UNIVERSITI PUTRA MALAYSIA

APPLICATION OF RICE HUSK BIOCHAR AS SOIL AMENDMENT FOR IMPROVEMENT OF RICE YIELD, NUTRIENT UPTAKE, SOIL PROPERTIES AND FERTILIZER NITROGEN RECOVERY

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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 of the Degree of Master of Science

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February 2017

Chairman : Rosenani Abu Bakar, PhD
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The excessive rice husk produced after each rice (*Oryza sativa*) harvesting period poses a severe threat to environmental and human health. In Malaysia, about 408, 000 Mg per annum of rice husks produced and only a small percent of rice husks is used as a source of heat energy for drying process and produced a by-product known as rice husk char (RHB). Although few studies have validated benefits of RHB application, no study regarding the RHB application effects on rice yield parameter, soil properties and fertilizer nitrogen recovery have been done in Malaysia. Thus, a field experiment was conducted in Barat Laut Selangor (BLS) at Sungai Burong, Tanjong Karang, Selangor to determine the effects of RHB on rice yield parameters and soil properties for two crop cycles. Four rates of RHB treatment 0, 5, 10 and 20 Mg ha^{-1} was laid out in RCBD with 4 replications. Soil is classified as Sulfic Endoaquepts (Sabrang series) with organic matter content of 17%. Results indicate that biochar significantly improved the soil chemical properties in general, particularly total C after second crop cycle compared to the control (without RHB). Also, N, P and K uptake was significantly ($P \leq 0.05$) improved under RHB treatment in both crop cycles. More importantly, rice grain yield also significantly ($P \leq 0.05$) increased with RHB application compared to control, with an increment of 44% in the first cycle and 45% in the second cycle. Biochar application significantly ($P \leq 0.05$) enhanced percent productive tiller, panicle length and weight per panicle in both crop cycles. A pot study was also carried out at Field 10, UPM, Serdang to investigate the effectiveness of RHB on urea nitrogen recovery under controlled condition. Results of this experiment show that RHB application although significantly ($P<0.05$) improved soil properties, shoot and root dry matter weight and nutrient uptake 75 days after application. Application of urea-N recovery in shoot was not significantly higher than control with ranged of 40.97 to 41.64% of applied N.

However, recovery of urea-N in soil was influenced only at application rate of 20 Mg ha^{-1} RHB compared to soil without RHB. Total urea-N recovery was about 60.39 to 70.20%. Overall, results of this study suggest that application of RHB as a soil amendment in rice cultivation has the potential to be an effective method for increasing rice grain yield productivity and reduce the amount of N fertilizer required for the sustainable rice production in the long-term apart than recycling rice waste. This study also indicates that RHB amended plot can still improve grain yield under drought condition. Loss of indigenous total soil C also seemed to be reduced with RHB amendment. Thus, addition of RHB into rice field may be a viable option to recycle waste back into rice field and sustain rice production. Further study, however, is needed to determine the long term effect of RHB soil amendment on rice in the BLS organic rich topsoil areas and in other rice bowl areas.

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

APLIKASI BIOCAR SEKAM PADI SEBAGAI PEMBAIKPULIH TANAH UNTUK PENINGKATAN HASIL PADI, PENGAMBILAN NUTRIEN, KONDISI TANAH DAN DAPATAN KEMBALI NITROGEN BAJA

Oleh

DENIEL ANAK SANG

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Pengeluaran sisa sekam padi yang berlebihan setiap kitaran tanaman padi (*Oryza sativa*) telah memberi impak negatif kepada persekitaran dan juga kesihatan manusia. Di Malaysia, pengeluaran sisa sekam adalah dilaporkan sebanyak 408,000 Mg per tahun dan hanya beberapa peratus sahaja yang digunakan untuk pembakaran sebagai sumber tenaga haba yang diperlukan untuk tujuan pengeringan hasil padi. Produk hasil daripada proses pembakaran dikenali sebagai biocar sekam padi (RHB). Banyak kajian yang telah dijalankan dengan menggunakan RHB sebagai pembaikpulih tanah dan menunjukkan kesan positif pengeluaran hasil tanaman serta kesuburan tanah. Namun, di Malaysia kajian kesan penggunaan RHB terhadap kesuburan tanah,pertumbuhan dan pengeluaran hasil padi masih lagi kurang. Kajian lapangan dijalankan di kawasan Sungai Burong, Tanjong Karang, Selangor untuk menentukan kesan penggunaan RHB terhadap pengeluaran hasil padi dan kesuburan tanah untuk dua kitaran tanaman. Empat jenis kadar RHB yang digunakan dalam kajian seperti 0, 5, 10 and 20 Mg ha^{-1}. Tanah di kawasan kajian diklasifikasikan sebagai Sulfic Endoaquepts (siri Sabrang) mengandungi jumlah karbon 17%. Kajian telah menunjukkan bahawa penggunaan pembaikpulih tanah di kawasan penanaman padi mampu memperbaiki sifat kimia tanah secara umum, terutama sekali jumlah C tanah selepas kitaran tanaman yang kedua, jika dibandingkan dengan rawatan kawalan. Malah, kadar pengambilan nutrien (N, P, K) meningkat dengan penggunaan RHB jika dibandingkan dengan plot yang tidak menerima rawatan. Pengeluaran hasil padi menunjukkan kesan yang positif terhadap penggunaan RHB seperti yang dibandingkan dengan kawalan, dengan peningkatan sebanyak 44% pada kitaran pertama dan 45% pada kitaran kedua. Keputusan menunjukan bahawa penggunaan RHB berpotensi sebagai cara efektif untuk meningkatkan hasil pengeluaran padi walaupun di kawasan penanaman yang mengandungi bahan organik yang tinggi serta keadaan kemarau pada kitaran tanaman kedua. Kajian di bawah rumah kaca yang terletak di Ladang 10, UPM, Serdang untuk menentukan keberkesanan RHB terhadap dapatan kembali nitrogen baja dalam persekitaran yang terkawal. Hasil

