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OIL PALM EMPTY FRUIT BUNCH BIOCHAR AND COMPOST AS AMENDMENT FOR IMPROVEMENT OF POLYBAG-GROWING MEDIA AND OIL PALM SEEDLINGS

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By

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The common practice of growing oil palm seedlings in the main nursery is using top soils as growing medium. These soils especially in tropical region are highly-weathered acidic soils, and low in soil organic matter content. Soil amendment using organic materials such as biochar or/and compost may potentially improve the soil physicochemical properties, promote plant growth and enhance rooting process. Both compost and biochar production are methods to recycle organic wastes and add carbon for sustainability of oil palm industry. Thus, the general aim of this study was to investigate the effects of oil palm empty fruit bunch (EFB) biochar and compost as amendment of polybag growing medium on oil palm seedlings in the main nursery stage. A field study was conducted with treatments of four rates of biochar (biochar was applied according to weight percentage of C added to polybag mixture; 0, 0.5, 1.0 and 1.5% w/w C (biochar C: soil mixture)), two compost rates (0 and 30% v/v) and three rates of fertilizer application (50, 75 and 100% of fertilizer recommended rate) laid out in randomized complete block design (RCBD) design with four replications. The effects of biochar, compost, and biochar-compost on oil palm seedling growth was evaluated and the effectiveness of EFB biochar in retaining soil nutrients to reduce nutrients leaching was determined indirectly by measuring nutrients leached. In addition, an incubation study was carried out in laboratory to investigate the effects of EFB biochar on soil carbon and nitrogen mineralisation over a period of 270 days. This laboratory study consisted of same compost and biochar rates as in field study (two compost rates and four biochar rates). Results showed that oil palm shoot dry weight responded to quadratic relationship with increasing biochar rates in media with and without compost amendment, with shoot biomass comparable to the control (media without amendment). However, the higher root dry weight was obtained with 1.5% C addition in growing media with 30% v/v compost and applied with 75% fertilizer rates. Regression analysis showed positive response for height, bole diameter and number of frond production to biochar application rates with or without compost.

Results also show that biochar and compost treatments positively affect the growing media properties (pH, total C and N, C:N ratio, CEC, Mg and Ca) when compared with the control treatment. Considering the potential effects of biochar on root growth and shoot:root ratio, the results suggested that 30% (v/v) compost and 1.5% biochar C (w/w) addition with 75% of fertilizer rates was the most promising growing media for oil palm seedling production in the main nursery for optimum seedling growth and reduction in fertiliser usage. Furthermore, nutrient leaching measurement indicates that, EFB biochar significantly retained ammonium-N nutrient (ammonium-N leaching reduced by 46%) over the nursery period, but, have no effects on retention of total nitrate-N, phosphate and Mg^{2+}, while K^{+} leaching increased with the increasing biochar rates. In the laboratory study, both biochar treatments with and without compost significantly increased dissolved organic carbon (DOC) content and soil respiration (CO_2 emissions), indicating microbial activity and C mineralisation. However, biochar may cause net N immobilisation when applied alone, but, showed positive synergistic effects on N mineralisation when co-application with compost. Overall, this study demonstrates the potential of co-application of biochar and compost as soil amendment in oil palm seedling growing medium in improving properties of growing medium and root growth development at main nursery which is a critical factor for establishment of the palm seedling in field.

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

BIOCHAR DAN KOMPOS TANDAN KOSONG KELAPA SAWIT SEBAGAI PERAPI TANAH UNTUK PEMBAIKAN POLIBEG MEDIA DAN ANAK BENIH KELAPA SAWIT

Oleh

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Amalan biasa penanaman benih kelapa sawit di tapak semaian utama ialah dengan menggunakan tanah lapisan atas sebagai media penanaman. Tanah ini, terutamanya di rantau tropika adalah tanah berasid yang terluluhawa, oleh itu, tanah ini mempunyai kandungan bahan organik yang rendah. Penggunaan perapi tanah daripada bahan-bahan organik seperti biochar atau kompos berpotensi meningkatkan ciri fisiko-kimia tanah dan menggalakkan pertumbuhan tumbuhan terutamanya pertumbuhan akar. Disamping itu, penghasilan biochar dan kompos adalah salah satu cara untuk menguruskan sisa buangan organik, disamping menambahkan kredit karbon untuk kelestarian industri kelapa sawit apabila biochar diaplikasikan. Oleh itu, objektif umum kajian ini adalah untuk mengkaji kesan EFB biochar dan EFB kompos sebagai perapi tanah dalam media tanaman anak benih kelapa sawit di peringkat tapak semaian utama. Satu kajian menggunakan polibeg media tanam di lapangan telah dijalankan dengan mengaplikasikan empat kadar biochar (Aplikasi biochar dalam polibeg media mengikut penambahan peratusan berat C kepada berat campuran media; 0, 0.5, 1.0 dan 1.5% w/w C), dua kadar kompos (0 dan 30% v/v) dan tiga kadar penggunaan baja (50, 75 dan 100% daripada kadar baja yang disyorkan). Kesan biochar, kompos, dan biochar-kompos terhadap pertumbuhan anak benih kelapa sawit dinilai dan keberkesanan EFB biochar dalam mengekalkan nutrien tanah daripada dilarut lesap juga ditentukan. Satu kajian inkubasi selama 270 hari telah dijalankan di makmal untuk mengkaji kesan EFB biochar pada mineralisasi karbon dan nitrogen pada tanah. Kajian ini menggunakan kadar kompos and biochar yang sama seperti di kajian lapangan (dua kadar kompos dan empat kadar biochar). Berat kering pucuk kelapa sawit menunjukkan hubungan kuadratik dengan peningkatan kadar biochar pada media penanaman dengan atau tanpa kompos dengan berat pucuk adalah setanding dengan rawatan kawalan (media tanpa perapi). Berat kering akar tinggi telah diperolehi dengan rawatan 1.5% biochar C pada media penanaman dengan 30% v/v kompos dan penggunaan kadar baja 75%. Analisis regresi menunjukkan tindak balas positif

