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EFFECTS OF PACLOBUTRAZOL, BIOCHAR AND WATER STRESS ON GROWTH OF OIL PALM (Elaeis guineensis Jacq.) SEEDLINGS

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EFFECTS OF PACLOBUTRAZOL, BIOCHAR AND WATER STRESS ON GROWTH OF OIL PALM *(Elaeis guineensis* Jacq.) SEEDLINGS

By

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EFFECTS OF PACLOBUTRAZOL, BIOCHAR AND WATER STRESS ON GROWTH OF OIL PALM *(Elaeis guineensis* Jacq.) SEEDLINGS

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September 2015

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Drought promotes water stress on oil palm seedlings in the main nursery or field. Biochar (BC) could improve soil moisture retention while paclobutrazol (PBZ) could protect plants against water stress during drought period. There is a lack of information on utilization of PBZ and BC and their rates on growth of oil palm seedlings. Experiment 1 was conducted to determine effect of BC and PBZ on growth of oil palm seedlings in main-nursery at the IOPRI Marihat substation, Indonesia. Three months olds DxP-Simalungun seedlings from pre-nursery were transplanted into polybags filled with soil containing 0, 50 or 100 g BC. After 3 months, seedlings were treated with 95% PBZ at 0, 100, 200 and 300 mg/seedling. At harvest, seedling height, rachis length and frond number were measured monthly. Leaf area, dry shoot and dry root weight, gibberellin (GA) contents and PBZ residue were measured at 12 months. Combination of BC and PBZ increased seedling high significantly by seedling ages, but the rate of increment was not as high as compared to treatment of BC alone. Seedling height increased gradually at 6 to 9 months, followed by a rapid increase from 9 to 12 months. Combination of 50 g BC + 100 mg PBZ produced desired seedling height of 120 cm. PBZ decreased rachis length after it was applied, the effect was reversed over time. The combination of BC and PBZ showed a synergistic effect, promoting or reducing root dry weight. The 50 g BC + 100 mg PBZ promoted seedling dry root weight. BC at 50 g/seedling combined with PBZ at 200-300 mg/seedling decreased root dry weight. GA contents decreased as PBZ application rates were increased. PBZ had a reversed effect on GA. The 50 g BC + 100 mg PBZ combination was selected for Experiment 2.

Experiment 2 was conducted to determine the effect of water stress on growth performances of oil palm seedling transplants from selected BC and PBZ treatments under simulated field condition. Twelve months old seedlings with 50 g BC + 100 mg PBZ and control were transplanted into polybags. Then, the seedlings were placed under a rain-shelter and exposed to three water stress treatments: 50, 75 and 100 of field capacity (FC). Seedling height, leaf area, leaf chlorophyll contents, photosynthetic and transpiration rates, shoot and root

dry weights and leaf proline contents were determined on 13, 14 15 and 16 months old seedlings. The 50 g BC + 100 mg PBZ treated seedlings had smaller leaf area, increasing chlorophyll contents, increased photosynthesis and stimulated transpiration rate compared to control seedlings. Higher proline contents of control seedlings indicated seedlings stress compared to those of treated seedlings.

In conclusion, BC produced better seedlings condition while PBZ retards seedling growth by blocking GA synthesis, thus producing compact seedlings. Compact seedlings were easy to maintain and transplant, requiring less transportation space. Thus, it recommended applying seedling with 50 g of BC and 100 mg PBZ per seedling to make it compact and prevent it from drought in the field.

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

KESAN PACLOBUTRAZOL, BIOCHAR DAN TEKANAN AIR KE ATAS PERTUMBUHAN ANAK POKOK KELAPA SAWIT (*Elaeis guineensis* Jacq.)