kajian menunjukkan bahawa penggunaan RHB memperbaiki sifat kimia tanah, berat kering biomass dan akar serta pengambilan nutrient. Dapatan kembali nitrogen baja dalam tanaman tidak menunjukkan peningkatan jika dibandingkan dengan rawatan kawalan dengan julat 40.97 hingga 41.64%. Walau bagaimanapun, dapatan kembali nitrogen baja dalam tanah hanya menunjukkan peningkatan pada kadar 20 Mg ha^{-1} RHB jika dibandingkan dengan rawatan kawalan. Jumlah dapatan kembali nitrogen baja keseluruhan adalah dengan julat 60.39 hingga 70.20%. Keseluruhannya, hasil kajian ini menunjukkan bahawa penggunaan RHB boleh dijadikan sebagai langkah yang efektif dalam meningkatkan pengeluaran hasil padi dan juga mengurangkan jumlah baja N yang diperlukan untuk pengeluaran hasil padi bagi jangka masa panjang selain daripada menggitar semula sisa sekam padi. Kajian ini juga menunjukkan bahawa aplikasi RHB boleh meningkatkan hasil padi walaupun pada musim kemarau. Malah, kadar kehilangan C tanah asal menunjukkan bahawa kehilangannya berkurang di bawah rawatan RHB jika dibandingkan dengan rawatan kawalan. Oleh itu, kajian lanjut diperlukan untuk menentukan kesan jangka panjang RHB terhadap pengeluaran hasil padi di BLS yang mengandungi bahan organic yang tinggi dan kawasan penanaman padi yang lain.

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I certify that a Thesis Examination Committee has met on 24 February 2017 to conduct the final examination of Deniel anak Sang on his thesis entitled "Application of Rice Husk Biochar as Soil Amendment for Improvement of Rice Yield, Nutrient Uptake, Soil Properties and Fertilizer Nitrogen Recovery" 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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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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This is to confirm that:

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LIST OF ABBREVIATIONS/NOTATIONS/GLOSSARY OF TERMS

AA	AutoAnalyzer
AAS	Atomic Absorption Spectrometer
ANOVA	Analysis of Variance
C	Carbon
Ca	Calcium
CEC	Cation exchange capacity
DAS	Days after sowing
DMWs	Dry matter weight straws
DOA	Department of Agriculture
Fe	Iron
EMS	Emission Mass spectrometer
FAO	Food and Agriculture Organization
FG	Filled grain
FTIR	Fourier transform infrared spectroscopy
GY	Grain yield
IADA	Integrated Agriculture Development Area
ICP	Inductively Coupled Plasma
K	Potassium
KADA	Kemubu Agricultural Development Authority
LSD	Least Significant Difference
Mt	Metric tonnes
$Mg\ ha^{-1}$	Mega grams per hectare
MADA	Muda Agriculture Development Authority
MARDI	Malaysian Agricultural Research and Development Institute
Mg	Magnesium
Mn	Manganese
MOA	Ministry of Agriculture
N	Nitrogen
Ndff	Nitrogen derived from fertilizer
Ndfs	Nitrogen derived from soil
NH_3	Ammonia
NH_4^+	Ammonium
NO^-_3	Nitrate
NP	Number of panicle
O.F	Organic fertilizer
P	Phosphorus
PL	Panicle length
PT	Productive tiller
r	Correlation coefficient
RH	Rice husks
RCBD	Randomized Complete Block Design
RHB	Rice husk biochar
RMK	Rancangan Malaysia ke-11
STDEV	Standard deviation
WPP	Weight per panicle
Zn	Zinc

CHAPTER 1

INTRODUCTION

In Asia, about 90% of rice production is consumed locally which provides 30%-70% of total calories intake (IRRI, 2017). Currently, with the increasing world population, rice consumption and demand has subsequently increased. As reported by Index Mundi (2016), total global rice production for 2016 was estimated at 716, 781, 000 Mt, from the total planted area of 161, 122, 000 ha. However, in Malaysia, total rice production for year 2016 was only 1820 Mt which harvested from 695, 000 ha, with an national average yield of about 4 Mg ha^{-1}. As stated by Shuanna et al., (2015), Malaysia has only achieved 72% of rice self-sufficiency but aiming for 100% by year 2020. In addition, the total rice consumption in Malaysia for the year 2014 was 2825 Mt, and 1050 Mt was required to be imported to meet the demand (Index Mundi, 2016).

