (Khairuddin et al., 2016) was used specifically for earthworm feedstock materials to produce vermicompost. The earthworm gut facilitates the vermicomposting process, which is quicker than traditional composting because the resulting earthworm castings are full of microbial activity and plant growth regulators (Makkar et al., 2022). The earthworm ingested treated POME sludge (TPS) for vermicomposting process produces a stable organic waste consisting of macro and micronutrients. Many researches have been studied on vermicompost by using raw POME sludge (Hayawin et al., 2016; Zainal, 2014; Zainal et al., 2013). However, a study on vermicompost by using treated POME sludge is limited. There aren't many literature sources that have looked into this issue, and no research has been done on the production of vermicompost from POME sludge that has been treated.

Since Malaysia is an agro-based industry and the majority of its productive soils have been used for agriculture, it is crucial to study the soil's physicochemical properties in advance. The soil media should also be well-drained and retain significant water to limit nutrient leaching with new aims in crop cultivation (higher yields and maximum nutrient efficiency of crop production) (Kaur, 2020). The most limiting and most variable environment factor affecting plant productivity is soil. Soils in South-East Asia typically have soil organic content is less than the minimal amount required (Brearley, 2005). The best way to improve the soil qualities is to incorporate organic elements in order to improve soil physicochemical properties. Organic additions applied over a large area can considerably improve soil's capacity to absorb nutrients and water (Karamina and Fikrinda, 2020). According to previous study, Shahzad et al., (2021) found that readily decomposable organic wastes are a superior alternative for restoring soil structure due to effectively binding the particles together to maintain the structure. The application of vermicompost could enhance the soil physicochemical properties.

Vermicomposting is one of the most efficient method as organic amendment to reduce and sustain issues with environmental pollution hence would sustain the crop growth without harming the environment (Lee et al., 2019). Enzyme from the microorganisms oxidise the organic compounds forming into easily available nutrient for the plants to take them up from the soil. Inoculation with a specific beneficial microorganism results in better and faster nutrient solubilization (Pascual et al., 2018). Vermicompost has many advantages such as able to increased soil nutrient availability from the soil microbial activity (Biabani and Gholizadeh, 2020), consist of balanced nutrients supply (Sahariah et al., 2020) and increased soil water availability (Nurhidayati et al., 2018). Higher plant growth performance and production will be obtained because of the incorporation of the microorganism in the organic matter. This showed that vermicompost is a safer alternative to the chemical fertilizer that could improve the soil fertility.

In Malaysia, the vermicompost sector is not well established among farmers either on a small or large scale. Agriculture methods are being used more and more frequently, and one of them is the use of chemical fertilizers, which promotes the growth of crops on a large scale. Inorganic chemical fertilizers are frequently used in agricultural circles to remedy nutrient deficiencies, but they have a detrimental effect on the soil's structure and acidity. The production of agricultural waste requires a long-term strategy for converting waste into usable resources. Among waste conversion products with low input eco-friendly technologies is vermicompost. Vermicomposting was practically widely to manage industrial waste resources. Vermicompost has a consistent quantity of macro and micronutrients, as well as the essential N, P and K for plants, in a shorter length of time. Thus, this experiment would be carried out with the objective to examine how TPS and vermicompost affect the physicochemical characteristics of the soil and to evaluate the physiological performance of maize.

The application rate of vermicompost on plant growth and yield also have been identified by many researchers (Bekele et al., 2018; Kmeťová & Kováčik, 2013; Xu & Mou, 2016; Zuo et al., 2018). However, the selected rates of application mixed with half of the NPK fertilizer recommended for maize growth have not fully studied on the effect of soil physicochemical properties and physiological performance. In summary, the research questions formulated from the problem statement need to be answered by the end of the thesis which were how TPS and vermicompost treatment can improve the soil physicochemical properties?

Then what are the factors that will influence the productivity of maize growth and yield? Lastly between 1 kg and 2 kg rate for TPS and vermicompost which can influence the best effect on soil physicochemical properties and maize growth performance?

The hypothesis of this study were that the effects of the chemical fertilizer, TPS and vermicompost will influence the soil physicochemical properties of Bungor soil series differently as well as maize growth parameters is expected showed differ among treatments due to the changes of the soil physicochemical properties. To investigate this hypothesis, an open field experiment was conducted using five fertilizer treatments, including NPK fertilizer, 1 kg vermicompost, 2 kg vermicompost, 1 kg TPS and 2 kg TPS on maize growth planted in polybag.

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