UNIVERSITI PUTRA MALAYSIA

APPLICATION OF COMPOST FROM OIL PALM EMPTY FRUIT BUNCH AND PALM OIL MILL EFFLUENT ANAEROBIC SLUDGE IN OIL PALM PLANTATION AS NUTRIENTS RECYCLING

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Malaysia is the world's second largest producer of palm oil. For every ton of crude palm oil, more than 3 tones of effluent is produced. The general thinking in the palm oil industry is that in order to increase the oil yield, more chemical fertilizers should be applied. This has caused increased consumption and excessive chemical fertilizer application at the plantations that eventually led to environmental pollution. At the same time, empty fruit bunch (EFB) and oil palm mill effluent (POME) anaerobic sludge are potential sources of raw material for the production of organic fertilizer. Although oil palm empty fruit bunches (EFB) as organic compost supplemented with inorganic fertilizer has been practiced in oil palm plantations, there is little evidence to support its effectiveness. In the absence of technical information, estates are applying large amounts of N, P and K fertilizers with the EFB due to the need to maintain high oil yield. At the same time fertilizer wastage occurs when excess fertilizer is lost by run-offs when it rains. Raw POME has been used as supplementary fertilizer in oil palm plantation as land application since POME contains some essential elements such as Ca, Mg, K, P and N and some micronutrients. POME contains water that enables it to reduce water deficit during the dry season. This study was initiated to study the effects of oil palm EFB together with POME anaerobic sludge on oil palm growth and yield and the soil chemical properties. The goal is to develop EFB and POME anaerobic sludge as organic fertilizer to improve crop yields, reduced fertilizer costs, increased soil fertility and reduced environmental pollution. The project is divided into three parts.

Firstly the soil characteristics in the oil palm plantation after 25 years of cultivation was compared to secondary forest soil as control. The results showed that the soil characteristics, especially the pH, were not significantly different. Regarding the bacterial community, the kingdom Achaea was only present at secondary forest. In the secondary forest soil, the phyla *Firmicute*s and *Bacteroidetes* were higher compared to *Proteobacteria*. In the oil palm plantation soil after 25 years of inorganic fertilizer

application, the phyla *Proteobacteria* and *Actinobacteria* were high, whereas *Firmicute*s and *Bacteroidetes* were low.

Secondly, different percentages of chemical fertilizer and compost fertilizer were then tested on the oil palm plantation over a period of 5 years. The results showed that application mixed inorganic fertilizer, even with 100% organic fertilizer, did not effect plant growth, soil and oil yield of oil palm. Achaea which is normally found at secondary forest appeared after four years application in treatment with 50% inorganic fertilizer: 50% organic fertilizer, 25 % inorganic fertilizer: 75 % organic fertilizer and 100 % organic fertilizer. The organic fertilizer increased the abundance of *Firmicute*s and *Bacteroidetes* as good bacterial indicators of soil. On the economic analysis, 50% inorganic fertilizer: 50 % organic fertilizer is compatible with 100 % inorganic fertilizer. Inorganic fertilizer from biomass of oil palm can save almost 50% cost of imported inorganic fertilizer.

Thirdly, in the oil palm main nursery study, the results showed that 50 % soil: 50 % compost with 100 % inorganic fertilizer can be adopted as commercial practice by the palm oil industry. Mixed media with 50 % soil: 50 % compost can maintain the nutrient composition in the soil and trigger plant growth comparable to 100 % soil with 100 % inorganic fertilizer. Increased of microbial diversity showed at treatment with 0 % soil: 50 % compost with 100 % inorganic fertilizer means suitable media and application inorganic fertilizer encouraging accumulation of microbial activity. The cost per polybag with 50 % soil: 50 % compost with 100 % inorganic fertilizer is RM 5.20, compared to 100 % soil with 100 % inorganic fertilizer at RM6.04; i.e. with a reduction RM0.84 per polybag.