Generally, rice plant is grown under two types of ecosystems, which are lowland and upland rice cultivation. In Malaysia, most of the lowland rice is cultivated in Peninsular Malaysia (76%), while 18% in Sarawak and 6 % in Sabah (Paddy Statistics of Malaysia, 2014). Upland rice in Malaysia is mainly cultivated in Sarawak and Sabah. In Peninsular Malaysia, there are eight major granary areas that are mainly distributed in west coast of Selangor, Perak, Kedah and east coast of Kelantan. Based on Paddy Statistics of Malaysia (2014), Barat Laut Selangor Integrated Agricultural Development Area (IADA BLS) has recorded the highest average yield among other granary areas, up to 6.4 Mg ha^{-1}, especially in the area with the most intensive fertilization. However, a lower yield of 4-6 Mg ha^{-1}, is obtained from small holders with lower input. This could be due to various factors that included fertilizer losses through volatilization and denitrification. This area has topsoil with high organic matter content as it used to be a wetland area before being opened for rice cultivation. The topsoil has subsided to 15-20 cm since the land was opened for rice 40 over years ago. High soil carbon was possibly lost due to decomposition of the soil organic materials as a result of continuous flooding and drying during rice cultivation. Although it has not been documented, it is expected that there are high emission of methane (CH_4) and nitrous oxide (N_2O) during flooding period and carbon dioxide (CO_2) in between cropping seasons due to high carbon substrate in the topsoil.

Recently, conversion of crop residues into biological charcoal (biochar) for application in agricultural soils has received great attention. This is attributed to the potential of biochar that act to increase soil carbon sequestration when used as a soil amendment for improvement of soil properties and crop performance. Biochar is defined as a porous carbonaceous solid product which is produced by thermochemical conversion of organic materials in an oxygen depleted atmosphere (Shackley and Sohi, 2010). Biochar can be produced from agricultural wastes such as rice husk and straw, oil palm empty fruit bunch, bamboo, wood chip, etc. Singla et al., (2014) stated that the application of biochar could help to improve soil fertility and crop productivity as well as reduce direct greenhouse gases emission. Also, it is an alternative method for waste management and for long-term storage of carbon. Furthermore, the application of biochar into agricultural soils may also directly add some nutrients to the soil and make them available to plants, especially from the ash content.

Rice husk (RH) is a major agricultural waste generated from rice milling process. The Ministry of Agriculture Malaysia (MOA) reported that more than 408,000 Mg of RH are produced annually. A fraction of the RH is used as biomass fuel to generate heat for drying the rice, resulting in production of rice husk biochar (RHB). It is also another by-product that accumulates outside the rice mills as waste. This is attributed to a series of environmental problems as this waste is not fully utilized or recycled. Several research have reported that rice grain yield increased with RHB application, for example, on acid sulfate soil in West Kalimantan, Indonesia (Masulili et al., 2010), clay loam and silt loam soil in Nanjing, China (Wang et al., 2012) and clay loam soil in Hangzhou, Zhejiang Province, China (Dong et al., 2015). Thus, the application of RHB as a soil amendment is deemed feasible, logistically, for the improvement of rice production. When not utilized RHB could be easily carried by wind and cause hazardous effect to human health. Furthermore, RHB can be recycled back to rice fields in the same area with minimum transportation cost. Currently, RHB is the main source of biochar available in Malaysia, which is produced by rice mills as a by-product. But, a small scale entrepreneur in Sekinchan, Selangor, also produces rice husk biochar for rice seedling production.

In Malaysia, research on biochar is still greatly lacking. Utilizing the abundant RHB from rice mill by applying it to the rice fields may potentially improve soil properties, nutrient uptake and rice crop yield. Thus, a study was conducted by UPM to investigate the effectiveness of RHB as a soil amendment in rice soils to improve soil properties and crop yield. Field experiments were carried out in the East Coast rice fields, on an acid sulphate soil and riverine alluvium, and in Barat Laut, Selangor. This study is part of the project and conducted in Barat Laut, Selangor which has high organic matter content in the topsoil that had undergone subsidence due to rice cultivation and C losses from decomposition process. This rice field was selected for logistic reasons, since it is the nearest rice field to Universiti Putra Malaysia. We hypothesized that RHB application helps to increase rice yield through improvement of soil properties and fertilizer nitrogen recovery on organic rich topsoil areas. The specific objectives of this study were:

1) To assess the effectiveness of RHB application on rice yield parameters, nutrient uptake and soil properties in two crop cycles;
2) To evaluate fertilizer N recovery by rice on soil amended with RHB using ^{15}N labelled nitrogen fertilizer urea, under controlled environment

A study to investigate greenhouse gas emissions from the same rice field was also carried out by another M.Sc. student.

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