UNIVERSITI PUTRA MALAYSIA

RESPONSE OF KENAF (Hibiscus cannabinus L.) CULTIVATED ON A BRIS SOIL TO APPLICATION OF CHARCOAL AND FERTILIZER

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By

MALISA BINTI MAT NOOR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

December 2014

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

RESPONSE OF KENAF (*Hibiscus cannabinus* L.) CULTIVATED ON A BRIS SOIL TO APPLICATION OF CHARCOAL AND FERTILIZER

By

MALISA MAT NOOR

December 2014

Chairman: **Associate Professor Hamdan Jol, PhD**

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Kenaf (*Hibiscus cannabinus* L.) was first introduced for commercial production in the East Coast Economic Region (ECER) program by Malaysian government in 2004. Although the production of kenaf in Malaysia was initially meant for animal feed, the demand has increased as research has shown that the plants' fiber is also compatible as material for car components, furniture and food packaging. The arising variability of kenaf-made products resulted in higher demand of kenaf fiber. However, there are constraints in optimizing the production of kenaf as the information on kenaf cultivation on sandy BRIS (Beach Ridges Interspersed with Swales) soils is scarce.

Over the years, charcoal has been proved to significantly enhanced soil properties and increased plant growth. Its' recalcitrant characteristics are appropriate for tropical soils' organic matter management. Amending charcoal into BRIS soils could be a suitable measure in dealing with concerns regarding fertilizer losses due to excessive leaching process, which inadvertently leads to low yield production.

A field study was conducted in Kg. Saujana, Setiu, Terengganu (05° 61393' N, 102° 73928' E) from April until July 2010 to assess kenaf response to the application of charcoal and fertilizer cultivated on BRIS (Rudua Series) soil. Five rates of NPK fertilizer (0, 0.2, 0.4, 0.6 and 0.8 t ha^{-1}) and four rates of charcoal (0, 5, 10 and 15 t ha^{-1}) with five replications were established with Factorial Randomized Complete Blocked Design (RCBD) on BRIS (Rudua Series) soil. The objectives of this study were to determine the chemical properties of charcoal, to determine effects of charcoal amendment on BRIS (Rudua series) soil as well as to determine the effect of charcoal and fertilization on kenaf growth and yield. Plants were maintained for 64 days and data on kenaf were categorized into yield (dry matter, biomass of aboveground plant and biomass of root) and growth components (heights, stem base diameter, leaf number, leaf length and leaf width). Soil sampling for determination of soil chemical properties were conducted on 30 and 64 days after planting (DAP). All data were analyzed using ANOVA of Minitab 17 for Windows and mean separation was conducted using Tukey test.

In addition to field study, a leachate experiment was also conducted at the same study area to determine the effectiveness of charcoal application in reducing nutrient losses by controlling leaching process in the soil. Four rates of charcoal (0, 1, 2 and 3 kg pot^{-1}) were mixed into pots containing 10 kg of BRIS (Rudua Series) soil each. Three

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hundred (300) g of fertilizer was applied into all pots excluding control. Leachate collection was based on rain intensity and analyzed for nitrogen (N) and potassium (K) content. All data were analyzed using ANOVA of Minitab 17 for Windows and mean separation was conducted using Tukey test.

Results obtained revealed that rates of charcoal and fertilizer significantly affected ($p \leq 0.05$) dry matter yield as well as fresh and dry biomass of kenaf. There were no significant differences ($p \geq 0.05$) found in all growth components. Significant differences ($p \leq 0.05$) were also found in nutrient content and nutrient use efficiency of kenaf plant tissue. Nitrogen (N), phosphorus (P) and potassium (K) content in plant tissue were significantly affected ($p \leq 0.05$) by both single and interaction between charcoal and fertilizer factors. Significant effects ($p \leq 0.05$) of single factor were observed in content of calcium (Ca) and magnesium (Mg). Both single and interaction between charcoal and fertilizer rates gave significant effects ($p \leq 0.05$) on N, P and K use efficiency in this study. Significant effects ($p \leq 0.05$) of interaction between charcoal and fertilizer rates were observed in soil total N, cation exchange capacity (CEC) and exchangeable Ca. Sampling times significantly affected ($p \leq 0.05$) values of soil pH_w, total N and available P. As for leachate experiment, there was no significant difference ($p \geq 0.05$) in N and K content resulted from charcoal application. However, sampling times did significantly affected ($p \leq 0.05$) the N content in collected leachate.