Overall, the results in this study showed that publication of organic fertilizer did not decrease the oil extraction rate of oil palm fruit. The data obtained suggests that 50% application of organic fertilizer from EFB and POME anaerobic sludge oil palm plantation not only reduced the cost of inorganic fertilizer, but can also resolve environmental problem from the waste of palm oil mill. Furthermore, the results of the study showed the impact of organic fertilizer application can increase the fertility or soil by facilitating the growth of Achaea, *Firmicutes* and *Bacterioidetes* as good soil bacteria.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGGUNAAN BAJA KOMPOS HASIL DARIPADA HAMPAS BUAH KELAPA SAWIT DAN KUMBAHAN AIR KELAPA SAWIT DARIPADA LADANG KELAPA SAWIT : PENGGUNAAN SEMULA NUTRIEN

Oleh

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Julai 2021

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Malaysia adalah pengeluar minyak sawit kedua terbesar di dunia. Untuk setiap tan minyak sawit mentah, lebih daripada 3 tan efluen dihasilkan. Pemikiran umum dalam industri kelapa sawit adalah bahawa untuk meningkatkan hasil minyak, lebih banyak baja kimia harus digunakan. Ini menyebabkan peningkatan penggunaan dan penggunaan baja kimia yang berlebihan di ladang yang akhirnya menyebabkan pencemaran alam sekitar. Pada masa yang sama, lumpur anerobik tandan buah kosong (EFB) dan efluen kilang kelapa sawit (POME) merupakan sumber bahan mentah yang berpotensi untuk pengeluaran baja organik. Walaupun tandan buah kosong kelapa sawit (EFB) sebagai kompos organik ditambah dengan baja anorganik telah dipraktikkan di ladang kelapa sawit, ada sedikit bukti yang menyokong keberkesanannya. Sekiranya tiada maklumat teknikal, ladang menggunakan sejumlah besar baja N, P dan K dengan EFB kerana keperluan untuk mengekalkan hasil minyak yang tinggi. Pada masa yang sama pembaziran baja berlaku apabila baja berlebihan hilang akibat limpahan ketika hujan. POME mentah telah digunakan sebagai baja tambahan di perkebunan kelapa sawit sebagai aplikasi tanah kerana POME mengandungi beberapa elemen penting seperti Ca, Mg, K, P dan N dan beberapa mikronutrien. POME mengandungi air yang memungkinkan untuk mengurangkan defisit air pada musim kemarau. Kajian ini dimulakan untuk mengkaji kesan EFB kelapa sawit bersama dengan enapcemar anaerobik POME terhadap pertumbuhan dan hasil kelapa sawit serta sifat kimia tanah. Tujuannya adalah untuk mengembangkan enerobik EFB dan POME sebagai baja organik untuk meningkatkan hasil tanaman, mengurangkan kos baja, meningkatkan kesuburan tanah dan mengurangkan pencemaran alam sekitar. Projek ini terbahagi kepada tiga bahagian.

Pertama ciri tanah di ladang kelapa sawit setelah 25 tahun penanaman dibandingkan dengan tanah hutan sekunder sebagai kawalan. Hasil kajian menunjukkan bahawa ciri tanah, terutama pH, tidak jauh berbeda. Mengenai komuniti bakteria, kerajaan Achaea

hanya ada di hutan sekunder. Di tanah hutan sekunder, phyla Firmicutes dan Bacteroidetes lebih tinggi berbanding Proteobacteria. Di tanah perkebunan kelapa sawit setelah 25 tahun penggunaan baja anorganik, phyla Proteobacteria dan Actinobacteria tinggi, sedangkan Firmicutes dan Bacteroidetes rendah.

Kedua, peratusan baja kimia dan baja kompos yang berlainan kemudian diuji di ladang kelapa sawit dalam jangka masa 5 tahun. Hasil kajian menunjukkan bahawa penggunaan campuran baja organik, walaupun dengan 100% baja organik, tidak mempengaruhi pertumbuhan tanaman, hasil tanah dan minyak kelapa sawit. Achaea yang biasanya dijumpai di hutan sekunder muncul setelah empat tahun digunakan dalam rawatan dengan 50% baja bukan organik: 50% baja organik, 25% baja anorganik: 75% baja organik dan 100% baja organik. Baja organik meningkatkan banyak Firmicutes dan Bacteroidetes sebagai petunjuk bakteria tanah yang baik. Berdasarkan analisis ekonomi, 50% baja bukan organik: 50% baja organik serasi dengan 100% baja bukan organik. Baja bukan organik dari biomas kelapa sawit dapat menjimatkan hampir 50% kos baja bukan organik yang diimport.

