UNIVERSITI PUTRA MALAYSIA

CO-COMPOSTING OF CHICKEN MANURE WITH RICE HUSK BIOCHAR AND ITS EFFECTS ON THE PERFORMANCE OF CUCUMIS SATIVUS L.

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By

THEEBA A/P MANICKAM

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the requirements for the Degree of Master of Science

December 2013

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DEDICATION

This thesis is dedicated to my beloved husband, children, parents and sisters for your unfailing support, love, care and prayers throughout my journey of completion. Without all of you this would not be possible. May god bless you all.

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

CO-COMPOSTING OF CHICKEN MANURE WITH RICE HUSK BIOCHAR AND ITS EFFECTS ON THE PERFORMANCE OF *CUCUMIS SATIVUS* L.

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December 2013

Chairman : Associate Professor Ahmad Husni bin Mohd. Hanif, PhD

Faculty : Agriculture

Rice husk biochar (RHC) in this study is a major by-product of the rice processing mill, abundantly available (estimated about 32,000 tonne/ year) and very low in cost. It is found underutilized and often paid, approximately RM8,000 annually to be disposed of by mill owners in some area especially Kelantan state. RHC was observed to increase crop growth and yield when used as polybag or potting media by farmers. However, there are inadequate detailed quantification on local mill RHC have been documented in relation to its capability in increasing crop production and soil improvement in Malaysia. This study was therefore carried out to, (i) determine physico-chemical properties of locally milled RHC, (ii) evaluate the effects of selected rates of RHC amendmend in composting process and compost properties of chicken manure and (iii) assess the effects of RHC and developed RHC compost on fruity vegetable crop production and soil properties.

RHC in this study was collected from a local mill which operates cyclone husk furnace to generate heat for rice drying activity. RHC was characterized for its physico-chemical properties such as to its particle size, ash content, nutrient contents, Methylene Blue adsorption capacity, Brunauer Emmett and Teller (BET) surface area, functional groups using FTIR and Scanning electron micrograph image (SEM). Selected RHC application rates of 5% and 10% were evaluated for its effects on chicken manure composting through determination of composting temperature and CO_2 release pattern, moisture, pH, nutrient content and microbial population. The finished compost were analysed for its leaching rates through laboratory column leaching test and the leached composts were viewed under SEM/EDX. RHC compost and fresh RHC were assessed for its efficacy through field trial on *Cucumis sativus* for two cropping cycles. The evaluation was based on crop growth and yield

performances, changes in soil physico-chemical properties, crop nutrient concentrations and crop nutrient use efficiency.

Results from the study showed that RHC is highly alkaline with pH 8.9, with a total carbon content of 16%, low bulk density of 0.17 g/cm^3, particle size < 1mm, possess moderately high surface area of 401 m^2g^{-1} with numerous meso to macropores ranging from (2.7 nm- 10 µm), presence of functional groups such as carboxylic acids and Methylene Blue adsorption capacity of 38.5 mg/g. RHC amendments at 5% and 10% was found to accelerate the composting process. The composts with RHC amendments showed early drops from the plateaued thermophilic temperature stage by 10 days supported by higher CO_2 respiration. The final RHC composts contained neutral pH characteristics (7-7.1). It was identified that higher moisture retention of 8% and 4% was obtained in the matured RHC compost 10% and RHC compost 5% respectively as compared to control. RHC was also found to minimize nitrogen loss during composting in which minimum losses of 0.4% for RHC compost 10% and 0.47% for RHC compost 5% was quantified at 10 days of composting as compared to 10.3% for compost without RHC (control). Laboratory leaching tests and SEM micrograph on RHC compost at both rates has proven that RHC does physically trapped and chemically sorb organic and inorganic molecules containing C, N, P and K and retained them against leaching losses.

Field assessment for two seasons on *Cucumis sativus* showed the plots treated with 10% RHC compost gave the highest yield in season 1 (51.2 t/ha) followed by 5% RHC compost (49.5 t/ha) and fresh RHC 3% applied into soil (49.4 t/ha). Meanwhile for season 2, the highest crop yield production was in 5% RHC compost (45.9 t/ha), followed by 10% RHC compost (45 %) and fresh RHC 3% (41 %). The yield achievement is strongly correlated with crop nutrient concentration of N, P, and K as well dry root mass which were significantly higher in plots under 5% RHC compost and 10% RHC compost and followed by fresh RHC at 3% amendment as compared to non-amended RHC compost plot. Meanwhile soil CEC, pH, water holding capacity and porosity were found the highest in plots treated with 3% RHC. Treatment of RHC 1% into soil showed lesser positive effects and plots without RHC treatment was showing significantly lowest values for crop yield, growth and changes in soil physico-chemical characteristics.