Based on the results obtained from the study, it was concluded that charcoal had the potential as one of the sustainable amendments to BRIS (Rudua Series) soil in the respected area. The suitable combination rates of application for BRIS (Rudua Series) soil at the respected study site appeared to be at 10 t ha^{-1} charcoal and 0.6 t ha^{-1} fertilizer. Application of charcoal did significantly ($p \leq 0.05$) enhanced the chemical properties of BRIS (Rudua Series) soil in the respected area. However, application of charcoal into soil should be conducted at least 2 months prior to planting for it to show positive effects on the soil. Results obtained from Study 2 revealed that application of charcoal into soil did not significantly ($p \geq 0.05$) reduced the losses of N and K from the soil.

Keyword: charcoal, BRIS soils, kenaf, yield, fertilizer

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

RESPON KENAF (*Hibiscus cannabinus* L.) TERHADAP APLIKASI ARANG DAN BAJA PADA TANAH BRIS

Oleh

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Pengerusi: **Professor Madya Hamdan Jol, PhD**

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Kenaf (*Hibiscus cannabinus* L.) telah diperkenalkan buat pertama kalinya sebagai tanaman komersial dalam program Ekonomi Daerah Pantai Timur (ECER) oleh kerajaan Malaysia pada tahun 2004. Walaupun pengeluaran kenaf di Malaysia pada awalnya bertujuan sebagai makanan ternakan, terdapat peningkatan terhadap permintaan semenjak penyelidik mengesahkan bahawa fiber tanaman ini sesuai dijadikan bahan dalam pembuatan komponen kereta, perabot dan pembungkusan makanan. Peningkatan kepelbagaian produk berasaskan kenaf membawa kepada peningkatan permintaan terhadap fiber kenaf. Bagaimanapun, terdapat sekatan dalam mengoptimakan pengeluaran kenaf memandangkan informasi berkaitan penanaman kenaf di tanah BRIS adalah terhad.

Sejak beberapa lama dahulu, arang telah terbukti mampu menambahbaik sifat-sifat tanah dan pertumbuhan tanaman. Sifatnya yang sukar diuraikan adalah sangat bersesuaian dengan pengurusan bahan organik di negara beriklim seperti di negara kita. Penggunaan arang dilihat sesuai dalam usaha mengurangkan kehilangan baja akibat proses larutlesap yang berlebihan.

Satu kajian lapangan telah dijalankan di Kg. Saujana, Setiu, Terengganu (05 61393'N, 102 73928'E) bermula April sehingga Julai 2010 bagi menilai respon kenaf terhadap penambahan arang dan kadar NPK hijau yang berbeza di tanah BRIS (siri Rudua). Rawatan terdiri daripada lima kadar baja (0, 0.2, 0.4, 0.6 and 0.8 t ha^{-1}) dan empat kadar arang (0, 5, 10 dan 15 t ha^{-1}). Terdapat lima replikasi dan aturan statistik yang digunakan adalah Randomized Complete Blocked Design (RCBD) di tanah BRIS (Siri Rudua). Objektif kajian ini adalah bagi menentukan sifat kimia arang, kesan aplikasi arang ke dalam tanah BRIS (Siri Rudua) dan kesan aplikasi arang serta baja ke atas pertumbuhan dan hasil kenaf. Tanaman diselenggara selama 64 hari dan data kenaf dikategorikan kepada hasil (berat kering, berat tanaman dan berat akar) dan komponen tumbesaran (tinggi, diameter batang, bilangan daun, panjang daun dan lebar daun). Persampelan tanah bagi penentuan sifat kimia tanah dijalankan pada hari ke-30 dan hari ke-64 selepas penanaman dilakukan. Analisis data dijalankan menggunakan ANOVA daripada perisian Minitab 17 untuk Windows dan pisahan purata dijalankan menggunakan kaedah Tukey.

Selain daripada itu, satu eksperimen larutlesap juga telah dijalankan di kawasan yang sama bagi menentukan keberkesanan aplikasi arang dalam mengurangkan kehilangan

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nutrien dengan cara mengawal proses larutlesap di dalam tanah. Empat kadar arang (0, 1, 2 and 3 kg pot^{-1}) digaulkan bersama 10 kg tanah BRIS (Siri Rudua) di dalam setiap bekas. Sebanyak 300g baja dicampurkan ke dalam setiap bekas kecuali bekas kawalan. Pengumpulan larutan larutlesap dijalankan berdasarkan kadar taburan hujan dan dianalisa bagi mendapatkan kandungan nitrogen (N) dan kalsium (K). Analisis data dijalankan menggunakan ANOVA daripada perisian Minitab 17 untuk Windows dan pisahan purata dijalankan menggunakan kaedah Tukey.