ketinggian pokok, diameter batang dan pengeluaran pelepah dengan kadar aplikasi biochar pada media penanaman dengan atau tanpa kompos. Rawatan biochar dan kompos juga memberi kesan positif kepada sifat-sifat media penanaman (pH, jumlah C dan N, nisbah C:N, CEC, Mg dan Ca) berbanding dengan rawatan kawalan. Walau bagaimanapun, berikutan potensi kesan biochar kepada pertumbuhan akar, hasil kajian ini mencadangkan 30% (v/v) kompos dan aplikasi 1.5% C (w/w) dari EFB biochar dengan kadar baja 75% adalah media penanaman yang paling baik bagi pengeluaran anak benih kelapa sawit di peringkat tapak semaian utama. Selain itu, pengekalan ammonium-N nutrien oleh biochar adalah signifikan (larut lesap ammonium-N dikurangkan sebanyak 46%) dalam tempoh nurseri, tetapi, tidak mempunyai kesan signifikan ke atas pengekalan jumlah nitrat-N, P dan Mg, manakala larut lesap K meningkat dengan peningkatan kadar aplikasi biochar . Dalam kajian makmal, rawatan biochar dengan kompos dan tanpa kompos adalah signifikan dalam meningkatkan kandungan DOC dan respirasi tanah (CO_2). Biochar boleh menyebabkan immobilisasi N tanah pada rawatan tanpa kompos, namun, ia menunjukkan kesan sinergi positif pada mineralisasi N apabila diaplikasikan bersama kompos. Secara keseluruhan, kajian ini menunjukkan penggunaan biochar dan kompos berpotensi sebagai perapi media penanaman anak benih kelapa sawit terutamanya dalam meningkatkan pertumbuhan akar dan sifat media penanaman pada peringkat semaian utama, yang merupakan faktor penting untuk penstabilan anak pokok sawit di lapangan.

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I certify that a Thesis Examination Committee has met on 8 February 2017 to conduct the final examination of Rovica anak Radin on her thesis entitled "Oil Palm Empty Fruit Bunch Biochar and Compost as Amendment for Improvement of Polybag-Growing Media and Oil Palm Seedlings" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

Av. P	Available P
°C	Degree celsius
µL	Microliter
ANOVA	Analysis of variance
CEC	Cation exchange capacity
cm	Centimeter
CPO	Crude palm oil
df	Degree of freedom
DOC	Dissolved organic carbon
DW	Dry weight
EFB	Empty fruit bunch
Ext.	Extraction
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
g	Gram
g/kg	gram per kilogram
g/plant	Gram per plant
kg	Kilogram
kg/plant	Kilogram per plant
L	Litre
LSD	Least significant differences
MF	Mesocarp fibre
mg	Miligram
mg/kg	miligram per kilogram
mL	Milliliter
mm	Milimeter
MPOB	Malaysian Palm Oil Board
m	meter
nm	Nanometer
OPF	Oil palm frond
OPT	Oil palm trunk
PKS	Palm kernel shell
R^2	Coefficient determination
RISDA	Rubber Industry Smallholders' Development Authority
RCBD	Randomized complete block design
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

Among the major oilseeds, oil palm (*Elaeis guineensis* Jacq) is one of the most efficient oil crop in terms of land use. The oil palm plantation only accounts for 6.6% of total global cultivated land for vegetable oils in 2015, yet it represented 38.7% of global oils and fats production, which is the largest world vegetable oil production (Oil World, 2016). To date, Indonesia and Malaysia are the world's largest palm oil producing countries, which contribute 85% of the global market (USDA, 2016). Malaysian oil palm industry has grown tremendously over the past 4 decades and currently occupied 5.39 M ha of total planting area with production of 20 million tonnes of crude oil palm (MPOB, 2016). The rapid growth of oil palm industry has raised concerns about sustainability and environmental issue, particularly for the vast amount of biomass generated from the processing mills as well as the field biomass.

