UNIVERSITI PUTRA MALAYSIA

AMELIORATION OF A SANDY BRIS SOIL USING CondiSoil™ FOR CULTIVATION OF KENAF (Hibiscus cannabinus L.)

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

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DEDICATION

Especially to whom their love and support is behind the
fulfillment of this study:
My father, Akinbola Miftaudeen
My mother, Akinbola Badirat
My brothers and sisters,
My fiancee, Olowoyo Hamdalah
My friends,
Thank you and I love you all

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

AMELIORATION OF A SANDY BRIS SOIL USING CondiSoil™ FOR CULTIVATION OF KENAF (*Hibiscus cannabinus* L.)

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Chairman : Mohamed Hanafi Musa, PhD
Institute : Tropical Agriculture and Food Security

Soil fertility management is a pre-requisite for successfully growing kenaf in marginal soil. 'CondiSoil' is a soil amendment, formulated and patent filed by Lynas Malaysia Sdn Bhd., a rare earths mining and processing company in Malaysia. Hence, the objectives of this study were: (i) to determine the effect of different pH on dissolution of CondiSoil in a sandy beach ridges interspersed with swales (BRIS) soil using an open leaching system and (ii) to evaluate the effect of CondiSoil on growth performance and yield of kenaf cultivated on BRIS soil. For the dissolution experiment, 'CondiSoil' made of Water Leach Purification (WLP), Neutralization Underflow (NUF) residue and composted oil palm empty fruit (EFB) was applied to the BRIS soil in the column. The dissolution of 'CondiSoil' was measured in an open-leaching system using leaching solutions of different pH (1.2, 3.6, 4.6, 5.6 and 8.8) values. For the second experiment, a field trial was conducted at the experimental site of Ladang Kenaf, Taman Industri Teknologi Terengganu (TITT), National Kenaf and Tobacco Board (LKTN), Merang, Setiu, Terengganu. Two kenaf varieties 'KB6' (season 1) and 'V36' (season 2) were planted on BRIS soil applied with CondiSoil at the rate of 28 tons ha^{-1} in combination with a full (500 kg ha^{-1}) and a half rate of recommended NPK fertilizer. The following treatments combination were used: (i) no CondiSoil + NPK (T_1) (control); (ii) CondiSoil + NPK (T_2); (iii) no CondiSoil + ½ NPK (T_3) (control); and (iv) CondiSoil + ½ NPK (T_4). In the second season, the treatments were split into with and without irrigation system. The growth and yield parameters were measured at growing stage and yield at harvest, respectively. The result of CondiSoil dissolution revealed that, most of the elements studied (P, Ca, Mg, Mn and Al) tend to be leached in higher concentrations in the earlier days, and gradually reduced by days, irrespective of the pH of leachant. Among the five leaching solutions used, there were significant differences ($\alpha = 0.05$) in the cumulative quantity of

phosphorus (P) dissolved at pH 1.2, 3.6 and 4.6 with the highest mean of 57.63 mg dissolved at pH 1.2. Considering the amount of 'CondiSoil' applied, only 66.2% (P), 73.5% (Ca) and 44.9% (Mg) was dissolved by pH 1.2 and 3.6 leachants at the end of the leaching studies (30-day). The results of field trial revealed that highest number of leaves, height growth, biomass for root, leaf, bast and core fibre of kenaf were obtained in T_2, plot treated with CondiSoil + NPK, for both seasons; followed by T_1, while T_3 gave the poorest result. The results revealed that treatments do not have effect on the number of plants per hectare. Besides, further increase in NPK significantly lead to increased growth and biomass. Application of irrigation due to insufficient rainfall experienced in the pre-planting season did not have impact on the yield in the season 2, because of heavy downpour that was later experienced in the growing period. The dissolution characteristics of most elements from 'CondiSoil' studied in first experiment depend on the pH of the leaching solution. Only 0.5 and 0.3% of Th and Sr element, respectively was able to dissolve and leach at the end of 30 days. The field trial study reiterates the fact that additional amendments is needed for BRIS soils in Malaysia to yield better in terms productivity of any plant being grown on it due to the poor fertility level of the soil.

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

PEMBAIKAN TANAH BERPASIR BRIS DENGAN MENGGUNAKAN CondiSoil™ UNTUK PENANAMAN KENAF (*Hibiscus cannabinus* L.)

