UNIVERSITI PUTRA MALAYSIA

LOCALLY-PRODUCED CHICKEN LITTER BIOCHAR AS SUBSTITUTE FERTILIZER IN PROMOTING Amaranthus viridis L. GROWTH IN TROPICAL SOIL

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By

MD ROZAIDI BIN MD YUSOF

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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Chairman : Professor Ahmed Osumanu Haruna, PhD
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Environmental pollution from chemical fertilizers and healthy food awareness have created an interest in the use of organic fertilizer in agriculture. Biochar is highly recommended in agriculture as a substitute for chemical fertilizers, as biochar applications can enhance soil and crop productivity. Thus, the objectives of this study were to determine: (i) appropriate method for producing biochar from chicken litter; (ii) the effects of biochar application on growth and yield of *Amaranthus viridis* (Spinach); (iii) the effects of biochar on selected soil physical and chemical properties; and (iv) the cost-effectiveness of using biochar as organic fertilizer in the cultivation of *Amaranthus viridis*. In this study, local chicken litter biochar (LCLB) was produced using clay pots, and the concept of self-combustion was used without efficient oxygen control in the clay pots. The chicken litter was dried for a week before being combusted in the clay pots for nine hours. The biochar was collected and sieved by using 2 mm sieve to separate the ash from biochar, and finally, the biochar was ground using Retsch Cutting Mill to get a fine grade of biochar. Scanning Electron Microscopy (SEM) attached to Energy Dispersive X-Ray (SEM-EDX JEOL JSM-6400) was used to determine surface morphology and elemental composition of the biochar. Standard procedures were also used to determine the selected chemical properties of the biochar. The selected chemical properties of the LCLB were compared with those of a commercial chicken litter biochar (CLB) from Black Earth, Australia (as a standard). Both biochars were high in pH due to their alkaline organic functional groups such as carboxyl, phenol, and alcohol, which were deprotonated to the conjugate base. The total organic C of CLB was 10.5% higher than that of LCLB. The CEC of the CLB and LCLB were 80.51 ± 0.12 and 75.45 ± 0.17 cmol kg^{-1}, respectively. Total N of the two biochars were low due to the gasification of N during combustion. Total K of the two biochars were high, indicating that, they are the ideal source for K. Phosphorous, Zn, and Cu contents of LCLB were higher than those of CLB. Field assessment of the biochars for two cropping trials of *Amaranthus viridis* showed that they improved soil pH, EC, P, K, Ca, and Mg. In the first planting cycle, LCLB and CLB improved nutrient uptake. In the first field trial, the plots with CLB at five tons ha^{-1} showed the highest yield (13.44 tons ha^{-1}), followed by six tons ha^{-1} of CLB with a yield of 12.68 tons ha^{-1}, and four tons ha^{-1} of CLB with a yield of 12.11 tons ha^{-1}. In contrast, at five, six, and four tons ha^{-1} of LCLB, the yields of *Amaranthus viridis* were 12.33, 11.73, and 11.32 tons ha^{-1}, respectively. These results revealed that five tons ha^{-1} of CLB and LCLB produced the optimum yield of *Amaranthus viridis* as the yields of the two at five tons ha^{-1} were significantly higher than the existing chemical fertilization. However, heavy rainfall and flood during the second planting season decreased the effectiveness of the biochars in improving the yield of *Amaranthus viridis* due to nutrient losses through runoff and leaching. Economic viability for using the biochars in *Amaranthus viridis* cultivation showed that the use of LCLB is economically viable, based on the B/C ratio of 10.98 indicates that every RM 1 invested will yield a capital return of RM 9.98 with a net profit of RM 171,774.15 per ha greater than the net earnings for CLB (RM 64,326.15) and inorganic fertilization (RM 39,157.65). The findings of this study suggest that locally produced chicken litter biochar (LCLB) can be used to improve soil productivity and the economic yield of *Amaranthus viridis*. Five tons ha^{-1} of LCLB is the optimum rate for optimum yield. The implication of this is that LCLB can be used to replace inorganic fertilization in *Amaranthus viridis* cultivation, and it can promote the growth of the plant as good as imported biochar and thus will provide the farmer with higher net profit. Several trials could be carried out to consolidate the findings of this present study.