Data yang diperolehi menunjukkan bahawa kadar arang dan baja member kesan secara bererti ($p \leq 0.05$) terhadap hasil, berat basah dan berat kering tanaman kenaf. Tiada kesan secara bererti ($p \geq 0.05$) ditunjukkan oleh semua komponen tumbesaran. Kesan secara bererti ($p \leq 0.05$) turut ditemui pada kandungan nutrien dan kecekapan penggunaaan nutrien (KPN). Faktor tunggal dan kombinasi kadar arang dan baja member kesan secara bererti ($p \leq 0.05$) terhadap kandungan nitrogen (N), fosforus (P) and kalium (K) dalam tisu kenaf. Faktor tunggal dan kombinsai faktor member kesan secara bererti ($p \leq 0.05$) terhadap nilai KPN bagi N, P dan K. Kesan secara bererti ($p \leq 0.05$) oleh kombinasi dua faktor dikesan pada nilai N tanah, kadar pertukaran kation (KPK), dan nilai kalsium boleh ubah (Ka). Masa persampelan member kesan secara bererti ($p \leq 0.05$) terhadap nilai pH_w tanah, jumlah N dan P tersedia. Bagi eksperimen larutlesap, tiada kesan secara bererti ($p \geq 0.05$) dikesan pada nilai N dan K. Bagaimanapun, terdapat kesan secara bererti ($p \leq 0.05$) pada nilai kandungan N hasil daripada masa pengumpulan yang berbeza.

Berdasarkan keputusan yang diperoleh daripada kajian, kesimpulan yang boleh dibuat adalah arang mempunyai potensi untuk menjadi salah satu penambahbaik bersifat mampan terhadap tanah BRIS (Siri Rudua) in kawasan tersebut. Kombinasi terbaik kadar aplikasi adalah 10 t ha^{-1} arang and 0.6 t ha^{-1} baja. Aplikasi arang telah dilihat dapat memberi kesan secara bererti ($p \leq 0.05$) dalam peningkatan sifat kimia tanah BRIS (Siri Rudua) di kawasan kajian. Bagaimanapun, aplikasi arang ke dalam tanah perlu dilakukan sekurang-kurangnya dua bulan sebelum penanaman dijalankan bagi mendapatkan hasil yang baik. Keputusan daripada Kajian 2 menunjukkan bahawa aplikasi arang ke dalam tanah tidak memberi kesan secara bererti ($p \geq 0.05$) dalam usaha mengurangkan kehilangan N dan K daripada tanah.

Kata kunci: arang, tanah BRIS, kenaf, hasil, baja

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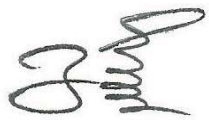

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LIST OF ABBREVIATIONS

AA	Auto- Analyzer
AAS	Atomic Absorption Spectrometer
BRIS	Beach Ridges Interspersed with Swales
C	Carbon
CEC	Cation Exchange Capacity
DAP	Days after planting
d.f.	Degree of Freedom
ECER	East Coast Economic Region
EXCHANG.	Exchangeable
LTKN	Lembaga Tembakau dan Kenaf Negara / National Tobacco and Kenaf Board
MARDI	Malaysia Agricultural Research and Development Institute
NEAC	National Economic Action Council
OM	Organic Matter
P. Malaysia	Peninsular Malaysia
SOM	Soil Organic Matter

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CHAPTER 1

INTRODUCTION

1.1 Background

The National Economic Action Council (NEAC) in 2001 stated that kenaf has a good potential to be a commodity crop. Kenaf *(Hibiscus cannabinus* L.) originated from east-central Africa has the potential to become a commodity crop in Malaysia. This crop has been cultivated for food and fiber, fiber strands, protein, oil and allelophatic chemical products (Webber and Bledsoe, 2002). Currently, there are about 200 farmers in Kelantan and Terengganu involved in the planting of kenaf for core, fiber and seed productions (Borneo Post, 2008). The yield of kenaf ranges from 18 to 35 ton ha yr^{-1} (MARDI, 2008).

Under the East Coast Economic Region (ECER) program, kenaf has been recommended as a substitute crop for tobacco. The area of tobacco planting is generally on BRIS (Beach Ridges Interspersed with Swales) soils. It was estimated that total area of BRIS soils is around 155,400 hectares in Peninsular Malaysia (Esnan et al., 2004). However, only 5 to 6% of these soils are utilized.