Oleh

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Kemarau menyebabkan tekanan air terhadap anak pokok kelapa sawit di nurseri utama atau di lapangan. Biochar (BC) didapati mampu mengekalkan kelembapan tanah sementara, paklobutrazol (PBZ) dapat melindungi tumbuh-tumbuhan daripada tekanan air semasa tempoh kemarau. Terdapat kekurangan maklumat mengenai penggunaan PBZ dan BC dan kadarnya terhadap pertumbuhan anak benih kelapa sawit. Eksperimen pertama telah dijalankan untuk menentukan kesan BC dan PBZ kepada pertumbuhan anak benih kelapa sawit di nurseri utama di IOPRI Marihat. Dalam kajian ini, variati DxP-Simalungun yang berumur tiga bulan dari pra-nurseri telah digunakan dan dipindahkan ke dalam beg poli yang mengandungi 0,50 atau 100 g BC. Tiga bulan selepas diubah, benih anak pokok dirawat dengan 95% PBZ (PP333-TC) pada 0, 100, 200 dan 300 mg/anak benih. Pada masa penuaian, ketinggian anak pokok, panjang batang pelepah, dan bilangan pelepah diukur pada bulan ke-12. Gabungan BC dan PBZ meningkatkan ketinggian anak pokok dengan peringkat umur secara ketara, tetapi kadar kenaikan tidak setinggi berbanding rawatan BC sahaja. Ketinggian anak pokok tinggi meningkat secara berperingkat pada 6 hingga 9 bulan, diikuti oleh peningkatan yang pesat dari 9 hingga 12 bulan. Gabungan 50 g BC + 100 mg PBZ memberikan ketinggian anak benih yang disasarkan iaitu pada 120 cm. PBZ mengurangkan panjang batang pelepah secara langsung selepas ia digunakan dan kesan yang telah bertukar dari masa ke masa. Gabungan BC dan PBZ menunjukkan kesan sinergi dalam menggalakkan atau mengurangkan berat kering akar. Campuran 50 g BC + 100 mg PBZ telah meningkatkan berat akar kering anak pokok kelapa sawit. Kombinasi rawatan BC pada 50 g/anak pokok dengan PBZ pada 200-300 mg/anak pokok didapati menurunkan berat akar kering. Kandungan GA didapati menurun apabila kadar PBZ meningkat. Ini menunjukkan PBZ memberi kesan kebalikan terhadap GA. Oleh itu, campuran BC 50 + PBZ 100 dipilih sebagai kombinasi yang terbaik untuk Eksperimen 2.

Percubaan kedua telah dijalankan untuk menentukan kesan tekanan air pada prestasi pertumbuhan anak pokok kelapa sawit yang dipindahkan daripada rawatan PBZ dan BC yang terpilih di bawah keadaan simulasi lapangan. Anak

pokok berusia 12 bulan dengan 50 g BC + 100 mg PBZ dan kawalan telah dipindahkan ke dalam beg poli . Anak pokok ditempatkan dibawah lindungan hujan dengan tiga rawatan tekanan air Selepas: 50, 75 dan 100 kapasiti lapangan (KL). Parameter seperti ketinggian anak benih, luas daun, kandungan klorofil daun, fotosintesis dan kadar transpirasi, berat kering pucuk dan akar dan daun dan kandungan prolina ditentukan pada anak benih berusia 13, 14, 15 dan 16 bulan. Anak pokok yang dirawat dengan PBZ100 mg + BC 50 g menunjukkan prestasi pertumbuhan yang lebih baik dalam keadaan tekanan air berbanding dengan kawalan. Anak pokok yang dirawat dengan PBZ 100 mg + BC 50 g mempunyai keluasan daun yang lebih kecil, peningkatan kandungan klorofil dan fotosintesis dan merangsang kadar transpirasi berbanding dengan anak pokok kawalan. Kandungan prolina yang lebih tinggi pada anak pokok kawalan menunjukkan anak pokok berada dalam keadaan tekanan berbanding anak pokok yang dirawat.

Kesimpulannya, BC menghasilkan keadaan anak benih yang lebih baik manakala PBZ merencat pertumbuhan anak benih dengan menyekat penghasilan GA seterusnya menghasilkan anak pokok yang padat. Anak pokok yang padat adalah mudah untuk diselenggara dan pemindahan memerlukan ruang yang kurang semasa pengangkutan. Oleh itu, anak pokok patut dirawat dengan 50 g BC dan 100 mg PBZ bagi setiap anak pokok.

