UNIVERSITI PUTRA MALAYSIA

EFFECT OF MAGNESIUM RICH SYNTHETIC GYPSUM APPLICATION ON ULTISOL PROPERTIES AND GROWTH OF OIL PALM SEEDLINGS

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By

AROLU FATAI AYANDA

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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DEDICATIONS

This work is dedicated to Almighty God and my parents for their unwavering support

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

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August 2017

Chairman: Shamshuddin Jusop, PhD
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Oil palm cultivation in Malaysia is mainly on the acidic Ultisols and Oxisols, which are highly weathered with low fertility. Despite the problem of low soil productivity, the good physical makeup of the soil makes them suitable for sustainable oil palm cultivation.

This study consisted of two parts. The first study was a field work conducted in an oil palm plantation at Bera, Pahang, in an attempt to classify the dominant soil types in the area and to determine their suitability for oil palm cultivation. The second study was a glasshouse trial at Universiti Putra Malaysia using oil palm seedlings planted in polybags, containing Ultisols collected the oil palm plantation. For the field study, a soil pit was dug for profile description on soil morphological characteristics, and samples were collected based on genetic horizons for analyses. Only one soil series was identified in the area under study. The main objective of this study was to evaluate the performance of magnesium rich synthetic gypsum (MRSG) obtained from a rare earth refining company in Malaysia (Gebeng, Pahang) as a potential magnesium source in fertilizer programme for sustainable oil palm cultivation in Malaysia.

The soil under study was formed under tropical environment with udic moisture regime on fine-grained sedimentary rocks, mixed with tuffs of Permian age. The soil in the area was reddish in colour, clayey, deep and highly weathered. The clay fraction of the soil was dominated by kaolinite, gibbsite, goethite, and hematite; thus, the plant nutrient status of the soil is low. The exchangeable aluminium in the soil was low, although the soil has an acidic reaction in water. Taxonomically, the soil was classified as Clayey Kaolinitic, isohyperthermic, Typic Paleudult due to its colour and the presence of diagnostic argillic horizon in the B-horizon (Bt). From the results of this study, it was deduced that the inherent soil properties in the field situation had no significant limitation for oil palm cultivation; hence, with proper agronomic practices, the area can be utilized for sustainable oil palm cultivation.

In meeting up with the world demand for oil palm products, the industry needs to sustain high productivity. This requires regular application of high amount of fertilizers, one of which is Mg-fertilizer.

A glasshouse study for 9 months, using oil palm seedlings, was conducted to examine the effectiveness of MRSG as a source of Mg for oil palm cultivation. In this study, plant performance, nutrient uptake, soil chemical characteristics, and population of soil microbes in comparison with other Mg fertilizer sources, such as ground magnesium limestone (GML) and kieserite ($MgSO_{4}.7H_{2}O$) were determined. The experimental design was Randomized Completely Block, with 7 treatments and 6 replications, the treatments were: T1- NPK without source of Magnesium; T2 - NPK + Kieserite at standard rate; T3 - NPK + GML at standard rate; T4 - NPK + MRSG at the recommended rate; T5 - NPK + MRSG at one-half the recommended rate; T6 – NPK + MRSG at double the recommended rate; T7 - NPK+ MRSG to equivalent amount of Ca in GML. Soil parameters at 0, 3, 6 and 9 months measured were pH, EC, exchangeable cations, carbon, nitrogen, sulphur and selected micronutrients, while the plant parameters were growth traits, fresh and dry biomass of the seedlings root and above ground portion, macronutrients (Ca, Mg, P, and K) and micronutrient (Zn and Mn).

Results showed that there were significant responses among soil to treatments; Treatment (T7) containing 36 gram of Mg i.e MRSG applied at double the recommended rate of magnesium required by oil palm seedlings showed the highest increase of soil pH (6.82), exchangeable calcium (1.52 $cmol_{c}$/ kg), magnesium (0.59 $cmol_{c}$/ kg) and total sulphur (0.07 %) in the soil, while the above-measured parameters were lowest in control. The exchangeable aluminium of the soil was low as soil pH under field condition was above 5. GML treatment (T3) was able to increase soil pH that helped enhance oil palm growth. It was found that kieserite ($MgSO_{4}.7H_{2}O$) treatment had a significant effect on soil fertility, especially in terms of increase in exchangeable magnesium and total sulphur.