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

PENGKOMPOSAN TINJA AYAM BERSAMA ARANG-BIO SEKAM PADI DAN KEBERKESANNYA TERHADAP PERTUMBUHAN *CUCUMIS SATIVUS* L.

Oleh

THEEBA A/P MANICKAM

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Arang-bio sekam padi (RHC) dalam kajian ini, merupakan hasil sampingan utama bagi kilang pemprosesan padi, yang mana ia boleh didapati dalam kuantiti yang banyak dan harganya sangat murah. Ia didapati kurang diguna-pakai malah pemilik kilang di sesetengah kawasan khususnya di Kelantan terpaksa mengeluarkan kos untuk ia dilupuskan. Terdapat juga RHC yang diguna-pakai oleh petani khususnya di Kedah yang mana ia digunakan sebagai media semaian benih padi untuk sistem 'transplanting' dan media polibeg untuk sistem fertigasi. Namun, masih kurang terdapatnya kajian mengenai kadar penggunaan RHC dalam meningkatkan hasil tanaman dan pembaikan tanah di Malaysia. Justeru itu, kajian ini telah di rekabentuk dan dijalankan dengan beberapa objektif iaitu (i) mengkaji ciri-ciri kimia-fizik RHC tempatan, (ii) mengkaji kesan kadar campuran RHC terpilih ke atas proses pengkomposan dan ciri-ciri kompos tinja ayam dan (iii) mengkaji kesan RHC dan pembuatan kompos RHC terhadap pengeluaran tanaman sayur buah (mentimun) dan perubahan ke atas ciri-ciri kimia- fizik tanah.

RHC untuk kajian ini, diperoleh dari kilang padi tempatan yang diusahakan oleh BERNAS yang menggunakan mesin pembakaran 'Cyclone Furnace' yang menggeluarkan haba panas untuk aktiviti pengeringan padi. RHC tersebut di analisa untuk ciri-ciri kimia-fizik seperti saiz partikel, kuantiti abu, kandungan nutrien, kapasiti penyerapan 'Methylene Blue', luas permukaan BET, kumpulan berfungsi FTIR dan imej mikrograf SEM/EDX. Kadar terpilih RHC pada nilai 10% dan 5% telah diuji keberkesanannya melalui proses pengkomposan dengan tinja ayam dan semasa aktiviti pengkomposan data-data seperti suhu kompos, kadar pelepasan karbon dioksida, kelembapan, pH, kandungan nutrien dan populasi mikrob telah di ambil. Kompos matang telah dikaji untuk kandungan nutrien semasa ujian tahap larut resap di dalam makmal dan kompos tersebut diteliti di bawah SEM/EDX. Bagi kajian lapangan pula, dua rawatan iaitu Kompos RHC (dua kadar berbeza 10% dan 5%) dan RHC sahaja (3% dan 1%) diuji ke atas tanaman mentimun (*Cucumis sativus*) untuk dua musim berturut. Penilaian ujikaji adalah berdasarkan kesan ke

atas pertumbuhan tanaman, pengeluaran hasil, perubahan kimia-fizik tanah, kuantiti nutrien dalam tanaman dan keefisienan penggunaannya terhadap tanaman.

Keputusan analisa menunjukkan, RHC sangat beralkali dengan pH 8.9, kandungan karbonnya ialah 16%, mempunyai ketumpatan yang rendah iaitu 0.17 g/cm^3, saiz partikel < 1mm, dengan luas permukaan 401 m^{2}g^{-1} yang meliputi pelbagai liang meso dan makro (berukuran anggaran 2.7nm-10µm), kedapatan kehadiran kumpulan berfungsi seperti asid karboksilik dan kapasiti penyerapan 'Methylene Blue' sebanyak 38.5 mg/g. Campuran RHC pada kadar 5% dan 10% didapati boleh mempercepatkan proses pengkomposan (pematangan awal). Campuran kompos dengan RHC menunjukkan penurunan suhu awal 10 hari dari keadaan termofilik dengan dibantu peningkatan lebih tinggi kadar respirasi CO_2. Kompos matang mempunyai nilai pH yang stabil (7-7.1). Nilai kelembapan yang tinggi pada kadar 8% dan 4% di dapati pada kompos RHC yang matang 10% dan kompos RHC 5%. RHC juga diukur kadar kehilangan nitrogen semasa proses pengkomposan dengan nilai 0.4% untuk kompos RHC 10% dan nilai 0.47% untuk kompos RHC 5%, manakala 10.3% untuk kompos tanpa RHC. Sementara itu, ujikaji tahap larut resap dan imej mikrograf SEM/EDX dalam makmal juga menunjukkan kedua-dua kadar RHC menunjukkan RHC secara fizikalnya mampu memerangkap molekul dan secara kimia mampu menyerap molekul organik dan tak organik seperti C, N, P, dan K serta mengekalkannya dari hilang melalui proses larut resap.