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Taufiq Caesar Hidayat

I certify that a Thesis Examination Committee has met on 29 September 2015 to conduct the final examination of Taufiq Caesar Hidayat on his thesis entitled "Effects of Paclobutrazol, Biochar and Water Stress on Growth of Oil Palm (*Elaeis guineensis* Jacq.) 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

ABA	Abscisic acid
APM	Advance planting material
a.i.	Active ingredient
BC	Biochar
C	Celsius
CEC	Cation exchange capacity
cm	Centimeter
CO_2	Carbon dioxide
C/N	Carbon/nitrogen
d^{-1}	Per day
Ec	Crop evapotranspiration potential
EFB	Empty fruit bunch
Eo	Standard evapotranspiration potential
FC	Field capacity
fw	Fresh weight
g	Gram
GA	Gibberellin
ha	hectare
HPLC	High performance liquid chromatography
IOPRI	Indonesian oil palm research institute
L	Liter
LAI	Leaf area index
LSD	Least significant different
Mg	Magnesium
mg	Milligram
$mEq.g^{-1}$	Mass Equivalence per gram
mm	Milimeter
NPK	Nitrogen phosphate kalium
ns	Non significant
P	Probability
PP333	Paclobutrazol
PBZ	Paclobutrazol
pH	Potential of hydrogen
PKS	Palm kernel shell
K	Potassium
RHB	Rice hush biochar
R^2	Coefficient determination
SA	Seedling age
SAS	Statistical analysis system
ST	Seedling transplant
TC	Talcum concentrate
t/ha	Ton per hectare
WB	Wood biochar
WS	Water stress
WP	Wet powder
yr^{-1}	Per year

CHAPTER 1

GENERAL INTRODUCTION

Oil palm or scientifically known as *Elaeis guineensis* Jacq., is a species of a palm tree which is commonly recognized as African oil palm or macaw-fat. Related to its name, oil palm is native to the west and the southwest of Africa, found between Angola and Gambia. The species *guineensis* was originated from Guinea (Lubis, 2011; Paterson, 2007). From Africa, oil palm had been distributed throughout the world and becomes a major commodity in term of producing vegetables oil.

Oil palm is a highly efficient vegetable oil producer compared to other oil-bearing crops (Basiron, 2007). It occupies less land, only 0.26 ha of land to produce a ton of vegetables oil compared to soybean, sunflower and rape seed which requires 2.2, 2.0 and 1.5 ha of land, respectively (Oil World, 2013; Wahid, 2011). Thus, oil palm efficiencies are 2.5 and 3 times higher as compared to soybean and rapeseed, respectively. Due to its highly efficient vegetable oil producers, oil palm enterprise has been the most important business in the world for more than two decades (Harahap, 2009).

Many countries in Southeast Asia especially Indonesia and Malaysia chose oil palm to play a vital role in economy (Amalia, 2012; Hidayat, 2007). Nowadays, 10.2 million hectares (about 2 million hectares under immature period) of land in Indonesia is under oil palm cultivation, while 5.3 million hectares is in Malaysia (Amalia, 2015). In 2013, Indonesia and Malaysia produced 33,500,000 and 21,250,000 metric ton crude palm oil (CPO), respectively (Oil world, 2014). More than 50% of those oil palm productions have been exported. The main countries that import CPO are Japan, China, India, Europe, and the United States. CPO is used in cooking oil, vegetables oil, baking, medical care, industry and biodiesel. In fact, Netherland has started to utilize CPO as source of green electricity (Ibrahim, 2008). In conjunction with the CPO application in various field, the amount of demand was progressively increase with time.

To meet up the demand of this vegetable oil, many companies has started scaling up their plantation. However, suitable land for oil palm plantation is limited. It pushes up the development of oil palm plantation to marginal and dry land, such as in south of Sumatera, Borneo and Sulawesi in Indonesia, and Perlis in Malaysia. In consequences of this development, the supplies of plant material from nursery need to be increased. Approximately, planters have to add an average 40% of seedling for each hectare of planting area. Those extra seedling are used to cover seedling selection around 20-35% (Fairhurst and Hardter, 2010), damage during transportation 10-15% and transplanting shock 5-15 % (Turner, 2003; Yusof et al., 2000). Fairhurst and Harder (2010) suggested that in a well-maintained nursery, culling should not be more than 20%. However, if the planting material is poor or taken from a poor maintenances nursery, it is necessary to cull more than 35%. Indeed, seedlings damages during transportation become serious problem and affect overall planting cost. It could be worse for seedlings with more than 1.6 m high. However, in the search for a superior plant material, many plant breeders are working on the advance-planting material (APM). Consequently, the seedling size produced from APM is bigger than common seedling. With these seedlings, transportation could be made at only one-third capacity compared to normal seedling. Frond pruning is also required to reduce seedling transpiration during transportation. This technique is practiced to decrease seedling transportation shock. Intensity of the transplanting shock varies with planting technique and weather conditions. According to Turner (2003), a good planting material should not be damage more than 3% during transportation, except damages caused from pest, weather and other problem. However, palm trees that are planted in ideal weather conditions will be affected by transplanting shock and will get worse by uncertainty drought season which stimulates the incidence of water stress in plants (Fairhurst and Hardter, 2010). Severe transplanting shock will result in growth setback for more than six months and up to a year, or even palm death. A lot of efforts have been taken to face these problems. The right techniques of seedling handling and planting should be adopted to avoid any unnecessary growth setback to the palm. Frond pruning, pre-transportation watering, field watering, caring at loading and unloading during transportation are some of techniques that have been practiced. Consequently, the production cost rise linearly with all of those special techniques.