Ketiga, dalam kajian semaian utama kelapa sawit, hasilnya menunjukkan bahawa 50% tanah: 50% kompos dengan 100% baja anorganik dapat diadopsi sebagai amalan komersial oleh industri kelapa sawit. Media campuran dengan tanah 50%: Kompos 50% dapat mengekalkan komposisi nutrien di dalam tanah dan mencetuskan pertumbuhan tanaman setanding dengan tanah 100% dengan baja anorganik 100%. Peningkatan kepelbagaian mikroba ditunjukkan pada rawatan dengan tanah 0%: kompos 50% dengan baja anorganik 100% bermaksud media yang sesuai dan penggunaan baja anorganik yang mendorong pengumpulan aktiviti mikroba. Kos per polibeg dengan tanah 50%: Kompos 50% dengan baja anorganik 100% adalah RM 5.20, berbanding tanah 100% dengan baja bukan organik 100% pada harga RM6.04; iaitu dengan pengurangan RM0.84 setiap polibeg.

Secara keseluruhan, hasil dalam kajian ini menunjukkan bahawa penggunaan baja organik tidak menurunkan kadar pengekstrakan minyak buah kelapa sawit. Data yang diperoleh menunjukkan bahawa penggunaan 50% baja organik dari ladang kelapa sawit enerobik EFB dan POME bukan sahaja dapat mengurangkan kos baja anorganik, tetapi juga dapat menyelesaikan masalah lingkungan dari sisa kilang kelapa sawit. Selanjutnya, hasil kajian menunjukkan kesan aplikasi baja organik dapat meningkatkan kesuburan atau tanah dengan mempermudah pertumbuhan Achaea, Firmicutes dan Bacterioidetes sebagai bakteria tanah yang baik.

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This thesis is submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of Supervisory Committee are as follows;

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AAS	Atomic absorption spectroscopy
Al	Aluminum
B	Boron
Bp	Base pair
BLAST	Basic logical alignment search tool
Ci	Calcium
Cu	Cuprum
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimetre
CEC	Cation exchange capacity
CMC	Carboxymethylcellulose
COD	Chemical oxygen demand
CPO	Crude palm oil
DGGE	Denaturing gel gradient electrophoresis
DAP	Diamonium phosphate
DNA	Deoxyribonucleic acid E.coli Escherichia coli
dNTP	deoxynucleotide triphosphate
EFB	Empty fruit bunch
Fe	Ferum
FASSB	Felda Agricultural Services Sdn Bhd
FELDA	Federal land development authority
FFB	Fresh fruit bunch

g	gram
HGFB	High grade fertilizer borate
K	Potassium
kg	kilogram
KCI	Muriate potash
L	liter
m	meter
mL	milliliter
mg	milligram
Mn	Manganese
Mg	Magnesium
MEGYP	Maximum exploitation of genetic yield potentials
MOP	potassium chloride
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Congress
N	Nitrogen
NGS	Next –generation sequencing
NCBI	National Center for Biotechnology Information
OPEFB	Oil palm empty fruit bunch
OTU	Operational Taxonomical unit
OPT	Oil palm trunks
OPF	Oil palm fronds
P	Phosphorus
PCoA	Principal coordinates analysis

PCR	Polymerase chain reaction
POME	Palm oil mill effluent
Qiime	Quantitative insight into microbial ecology
RCBD	Randomized complete block design
RM	Ringgit Malaysia
RDP	Ribosomal database project
RP	Rock phosphate
RSPO	Rountable on Sustainable of palm oil
RT-PCR	Real-time polymerase chain reaction
rRNA	Ribosomal ribonucleic
S	Sulfur
Si	Silica
SIRIM	Standard & industrial research institute of Malaysia
SMS	Synthetic magnesium sulphate
SMP	Soluble microbial products
TSP	triple superphosphate
Zn	Zink
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 Overview of research

The oil palm (*Elaeis guineensis* Jacquin) is economically important for Malaysia for its oil, whereby Malaysia has become the second biggest exporter in the world after Indonesia. The climate, soil and agro-ecological zone in Malaysia are suitable for oil palm. Malaysia has a total land area of 329,733 km^2 which is divided into two geographical regions, Peninsular with land area of 131,573 km^2 and East Malaysia which comprises Sabah and Sarawak with land of 73,711 km^2 and 124,449 km^2. Malaysia has warm humid tropical climate throughout the year. Humidity is about 85% with temperature range from 21-32°C, annual rainfall 2,450 mm and above and year round day length of 12.5 hours (Lim *et al.* 2011). The soil in Malaysia can be divided broadly into 2 main groups, sedentary soil from rock type and soil of the coastal alluvial plains.