Oleh

AKINBOLA SHEU TIJANI

Januari 2020

Pengerusi: **Profesor Mohamed Hanafi Musa, PhD**
Institut: **Pertanian Tropika dan Keselamatan Makanan**

Pengurusan kesuburan tanah adalah prasyarat untuk pertumbuhan kenaf di tanah marginal. 'CondiSoil' adalah pembaiktanah, dirumus dan dipatenkan oleh Lynas Malaysia Sdn Bhd, syarikat perlombongan dan pemprosesan nadir bumi di Malaysia. Oleh yang demikian, objektif kajian ini adalah: (i) untuk menentukan kesan pH yang berlainan terhadap penglarutan CondiSoil pada tanah pantai berpasir yang dikenali sebagai BRIS dengan menggunakan sistem penglarutan terbuka dan (ii) untuk menilai kesan 'CondiSoil' terhadap prestasi pertumbuhan dan hasil kenaf yang ditanam di tanah BRIS. Dalam kajian menggunakan kaedah larut lesap, 'CondiSoil' yang diperbuat daripada Pemurnian Larut Resap Air (WLP), residu Peneutralan Aliran Masuk (NUF) dan kompos dari tandan kosong buah kelapa sawit (EFB) telah diaplikasikan kepada tanah BRIS di dalam kolum. Penglarutan 'CondiSoil' diukur dalam sistem terbuka dengan menggunakan larutan-larutan pH yang berbeza (1.2, 3.6, 4.6, 5.6 dan 8.8). Untuk kajian kedua, percubaan lapangan telah dilakukan di tapak percubaan Ladang Kenaf, Taman Industri Teknologi Terengganu (TITT), Lembaga Kenaf dan Tembakau Kebangsaan (LKTN), Merang, Setiu, Terengganu. Dua varieti kenaf 'KB6' (musim 1) dan 'V36' (musim 2) telah ditanam di tanah BRIS yang dirawat dengan CondiSoil pada kadar 28 tan ha^{-1} dengan gabungan penuh (500 kg ha^{-1}) dan separuh kadar baja NPK yang disyorkan. Kombinasi rawatan berikut telah digunakan: (i) tiada CondiSoil + NPK (T_1) (kawalan); (ii) CondiSoil + NPK (T_2); (iii) tiada CondiSoil + ½ NPK (T_3); dan (iv) CondiSoil + ½ NPK (T_4). Pada musim kedua, rawatan telah dibahagikan kepada dengan dan tanpa sistem pengairan. Parameter pertumbuhan dan hasil telah diukur masing-masing pada peringkat pertumbuhan dan hasil penuaian. Keputusan kajian larut lesap menunjukkan bahawa kebanyakan unsur yang dikaji (P, Ca, Mg, Mn dan Al) cenderung terlarut dalam kepekatan yang lebih tinggi pada hari-hari awal, dan secara beransur-ansur

berkurangan selepas itu, tanpa mengira pH larutan. Antara lima jenis larutan yang digunakan, terdapat perbezaan yang signifikan ($\alpha = 0.05$) dalam kuantiti kumulatif fosforus (P) yang dibebaskan pada pH 1.2, 3.6 dan 4.6 dengan min tertinggi 57.63 mg dibebaskan pada pH 1.2. Pada akhir kajian (30 hari), sebanyak 66.2% (P), 73.5% (Ca) dan 44.9% (Mg) dibebaskan oleh larutan pH 1.2 dan 3.6 berbanding dengan jumlah unsur-unsur yang ada dalam 'CondiSoil'. Hasil percubaan lapangan menunjukkan bahawa jumlah tertinggi daun, tinggi, biomas akar, daun, bast dan serat teras kenaf diperoleh dalam T_2 iaitu plot dengan CondiSoil + NPK yang dirawat untuk kedua-dua musim; diikuti dengan T_1, sementara T_3 memberikan hasil yang paling rendah. Hasil kajian menunjukkan bahawa rawatan tidak mempengaruhi jumlah tanaman per hektar. Selain itu, pertambahan NPK membawa kepada peningkatan ketara pertumbuhan dan biomas. Penggunaan sistem pengairan kerana taburan hujan yang tidak mencukupi ketika musim pra-penanaman tidak memberi kesan kepada hasil pada musim 2, karena hujan lebat yang kemudian dialami pada masa pertumbuhan. Pembebasan kebanyakan unsur dari 'CondiSoil' bergantung kepada pH larutan. Hanya 0.5 dan 0.3% daripada unsur-unsur Th dan Sr, masing-masing dapat dibebaskan pada akhir 30 hari. Kajian ini mengulangi fakta bahawa rawatan pembaikan diperlukan untuk tanah BRIS di Malaysia untuk menghasilkan hasil yang lebih baik dari segi produktiviti tumbuhan yang ditanam di atasnya kerana tahap kesuburan tanah yang rendah.