Plant hormones, have also been referred to as phytohormones, are a group of organic substances, naturally occurring which influence physiological processes at low concentrations (Davies, 2004). It plays a key role as a mediator between environmental signals and adaptive plant response (Ebofin, 2003).The effects of phytohormones are commonly demonstrated either by their exogenous application to a growing plant, retard plant growth or by the inhibition or exaggeration of their influence in mutant plants (Teale, 2005). One of the plant hormones that could retard growth and leaf expansion is paclobutrazol (PBZ). PBZ is a triazole that has been reported to protect plants against several environmental stresses such as drought and extreme temperature (Asare-Boamah, 1986; Fletcher, 2000; Marshall, 2000). PBZ interferes gibberellin biosynthesis by inhibiting the oxidation of ent-kaurene to ent-kaurenoic acid through inactivating cytochrome p450-dependent oxygenases (Graebe, 1987). It is also reported that PBZ stimulate the accumulation of proline in the leaves (Asare-Boamah, 1986) and responsible in controlling the stomata closure and stability of cell during drought period. The response varies depending on the type of application, doses, concentrations and plant species (Corbineau et al., 1990; Sambanthamurthi et al., 2000; Sawan, 1993; Tabur, 2009).They are several research indicated that a plant could be compacted by using PBZ such as cocoa, apple, peach, plum and mango trees (Abou et al., 1997; Blaikie et al., 2004; Kasran, 1994; Wieland and Wample, 1985). Compact plants which produced by using PBZ showed a positive result to overcome drought season (Ali and Shawn, 2010; Anonymous, 2007; Carvajal, 1998; Hashim, 1991; Latimer, 1992; Wang and Steffens, 1985). With compact seedlings, it is easy to maintain and transplant to the field (Hashim, 1991). Indeed, the function of PBZ in inducing proline would be an indication in drought tolerant effect.

Biochar is a charcoal or carbon rich by-product produced by biomass (e.g. agricultural crop residues, wood, waste, etc.) which is heated through the process of pyrolysis in an oxygen-depleted environment (Bruun et al., 2012; Denyes et al., 2012; Galinato et al., 2011; Karhu et al., 2011; Kookana et al., 2011). Attention has been received from the environmentalist to biochar because of its ability in sequestration of carbon in the soil for a long time and mitigate greenhouse gases (Galinato et al., 2011; Laird, 2010). In addition, some research has found that applying biochar to soil can increase crop yield, reduce the leaching of nutrients and stimulate soil microbial activity (Kolb et al., 2009). Some of benefits of applying biochar to agricultural soil are increasing soil pH, stabilizing solutes and nutrient ions, improved soil structure and the retention of soil moisture (Brodowski, 2006; Clough, 2010; Laird et al., 2010; Lehmann et al., 2011). Consequently, the intrinsic properties of biochar and its complex interaction with different soil types would give impact on soilï plantï microbe interactions and changes in nutrient cycle and improving crop growth. Biochar has also been reported to produce drought resistant plants (Anonymous, 2009; Barrow, 2011; Downie et al., 2009; Galinato et al., 2011; Karhu et al., 2011; Kookana et al., 2011; Lehmann et al., 2011).

Information on utilization of PBZ and biochar and their rates on growth of oil palm seedlings in the field are still lacking, especially on plant vegetative, physiological aspects, and water stress. Thus, the main objective of this study is to investigate the effects of PBZ, biochar and water stress on growth of oil palm seedlings. The specific objectives are to examine the effects of PBZ and biochar on the growth performance of oil palm seedlings in main-nursery, and to investigate growth and physiologies performance of oil palm seedling that was treated with PBZ and biochar under field water stress simulated condition.

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