Hasil kajian lapangan ke atas tanaman mentimun menunjukkan pada musim pertama Kompos RHC 10% mempunyai hasil pengeluaran yang tertinggi (51.2 t/ha), diikuti oleh Kompos RHC 5% (49.5 t/ha) dan RHC 3% (49.4 t/ha). Manakala pada musim ke dua hasil tertinggi didapati dari plot Kompos RHC 5% (45.9 t/ha), diikuti Kompos RHC 10% (45 t/ha) dan RHC 3% (41 %). Pengeluaran hasil didapati sangat berkaitan (korelasi positif) dengan kuantiti nutrien N, P, dan K dalam tanaman dan berat kering biomas akar yang mana ia menunjukkan nilai lebih tinggi pada plot yang menggunakan rawatan berikut mengikuti hierarki: Kompos RHC 5% > Kompos RHC 10% > RHC sahaja 3%. Namun begitu, nilai CEC tanah, nilai pH, kadar pegangan air dalam tanah dan porositi didapati tertinggi dalam plot rawatan RHC sahaja 3%. Penggunaan RHC 1% pula tidak menunjukkan peningkatan begitu signifikan berbanding dengan plot kompos tanpa RHC manakala plot rawatan kompos tanpa RHC pula mempunyai nilai kedua paling rendah untuk hasil tanaman, pertumbuhan dan perubahan dalam sifat kimia fizik tanah untuk dua musim penanaman.

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I certify that a Thesis Examination Committee has met on 24th December 2013 to conduct the final examination of Theeba a/p Manickam on her thesis entitled "Co-Composting of Chicken Manure with Rice Husk Biochar and its Effects on The Performance of *Cucumis sativus* L." in accordance with 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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Date: 13 February 2014

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

_____

THEEBA A/P MANICKAM

Date: 24 Dec 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS/NOTATIONS/GLOSSARY OF TERMS

ANOVA	Analysis of Variance
BERNAS	Padi Beras Nasional
BET	Brunauer–Emmett–Teller
CEC	Cation Exchange Capacity
CHF	Cyclone Husk Furnace
CRD	Completely Randomized Design
DMRT	Duncan Multiple Range Test
EDX	Energy Dispersive X-ray
FTIR	Fourier Transform Infrared
HCl	Hydrochloric Acid
HSD	Honestly Significant Different
ICP-OES	Inductively Couple Plasma-Optical Emission Spectrometer
ISO	International Organization for Standardization
IUPAC	International Union for Pure and Applied Chemistry
K_2SO_4	Potassium Sulphate
MB	Methylene Blue
mL	millilitre
NA	Nutrient Agar
NH_4	Ammonium
NH_4OAC	Ammonium Acetate
PDA	Potato Dextrose Agar
SAS	Statistical Analysis System
SEM	Scanning Electron Microscopy

CHAPTER 1

INTRODUCTION

In the year 2011 Malaysia's paddy production was 2,575,988 tonnes obtained from 687,516 hectares of the total rice cultivated area. The total production of milled rice was 1, 648,632 tonne which comprised about 64% of the total paddy production in nation (Department of Agriculture, 2011). The remaining 36% consist of biomass waste that was removed during the rice processing operations in the mill. Rice husk constitute 23% of the removed biomass waste (Padi Beras Nasional Berhad, 2011). Thus, it is estimated that, in 2011 alone, a total amount of 592,477 tonnes of rice husk were generated from rice milling operation.

In major rice processing mills such as BERNAS owned rice mills, the rice husks generated are utilized as fuel. They are gasified using cyclone furnace to generate heat for the rice drying activity. Rice drying is a batch process and carried out over a period of three months per annum. The cyclone furnace system produces a byproduct namely rice husk biochar (RHC) or rather widely known as rice husk black ash at a RHC recovery rate of 30%. Shackley et al., (2012) had stated that rice husk biomass is widely used as a renewable energy worldwide in developing and industrialized countries. The fuel generation is done through various processes from downdraft gasification, rapid pyrolysis to fluidized bed reactors in the rice processing mills. Beagle (1978) had done a comprehensive survey on the utilization of rice husk for energy purposes and identified gasification as one of the viable routes for effective use of rice husk for thermal and mechanical/electrical applications.