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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: 10 December 2020

Declaration by graduate student

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
AELB	The Atomic Energy Licensing Board
ANOVA	Analysis of Variance
ATP	Adenosine Triphosphate
BRIS	Bridge Ridges Interspersed with Swales
CEC	Cation Exchange Capacity
DNMRT	Duncan's New Multiple Range Test
DOA	Department of Agriculture
DoE	Department of Environment
EC	Electrical Conductivity
EFB	Empty Fruit Bunch
ICAP-MS	Inductively Coupled Argon Plasma Mass Spectrometry
IPNI	International Plant Nutrition Institute
LAMP	Lynas Advanced Materials Plant
LKTN	Lembaga Kenaf dan Tembakau Kebangsaan
MARDI	Malaysian Agricultural Research and Development Institute
NKTB	National Kenaf and Tobacco Board
NPK	Nitrogen Phosphorus Potassium
NUF	Neutralization Underflow Residue
POME	Palm Oil Mill Effluent
PVC	Poly Vinyl Chloride
RIA	Radiological Impact Assessmant
SAS	Statistical Analysis System
SD	Standard Deviation
SIRIM	Standard and Industrial Research Institute of Malaysia
TEOC	Trace elements of concern
TITT	Taman Industri Teknologi Terengganu
WLP	Water Leach Purification

CHAPTER 1

INTRODUCTION

1.1 Background

One of the eco-friendly crops for commercial exploitation in Malaysia is kenaf, scientifically known as *Hibiscus cannabinus* L. In order to reduce the number of Malaysians who smoke, the Malaysian government is now encouraging the farmers to plant kenaf instead of tobacco (Roslan et al., 2010). Cultivation of kenaf in Malaysia is still new and the yield has yet to reach the potential due to cultivation of kenaf in low fertility soil type, such as the beach ridges interspersed with swales (BRIS) soil.

The kenaf industry, which has been developed in Malaysia since 2000, is still facing a number of challenges, which include high production costs, low productivity, non-availability of efficient technology for large scale production, and agricultural management practices especially in BRIS soil. This is due to the fact that majority of tobacco plant was cultivated on a sandy BRIS soil. Therefore, there is need for continuous research on the possibility of increasing the performance and yield of kenaf, by amending the low fertility BRIS soil with soil amendment, such as the 'CondiSoil'.

CondiSoil is a soil amendment, formulated and patent filed by Lynas Malaysia Sdn Bhd, a rare earths mining and processing company, located in Gebeng Industrial Areas, Gebeng, Kuantan, Pahang, Malaysia. This formulation contains the mixture of Water Leach Purification (WLP), Neutralization Underflow Residue (NUF) and composted oil palm empty fruit bunch in a ratio of 1: 2: 7. The WLP and NUF is a by-products derived from Lynas Advanced Materials Plant (LAMP) factory. Various mining by-products have a potential to be used as soil amendments and sources of nutrients and may have other potential benefits regarding soil properties and plant growth (Gherardi and Rengel, 2003). The magnesium rich properties and other chemical properties contained in these materials can be used to condition low fertility agricultural soil, and to rejuvenate and rehabilitate unproductive soil, such as the sandy BRIS soil.

The soils found on the ridges of beach are commonly called BRIS soils due to the distribution in the coastal landscape and the nature of their properties. The BRIS soil is a sandy marine deposit and known as problematic soil in Malaysia, and lacks many important physical and chemical properties (Mohd-Ekhwan et al., 2009). Most of the crops grown on BRIS soils do not yield well due to the high infiltration rate and high surface soil temperature,

low nutrients availability, organic content, and water holding capacity of the soil (Hanafi et al., 2010; Akbar Basri et al., 2013). The coastal areas of Kelantan and Terengganu are mostly dominated by BRIS soils, which is a challenge for farmers. The BRIS soil is found in the east coast of Peninsular Malaysia, with 17,806.2 hectares in Kelantan, 67,582.61 hectares in Terengganu, and 36,071.17 hectares in Pahang up to the west coast of Johor (Mohd-Ekhwan et al., 2009). The BRIS soil was reported to have been characterized by mineral quartz which is categorized into diverse soil series, such as Rudua, Baging, Rusila and Rhu Tapai (Roslan, 2010), while Aminah et al. (2006) reported BRIS soil to have been characterized by over 95% sand with less than 3% silt and clay. There was no information on the use of CondiSoil to improve the fertility of BRIS. Hence, the aim of this study was to examine the possibility of enhancing the performance of kenaf planted on low fertility sandy BRIS soil.