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

BIOARANG TINJA AYAM PENGHASILAN TEMPATAN SEBAGAI PENGGANTI BAJA BAGI MENGGALAKKAN PERTUMBUHAN *Amaranthus viridis* L. DI TANAH TROPIKA

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Pencemaran alam sekitar daripada baja kimia dan peningkatan tahap kesedaran terhadap makanan yang sihat telah menimbulkan minat terhadap penggunaan baja organik di dalam pertanian. Bioarang telah disyorkan dalam pertanian sebagai alternatif kepada baja kimia, kerana penggunaan bioarang dapat meningkatkan kesuburan tanah dan produktiviti tanaman. Oleh itu, objektif kajian ini adalah untuk menentukan: (i) kaedah yang sesuai untuk pengeluaran bioarang yang dihasilkan daripada tinja ayam; (ii) kesan penggunaan bioarang kepada pertumbuhan dan penghasilan *Amaranthus viridis* (bayam); (iii) kesan bioarang terhadap sifat fizikal dan kimia tanah; dan (iv) keberkesanan kos menggunakan bioarang sebagai baja organik dalam penanaman *Amaranthus viridis*. Dalam kajian ini, bioarang tinja ayam yang dihasilkan sendiri (LCLB) telah dihasilkan dengan menggunakan pasu tanah liat, dan konsep pembakaran sendiri telah digunakan tanpa kawalan oksigen yang cekap di dalam pasu tanah liat. Tinja ayam telah dikeringkan selama seminggu sebelum dibakar di dalam pasu selama sembilan jam. Bioarang yang telah terhasil kemudiannya dikumpulkan dan ditapis dengan menggunakan penapis 2 mm untuk memisahkan abu daripada bioarang, dan akhirnya, bioarang tersebut telah dihancurkan dengan menggunakan Retsch Cutting Mill untuk mendapatkan gred bioarang yang halus. Pengimbasan Mikroskopi Elektron (SEM) dan Tenaga Dispersive X-Ray (SEM-EDX JEOL JSM-6400) telah digunakan untuk meneliti morfologi permukaan dan komposisi elemen bioarang. Analisis kimia juga telah dilakukan dengan menggunakan prosedur piawai untuk mengenalpasti sifat kimia yang terpilih bagi bioarang. Perbandingan komposisi kimia telah dibuat diantara LCLB dan bioarang tinja ayam komersil (CLB) daripada Black Earth, Australia (sebagai piawai). Kedua-dua bioarang ini didapati tinggi dalam pH disebabkan oleh komponen alkali yang terdapat dalam kumpulan berfungsi organik seperti karboksil, fenol, dan alkohol, yang telah dipecahkan kepada asas konjugasi. Jumlah organik C bagi CLB lebih tinggi sedikit daripada LCLB sebanyak 10.5%. CEC bagi CLB dan LCLB masing-masing adalah

80.51 ± 0.12 cmol kg^{-1} dan 75.45 ± 0.17 cmol kg^{-1}. Jumlah kepekatan N bagi kedua-dua bioarang adalah rendah, menunjukkan bahawa N telah meruap semasa proses pembakaran. Jumlah K dari kedua-dua bioarang adalah sangat tinggi, yang menunjukkan bahawa bahan ini sesuai untuk menjadi sumber K. Fosforus, Zn, dan Cu dalam bioarang yang dihasilkan secara local (LCLB) adalah lebih tinggi daripada bioarang komersil (CLB). Hasil daripada penilaian di ladang selama dua pusingan penanaman *Amaranthus viridis* telah menunjukkan bahawa pH tanah, EC, P, K, Ca, dan Mg telah meningkat dengan kenaikan kadar penggunaan terhadap kedua-dua bioarang. Penggunaan CLB dan LCLB juga mempunyai kesan yang signifikan terhadap pengambilan nutrien tumbuhan dalam musim penanaman yang pertama. Dari segi hasil, plot yang dirawat dengan CLB pada kadar lima tan ha^{-1} telah memberikan hasil yang tertinggi dalam musim yang pertama (13.44 tan ha^{-1}), diikuti oleh kadar enam tan ha^{-1} (12.68 tan ha^{-1}), dan kadar empat tan ha^{-1} (12.11 tan ha^{-1}). Sementara itu, hasil terbaik untuk plot yang dirawat dengan LCLB adalah 12.33, 11.73, dan 11.30 tan ha^{-1} dengan kadar lima, enam dan empat tan per hektar masing-masing. Ini menunjukkan bahawa penggunaan bioarang pada kadar lima tan ha^{-1} telah menunjukkan prestasi pengeluaran hasil yang tertinggi dalam kedua-dua kajian. Walau bagaimanapun, hujan lebat dan banjir semasa musim penanaman yang kedua telah mengakibatkan pengurangan kandungan nutrien di dalam tanah, akibat larutlesap, yang turut menjejaskan hasil tanaman. Kajian terhadap penilaian ekonomi bagi penanaman bayam secara organik telah mendapati bahawa penggunaan LCLB adalah ekonomik dan berdaya maju berdasarkan nisbah B/C iaitu 10.98 yang menunjukkan bahawa setiap RM 1 yang dilaburkan akan menghasilkan pulangan modal sebanyak RM 9.98, dan keuntungan bersih yang dihasilkan adalah RM 171,774.15, lebih besar daripada keuntungan bersih yang dicatatkan oleh penggunaan CLB (RM 64,326.15) dan kaedah penanaman secara konvensional (RM 39,157.65). Hasil kajian telah menunjukkan bahawa bioarang daripada tinja ayam yang dihasilkan secara lokal ini boleh digunakan untuk meningkatkan produktiviti tanah dan pengeluaran hasil yang ekonomik bagi *Amaranthus viridis* dengan menggunakan lima tan ha^{-1} LCLB sebagai kadar optimum untuk hasil yang optimum. Implikasinya adalah bahawa bioarang tinja ayam yang dihasilkan secara lokal boleh digunakan untuk menggantikan baja kimia dalam penanaman *Amaranthus viridis* dan juga ia boleh menggalakkan pertumbuhan tanaman dengan kualiti yang setanding dengan bioarang yang diimport, dan dengan itu akan dapat memberikan pulangan dan keuntungan yang lebih tinggi kepada petani. Beberapa kajian boleh dilakukan untuk menyatukan penemuan kajian ini.