BRIS soils are classified based on their profile morphology and chemical properties (Roslan et al., 2011). Some series of BRIS soils are Rudua, Rusila, Rhu Tapai, Baging, and Jambu Series. BRIS soils composed of more than 95% sand with less than 3% silt and clay (Aminah et al., 2006). Sandy (BRIS) soils pose a critical challenge for water and nutrient management due to low water holding and nutrient retention capacities of these substrates (Pathan et al., 2003). They also experience excessive nutrient leaching, low organic matter content and high surface soil temperature (Niazuddin et al., 2005).

The application of various organic matter amendments has proved to improve the fertility of this soil (Othman et al., 1992). As reported by many researchers, organic matter application into the soil resulted in higher water and nutrient retention, besides enhancing the nutrient contents in the soil. Apart from that, application of organic matter also resulted in higher microbial activity, which induces the fertility of the soil. However, under humid Malaysia tropical condition, organic matter tends to decompose very rapidly. As a result, the positive effects of fertilizer and organic matter applied to the soil only last for a short period.

Application of chemical fertilizer is also crucial in order to establish and maintain the growth of kenaf. Nitrogen (N), phosphorus (P) and potassium (K) are major elements required for growth and optimum yield of kenaf. Application of N and K led to longer, thicker stems and higher fiber yield of the crop (Ivanyi and Izsaki, 2009). Due to occurrence of extensive leaching process and high increment of chemical fertilizers price, an effective management should be implied in order to reduce the losses of applied fertilizers. Thus, by retaining the fertilizer losses, this method will not only enable us to enhance the fertility of the soil, but also helps in reducing cost for fertilizer supplement.

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Charcoal is one of the alternatives of organic amendment to BRIS soils. The unique characteristics of charcoal lead to its' ability to last longer than any other organic amendment. The application of a mixture of manioc peel and charcoal (Topoliantz et al., 2005) is a highly potential organic amendment that can be applied in the tropics. Charcoal amendment to the infertile BRIS soil is a simulation to the "Terra Preta" phenomenon which may result in a sustainable agriculture in the humid tropics (Glaser et al., 2001).

1.2 Problem statement

The total area of BRIS soils that is utilized for agricultural practices in Peninsular Malaysia is small, despite the large potential of the area development. This is due to severe problems encountered in managing the soils, such as excessive nutrient leaching and lack of organic matter (OM) or soil organic matter (SOM) content. The poor properties of BRIS soils also resulted in losses of fertilizer applied as it tends to be leached out before being consumed by plants. Current management practice of BRIS soils is by adding various types of organic matter into the soils. Chicken dung, cow dung and composts are common examples of organic matter applied in crop production on BRIS soils. However, due to humid tropical condition, these OM tend to mineralize at fast rate which directly shortening the period of lasting effects of these amendments. Thus, there is a need to find an alternative soil amendment towards BRIS soils fertility management. In order to overcome this problem, an alternative management practice or amendments is crucial. Since the main problem is regarding the rapid decomposition of OM applied, black carbon is considered as one of the best solutions in overcoming this matter. The recalcitrant characteristic of it is desired, as it is not only able to last longer, but also able to promote the fertility of soils. Besides that, charcoal is capable of improving water holding capacity of soil. This desired characteristic of charcoal can be the solution to the excessive leaching process and pollution of soil water. Apart from that, as kenaf has been introduced as a substitute crop for tobacco, there is a need to come up with an appropriate management practice in order to optimize the kenaf crop production. At this time, the information of kenaf production on BRIS soils is limited. The findings from this study may provide additional information for farmers to improve kenaf yield cultivated on BRIS (Rudua Series) soil.

1.3 Objectives of the study

This research consisted of two studies which were (1) cultivation of kenaf on BRIS (Rudua Series) soils and (2) pot experiment of leachate collected from charcoal amended BRIS (Rudua Series) soils. The objectives of study (1) were to determine the chemical properties of charcoal, to determine effects of charcoal amendment on sandy soil chemical properties and to study effect of charcoal and fertilization on kenaf yield and growth, while study (2) was conducted with a single objective of determining the

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efficiency of charcoal amendment in reducing leaching activity on BRIS soils by analyzing collected leachate.

1.4 Scope of study

This study focused on enhancing the fertility of BRIS (Rudua Series) soil and optimizing kenaf yield by amending charcoal as source of black carbon. The experiment was conducted in the field in order to obtain results that are significant for farmers' benefits. There is also a need of conducting research regarding economic effectiveness of soil management using charcoal. This study was carried out with the hope that it will benefits farmers whom currently cultivating kenaf crops and consequently more BRIS soils will be developed for kenaf crop production.

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