1.2 Objectives of study

The specific objectives of this study include the following:

i. To determine the effect of different pH on dissolution of CondiSoil in BRIS soil using an open leaching system.
ii. To determine the effect of CondiSoil on growth performance and yield of kenaf cultivated on BRIS soil.

1.3 Significance of study

CondiSoil is selected for use in agricultural practices because it contains a great amount of gypsum and liming materials, and other essential nutrients, such as phosphorus (P), calcium (Ca) and magnesium (Mg), which are very productive to the crop. The liming materials and gypsum in CondiSoil help to reduce the acidity of BRIS soil, especially due to the presence of calcium (Ca) and magnesium (Mg). At the time of this research, WLP and NUF which are components of CondiSoil are free of charge, these materials were collected at Lynas Advanced Materials Plant (LAMP) factory, Pahang. Thereby, justifying experimenting a trial research on it, due to a possible economic benefit of using this material as soil amendment, as production cost is expected to be reduced. The concern on the radioactive contents and heavy metal pollution of these materials (WLP and NUF) may be an issue, however, NUF had been researched and contained no radioactivity. On the other hand, WLP contained a low level radioactivity measured at 6200 Bq kg^{-1}, as reported by RIA (2011), but radioactivity in sample used in this studies had been initially removed at LAMP, before the commencement of this research. Yet, these aforementioned concerns shall be assessed and confirmed after the experiment.

The leaching studies conducted on CondiSoil-BRIS mixture was necessary to ascertain the release of elements in CondiSoil, especially at different soil pH, as there was no previous information related to this. Having information on the release of elements in CondiSoil at different soil pH, will therefore, project how plant roots would uptake nutrients released by CondiSoil when used to grow plant, such as kenaf as was experimented in experiment two of this study.

Combining organic matter amendments with NPK will produce high and sustained crop yield (Kang and Balasubramaniam, 1990; Palm et al., 1997; and Makinde et. al., 2001). This complementary use of amendment and minerals absolutely will improve the management strategy for soil fertility in many countries of the world (Lombin et al., 1991).

This study will have many benefits for local farmers and researchers especially economic benefits. The NUF increases soil pH and can replace dolomitic limestone as Ca or Mg, or kieserite as Mg source. While, WLP also contains 25-50% iron phosphate, and can be a source of P fertilizer. Plantation of kenaf in BRIS soil will provide employment opportunities and increase the disposable income of tobacco farmers. Moreover, because of application of amendments, the soil become fertile and increases the growth performance of the plant. Kenaf growing will enable the developer to provide greater socio-economic value to the states and will serve as an important economic activity in the agricultural sector.

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BIODATA OF STUDENT

Akinbola Sheu Tijani was born at Agege, Lagos State, western Nigeria on September 13, 1987. He received his early education at Ojodu Abiodun Community Primary School, Ogun State. In September 2000, he started as a secondary school student in Ojodu Abiodun Community High School, Ogun State. After completion in 2006, he successfully passed the West African Senior School Certificate Examination (WASSCE), receiving excellent grades in all subjects registered for, he then registered and successfully passed the University Matriculation Examination (UME) conducted by The Joint Admissions and Matriculations Board (JAMB), a Nigerian entrance examination board for tertiary-level institutions. Then in September 2006, he enrolled his undergraduate study to earn a bachelor of agricultural technology at the Federal University of Technology Akure (FUTA), where he embarked on a study related to agriculture, specifically, Crop, Soil and Pest Management. He enrolled in undergraduate studies for 5 years and graduated as the best graduating student in the department with upper second class honours in September 2011. In 2012, he then proceeded to embark on National Youth Service Corps, a compulsory 1-year national scheme for Nigerian graduates. In 2013, he was employed on a 1-year contract as a teaching assistant at the Federal University of Technology Akure (FUTA). Between the year 2014 and 2016, he engaged in many other skilled works and services, including working as an ad hoc staff for Independent National Electoral Commission (INEC) as assistant Presiding Officer during 2015 Nigerian Presidential Election. In September 2016, he was registered as self-sponsored fulltime student in the masters of science program at the Universiti Putra Malaysia, Serdang, Selangor. At the moment of this submission, he is currently working on publishing some of his research papers and findings in international journals.

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