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I certify that a Thesis Examination Committee has met on 12 December 2019 to conduct the final examination of Md Rozaidi bin Md Yusof on his thesis entitled "Locally-Produced Chicken Litter Biochar as Substitute Fertilizer in Promoting *Amaranthus viridis* L. Growth in Tropical Soil" 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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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
BEP	Break Even Point
CEC	Cation Exchange Capacity
CLB	Commercialized Biochar
DAS	Day After Sowing
LA	Leaf Area
LAI	Leaf Area Index
LCLB	Locally Produced Biochar
PGPR	Plant Growth Promoting Rhizobacteria
SAS	Statistical Analysis System
TOC	Total Organic Carbon
TOM	Total Organic Matter

CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statement

The agriculture sector has played an imperative role in the growth of Malaysia and simultaneously makes a significant impact on the domestic economy. Department of Statistics Malaysia (2018a) reported that the contribution of the agriculture sector to the Malaysian Gross Domestic Product (GDP) was 8.2% (RM96 billion) in 2018 with a growth of 0.1% as compared to the preceding year. The Malaysian government's strategy for agriculture is to aim at improving crops production to achieve food self-sufficiency as well as to create exports effectively and competitively (Economic Planning Unit, 2015). The active development and intensification of cultivation have also led to an increasing need for the use of agricultural inputs efficiently, especially chemical fertilizers.

In sustaining high crop yield and to as well enhance the quality of crops, the use of chemical fertilizers is a critical component. However, improper use of fertilizers does not only waste limited resources, but it also increases the cost of production besides polluting the environment (Yusof et al., 2015). Moreover, degraded agricultural soils that are acidic, infertile, and requiring many synthetic chemical fertilizers, further exacerbate the crisis of decreasing crop yield. Therefore, proper soils management and sustainable crop production system are necessary to solve this issue.

Sustainable agriculture is an agriculture that is ecologically sound, economically viable, and it conserves resources such as soil, ground and surface water, minerals, and biodiversity (Nandwani, 2016). It also provides the needs of the present generation without compromising the ability of future generations to meet their needs. It is crucial to care for soil health and the ecosystem to sustain agricultural productivity (Laffan, 2016). Sustainable crop production is only possible when the natural resources based on which the production activity depends on are not eroded or harmed in any manner (Tiraieyari et al., 2014). Therefore, organic agriculture is the best alternative in sustaining agricultural productivity.

Organic agriculture is necessary for the sustainable use and management of natural resources (Nandwani, 2016). Organic farming is gaining importance due to environmental and health-related concerns (Stockdale et al., 2002). The use of organic fertilizers as an alternative to chemical fertilizers in Malaysia is essential to move towards more natural and healthier food productions. Increasing demand for green food products is evident with increasing public sensitivity of health as well as the need to deal with climate change (KeTTHA, 2010). An approach towards justifying such concerns is by improving soil fertility and nutrient management through the use of biochar.