During the gasification process approximately 30 kg of rice husk biochar (RHC) are produced/ hour per rice mill from 100 kg rice husks per hour per mill at temperatures ranging from 350-600°C. A total of about 650 tonnes of RHC per mill yearly are produced. Based on the surveys done in Kedah, Kelantan, and Selangor, there are more than 50 RHC producing mills identified, thus an estimated amount of 32,000 tonne of RHC are generated in these states every year. RHC in Kelantan rice mills can be obtained free of charge up to 300kg. On the other hand, rice mill operators in Kedah and Sekinchan have started to charge approximately RM 10 for 300 kg, since RHC has potential as an efficient cropping medium. Local mill RHC shares some of the characteristics of biochar, which has been defined as the porous carbonaceous solid produced by thermochemical conversion suitable for the safe and long-term storage of carbon (Shackley and Sohi, 2010).

In Kedah, RHC are widely utilized as polybag medium and in transplanting beds for rice seedlings as it encourages high rooting capacity. On the other hand in Kelantan, RHC is paid to be disposed of by the rice mills costing approximately RM 8000 /mill/year (BERNAS, 2011). The disposal of RHC is mainly due to ineffective utilization of RHC for any beneficial purposes because Kelantan farmers normally practise direct seeding which does not make use of RHC in any way.

Through observation on farmer's crops which used RHC as media, the ability of RHC in crop improvement especially with regards to its high rooting development, water and nutrient retention was identified. Thus there is a need to further investigate the potential of RHC in retaining nutrients of fertilizers such as compost. There are some studies done on other biomass biocharcoal such as bamboo biocharcoal and wood biocharcoal that showed some properties of biocharcoal that enhanced the composting properties (Yoshizawa et al., 2007). Glaser (2007) and Glaser and Birk (2011) explained that the world's most fertile soil located at *Terra Preta* was most likely formed by the mixing of charred residues (biochar) with biogenic wastes from human settlements (excrements and food wastes including bones and ashes) which were converted by microbes to a biochar-compost-like substrate. This explains why co-composting of biochar and fresh organic material is likely to have more benefits as compared to the mixing of biochar or compost separately into soil. The benefits include, enhanced nutrient use efficiency, higher and long-term C sequestration potential, biological activation of biochar and better material flow management compared to individual compost and biochar applications (negative priming effect).

In Malaysia, composting of biomass and animal waste is being widely practised mainly as fertilizers for crop production. Currently, waste generated from chicken farms keeps increasing as a result from rapid growth of the chicken industry. Based on report by Department of Agriculture (2012), price per kg for composted chicken manure is RM 1.40 and untreated is RM 0.36. Chicken manure is still preferred and widely used by farmers as organic fertilizers as it is cheaper than other locally produced commercial organic fertilizers such as Complehumus® (RM 2.50 /kg), Wonderful Organic® (RM2.00/kg) and AmmoGold® (RM 1.40/kg). The utilization of the chicken farm waste mainly chicken manure as sources of nutrients for food crop production is becoming very important as it appears to be the most cost-effective source. However, direct applications of chicken manure onto the soil as fertilizers may cause environmental problems such as release of foul odors and may trigger pest infestations which can be minimised if chicken manure is composted. The disadvantages of composting include the inefficiency of the composting process due to nutrient losses through volatilization and leaching (Eghball et al., 1997); possible odor (Walker, 1993) equipment, labour requirement and process time. The biological transformation of chicken manure via

composting takes several weeks and may have nutrient losses through leaching during the process. Thus, it is expected that the additions of RHC will enhance the composting process and quality of compost as achieved by other studies using various types of biochars.

In summary, RHC produced by local rice mill is either a waste or low in cost and found in abundance. Most importantly, it was observed to increase crop growth and yield when used as polybag or potting medium. However, there is a lack of quantitative data on the capability of RHC to increase crop production and soil improvement in Malaysia. Apart from that there is an urgent need to increase the utilization of RHC to solve the waste disposal problem in some states by the use of RHC in composting of animal manure and as soil amendment for other crops. Therefore, a study was embarked with the following hypothesis and objectives.

Hypothesis:

Local mill rice husk biochar gives positive effects in enhancing composting process of chicken manure, improves crop production and soil physico-chemical properties

Objectives:

1. To determine physico-chemical properties of locally milled RHC.
2. To evaluate the effects of selected rates of RHC amendment in composting process and compost properties of chicken manure.
3. To assess the effects of RHC and developed RHC compost on fruity vegetable crop production and soil properties

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