For instance, about 80 M tonnes of dry oil palm biomass was produced in the year 2010 (Ooi et al., 2014) and it is expected to reach 100 M tonnes in 2020 (Agensi Inovasi Malaysia, 2013; Rahman et al., 2014; Umar et al., 2014). The oil palm solid waste mainly consists of empty fruit bunch (EFB), palm kernel shell (PKS), mesocarp fibre (MF), oil palm trunk (OPT) and oil palm frond (OPF) (Kong et al., 2014). Due to the air quality regulation 1998 (ACT A1030) (prohibition of open burning of biomass agrowastes), oil palm biomass wastes have been converted into various valuable products to ensure zero waste operation. For instance, PKS and MF are used as fuel in most of palm oil mill to generate electricity (Subramaniam et al. 2008). The OPT, OPF and EFB raw material are used for pulp paper industry (Wanrosli 2007), plywood for furniture manufacturing industry (Wahid et al. 2009; Sulaiman et al. 2011) and bioethanol production (Yamada et al., 2010; Kassim et al., 2011; Tan et al., 2013). The OPT, OPF and EFB are also directly applied into the field as mulching materials to recycle the nutrients back into the soil. (Basiron and Chan, 2004; Subramaniam et al., 2008; Hansen, 2012). Among oil palm waste by-products, EFB is also commonly used as raw material for composting to produce soil amendment and organic fertilizers.

Biochar, a carbonaceous solid product of biomass produced by pyrolysis, is gaining interest as a soil amendment in the past decade to increase carbon sequestration for mitigation of climate change and at the same time improvement of crop productivity. Numerous studies on biochar incorporation into agricultural soils have shown that it is able to improve soil properties and subsequently improved crop. For example, adding biochar to infertile soils can increase the cation exchange capacity of the soil and nutrient sorption due to its high net negative charge and porosity (Burrell et al., 2016); stimulate soil microorganism activities by improving the physical and chemical environment in soils and provide microbes with a more favourable habitat (Lehmann et. al., 2011; Anderson et al., 2011); improve soil nutrient availability which resulted from high concentration of basic cation, liming effects (Uzoma et al., 2011; Kuka et al., 2013; Yang et al., 2013) and reduce nutrient leaching losses because of the

biochar's sorptive properties (Ding et al., 2010; Laird et al., 2010; Kameyama et al., 2012).

In Malaysia, there are several available biomass wastes that have the potential to be converted into biochar as an alternative waste management method. The conversion of oil palm waste into biochar constitutes a promising strategy towards obtaining carbon credit in the oil palm industry as part of the efforts in achieving sustainability in palm oil production. In 1999, a pilot carbonator to produce biochar was designed and setup in Dengkil, Selangor, next to an oil palm mill through a collaboration between UPM and Nasmech Technology Sdn Bhd, funded by Science, Technology and Innovation Ministry. This EFB biochar was then used to initiate biochar research in Malaysia. In the oil palm sector, biochar has the potential to be applied in the field as well as in the nursery for oil palm seedling production.

For good oil palm establishment after transplanting in the field, it is of utmost importance for nursery to produce good quality oil palm seedlings. Traditionally, top soil is use as a polybag growing media for oil palm seedlings.
Compost had been widely used in nursery polybag medium for oil palm seedlings which has been reported to improve seedling growth (Danso et al., 2013; Ovie et al., 2014; Suryanto et al., 2015). Several studies have been carried out to search for alternative growing media that are cost-effective and at the same time provide adequate amount of nutrients for optimum seedling growth, particularly at main nursery stage. For example, the use of palm kernel de-oil cake and compost in the growing media has shown improvement in seedling growth in the main nursery (Bello et al., 2014; Suryanto et al., 2015).

Biochar also has the potential to be applied in the main nursery whereby the stable carbonaceous carbon may then be transferred into the oil palm field when the seedlings is transplanted in the field. The transfered stable carbon would then remain in the field and contribute towards carbon credit in the field. Until now, research on use of biochar in oil palm plantation and its nursery is still greatly lacking. Oil palm waste biochar may be applied in polybag growing media with compost to reduce usage of chemical fertilizers and yet produce quality oil palm seedlings that is with good root development.

Thus, the general aim for this study is to investigate the effects of EFB biochar as a soil amendment with compost on oil palm seedlings at the main nursery stage.

The specific objectives of this study were:

1. To evaluate the effects of EFB biochar, compost, and biochar-compost mixture on oil palm seedling growth performance and media chemical properties.
2. To determine the effectiveness of EFB biochar to reduce leaching loss of nutrients.
3. To investigate the effects of EFB biochar on carbon and nitrogen mineralisation in soil with and without compost.

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