Biochar has been proposed to aid in increased agricultural productivity due to some of its positive attributes. Biochar is a carbon material that is pyrolyzed under controlled conditions from sustainably obtained biomass and used for any intent that does not involve rapid CO_2 mineralization (European Biochar Certificate, 2003). It is a valuable material for long-term sustainable farming as it increases the sequestration of soil C, promotes soil fertility, and decreases greenhouse gases (Jeffery et al., 2015). It could also increase crop productivity directly because of its nutrient content, which is released timely for optimum plant uptake (Lehmann et al., 2003). Biochar's large surface area and porous structure provide a habitat for beneficial soil microorganisms, which enhances plant rhizosphere that can stimulate soil biological activity (Lehmann et al., 2011). Due to its high pH and alkalinity, biochar may be used as a liming material. An increase in pH can provide a wide range of benefits in terms of soil quality, notably by improving the chemical availability of plant nutrients, and in some cases, it reduces the availability of harmful elements such as Al and Fe (Brady and Weil, 2008).

Biochar offers great potential as an organic fertilizer for crops, as it creates sustainability in agricultural practices and production. It will render biochar as a valuable organic input under the green technology initiative which is currently being actively promoted by the Malaysian government. Thus, the underlying hypothesis of this study was to explored if the abundant chicken litter in Malaysia could properly be utilized as locally produced biochar in the cultivation of vegetables, particularly the economic yield of *Amaranthus viridis* L. (Spinach) without using any inorganic fertilizer.

1.2 Objectives

The objectives of this study were to determine:

1. Appropriate method for producing biochar from chicken litter.
2. The effects of biochar application on growth and yield of *Amaranthus viridis* (Spinach).
3. The effects of biochar on selected soil physical and chemical properties.
4. The cost-effectiveness of using biochar as organic fertilizer in the cultivation of *Amaranthus viridis.*

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BIODATA OF STUDENT

Md Rozaidi bin Md Yusof originated from Kluang, Johor. He received his primary education from Sekolah Kebangsaan L.K.T.P Ayer Hitam, Johor. After completing his secondary school education at Sekolah Menengah Datuk Menteri, Ayer Hitam, Johor, he was registered as a student of Matriculation Science at Kolej Islam YPJ, Johor, under Universiti Putra Malaysia franchise program from 1998 to 1999. Md Rozaidi pursued his undergraduate first degree at UPM from 1999 to 2002 where he was awarded Bachelor Science of Bioindustry. After graduated, he was appointed as an Agriculture Officer at University Agriculture Park, Universiti Putra Malaysia. He is a part of the managerial team of University Agriculture Park with the position as a Head of Division for Seedling Productions and Hatchery. Based on the working performances and experiences, he has been offered a scholarship by UPM to pursue his master's degree in the year 2013. His research interests relate to agricultural waste management through the thermochemical biomass decomposition to produce biochar and its use for soil and plant improvement in a sustainable crop production system. In the year 2016, he has won a silver medal in Invention and Innovation Award 2016, at Malaysia Technology Expo. During the same year, a gold medal has been awarded to him in Pameran Rekacipta, Penyelidikan dan Inovasi 2016 at Universiti Putra Malaysia. In the year 2019, he was awarded with 'Anugerah Perkhidmatan Cemerlang' from Universiti Putra Malaysia.

PUBLICATION

Papers Published or Submitted

Md Rozaidi Md Yusof, Osumanu Haruna Ahmed, Wong Sing King, and Zakry Fitri Abd. Aziz. 2015. Effects of biochar and chicken litter ash on selected soil chemical properties and nutrients uptake by *Oryza sativa* L. var. MR 219. International Journal of Biosciences Vol. 6 (3): 360-369.

List of Awards

1. Silver medal, "Biological agriculture to improve crops productivity without polluting the environment". Invention and Innovation Awards 2016. Malaysia Technology Expo 2016 on 18 – 20 February 2016. Putra World Trade Centre, Kuala Lumpur.

2. Gold medal, "Improving rice yield using activated humic substances". Pameran Rekacipta, Penyelidikan dan Inovasi 2016 on 15 – 16 November 2016, Dewan Besar, Pusat Kebudayaan dan Kesenian Sultan Salahuddin Abdul Aziz Shah, UPM Serdang, Selangor.

3. Anugerah Perkhidmatan Cemerlang, Majlis Gemilang Putra dan Sambutan Hari Pekerja 2019 on 3 May 2019. Dewan Besar, Pusat Kebudayaan dan Kesenian Sultan Salahuddin Abdul Aziz Shah, UPM Serdang, Selangor.