Climate requirement for oil palm is high rainfall between 200 and 300 cm/year, 15cm of rainfall is requirement for each month without distinct drought season or months with less than 10cm rain (Goh 2004). Optimal temperature range between 22°C and 33°C with the lowest temperature supporting the plant close to 20°C (Goh 2004). The daily requirement of sunlight is between 5 and 7 daylight hours and at least 2000 hours of sunshine annually (Lim *et al.* 2011). Relative humidity should between 75 and 100 percent (Lim *et al.* 2011). Most soil are suitable and the crop does not demand high fertility soil, except the soil should not be heavy with large amount of clay due to water logging during the monsoon season (Lim *et al.* 2011). Suitable soil texture is sandy loam of more than 75cm depth. Lateritic, sandy or peat soils are problematic soils that need proper manuring and maintenance for optimum palm growth (Tan et al. 2014). Ideally, oil palm should be grown in flat areas. For inland soils, planting is done in a triangular form, with a distance of 8.8 m, giving 148 palms/ha, coastal alluvial soil is 136 palms/ha and peat soils 160 palms/ha.

Consequently, fertilizers are essential for economic production as attested by field experiments and growth in fertilizer usage in the oil palm sector. For good yields to be sustained, fertilizer inputs are necessary and typically constitute 40-50 % of total field upkeep cost. With palm oil projected to grow to 35 million tons by 2020, the expansion in fertilizer requirements is assured and this makes pleasant news to people in the trade. Most of fertilizers used in Malaysia are imported. Urea was imported from Indonesia, Vietnam, China, Saudi Arabia, Thailand, Australia, India, Japan and Philippines. Ammonium sulphate imported from Japan, China, Russia, Korea, and Taiwan. Rock phosphate imported from Egypt, Tunisia, Algeria, Christmas Island and Australia.

At the same time, both the expected increase in palm oil production and concomitant fertilizer usage have to take full cognizance of worldwide environmental concerns on two major counts. The first focuses on huge quantities of biomass by-products are also generated annually and renewable source is not fully wisely utilized, while the second concerns pollution of water and the air by agro-chemicals, including fertilizers. In the 2012, from the 82.39 million tons of total fresh fruit bunch processed, the biomass produced are as follows: shell 4.94 million tons, fiber 9.87 million tons, empty fruit bunch 18.13 million tons and palm oil mill effluent (POME) 49.43 tons.

1.2 Problem statement

Every year, Malaysia's oil palm industry has to import a large amount of chemical fertilizers to meet the needs for the growth of oil palm trees. Statistics recorded by Food and Agriculture Organization of the United Nations (2016) states that in 2001, Malaysia imported RM 1144 million worth of chemical fertilizers. The reasons included by Food and Agriculture Organization of the United Nations (FAO) is Malaysia lacks the raw materials of P and K. Although Malaysia exports 1.75 million tones urea, Malaysia still imported 386,571 million tons per year urea for local use from Russian Federation Company. In addition to that, it is proven in many studies that prolonged use of chemical fertilizer is detrimental to the soil fertility (Ge *et al*. 2018). In order to mitigate the problem, a partial substitution of the chemical fertilizer with the use of compost was proposed. Furthermore, the use of EFB and POME sludge to the composting process also solved some waste management problems faced by the industry. Therefore, this research aims to determine the effect of compost as a partial substitute for chemical fertilizers to the oil palm at nursery and growth stage and to determine its effect on the soil characteristics and microbial profile

1.3 Research objectives

The objectives of this research are:

1. To conduct baseline study, characterize macronutrient, micronutrient and microbial diversity profile to soil planted with oil palm plantation.
2. To evaluate the effect of organic and inorganic fertilizer on changes of oil yield, the physical characteristics of oil palm, soil microbial diversity profile, oil extraction and economical statistic.
3. To determine the effect of compost as media to reduce inorganic fertilizer used at oil palm nursery stage.

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