It was found that MRSG treatments (T4, T5, T6 and T7) had positive effect on soil fertility, shown by the increase in exchangeable Mg, Ca and soil pH. MRSG application did not have negative effect on microbial activities in the soil. Due to the improved soil fertility, the growth of the oil palm seedlings in terms of height, bole diameter, chlorophyll index and root performance was as good as those planted on soil treated with GML or kieserite. As such, Magnesium rich synthetic gypsum can replace kieserite as Mg source for immature oil palm cultivation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebangai memenuhi keperluan untuk ijazah master sains

KESAN PENGGUNAAN APLIKASI GYPSUM MAGNESIUM RICH SYNTHETIC PADA HARTANAH ULTISOL DAN PERTUMBUHAN MINYAK KELAPASAWIT

Oleh

AROLU FATAI AYANDA

August 2017

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Majoriti pokok kelapa sawit di Malaysia ditanam di kawasan tanah sangat berasid dan terluluhawa dan dengan mengamalkan amalan pertanian yang sangat baik, industri ini telah menghasilkan pengeluaran dalam kuantiti yang besar untuk pasaran ekspot. Penanaman kelapa sawit di Malaysia kebanyakannya dijalankan di tanah Ultisol dan Oxisol yang berasid, terluluhawa dan mempunyai tahap kesuburan yang rendah. Walaupun menghadapi masalah produktiviti yang rendah, pengurusan fizikal yang baik menjadikan tanah tersebut mapan untuk pengeluaran kelapa sawit.

Kajian ini terdiri daripada dua bahagian. Kajian pertama adalah kajian lapangan di lading kelapa sawit di Bera, Pahang bertujuan mengklasifikasi jenis tanah dominan di kawasan terbabit dan menetukan kesesuaiannya dalam penanaman kelapa sawit. Selain itu, pembentukan (genesis) tanah di kawasan tersebut perlu diperincikan. Kajian kedua adalah kajian rumah kaca di Universiti Putra Malaysia dengan menggunakan anak pokok kelapa sawit yang ditanam dalam polibeg, menggunakan tanah Ultisols daripada lading kelapa sawit di Bera. Bagi kajian di lapangan, satu pit tanah digali untuk tujuan deskripsi profil ke atas sifat-sifat morfologi, dan sampel diambil berdasarkan ufuk genetik bagi analisis. Hanya satu siri tanah yang dikenal pasti terdapat di kawasan kajian tersebut. Objektif utama kajian ini adalah bagi menilai keberkesanan *magnesium rich synthetic gypsum* (MRSG) yang diperoleh daripada sebuah tapak pemprosesan bahan kimia di Malaysia (Gebeng, Pahang) sebagai bahan yang berpotensi menjadi sumber magnesim dalam program pembajaan untuk pengeluaran kelapa sawit mapan di Malaysia.

Tanah yang digunakan dalam kajian ini terbentuk dalam persekitaran tropika dengan rejim kelembapan udic pada batu sedimen halus, bercampur dengan batuan gunung berapi pada zaman Permian. Disebabkan oleh pendedahan kepada suhu tinggi dan hujan lebat berterusan sepanjang pembentukannya, tanah di kawasan tersebut berwarna

kemerah-merahan, liat, dalam dan terluluhawa. Pecahan liat tanah didominasi oleh kaolinite, gibbsite, goethite dan hematite; mengakibatkan kandungan nutriennya rendah. Aluminium tukarganti dalam tanah adalah rendah, walaupun tanah tersebut memberikan tindakbalas berasid dalam air. -Ia tergolong dalam dalam kumpulan kaolinite lempung, isohipertermik, typic paleudult.

Secara taksonomi, tanah di kawasan kajian diklasifikasikan sebagai Ultisol kerana warna dan kehadiran ufuk diagnostik argilik pada horizon B (Bt). Tanah jenis ini biasa ditemui di Semenanjung Malaysia di mana tanaman kelapa sawit tumbuh dengan baik. Berdasarkan hasil kajian, disimpulkan bahawa sifat tanah di lapangan tidak mengakibatkan kekangan kepada penanaman kelapa sawit, dan dengan amalan agronomi yang betul, kawasan tersebut boleh digunakan bagi penghasilan kelapa sawit secara mapan.

Sebagai tanaman komersil terbesar di Malaysia, penanaman kelapa sawit meluputi 50% tanah. Nabi memenuhi keperluan dunia dalam pengeluaran minyak kelapa sawit dan bagi mengukuhkan kedudukan Malaysia sebagai salah sebuah negara pengeluar minyak kelapa sawit terbesar dunia, industri ini perlu penghasilan tinggi berterusan. Ini memerlukan pembajaan pada kadar tinggi secara berkala dan salah satunya adalah baja Mg.

Satu kajian di rumah kaca dijalankan selama 9 bulan, menggunakan anak pokok kelapa sawit bagi menguji keberkesanan MRSG sebagai sumber Mg bagi pertumbuhan kelapa sawit. Dalam kajian ini, pertumbuhan tanaman, pengambilan nutrien, sifat kimia tanah dan populasi mikrob berbanding baja Mg yang lain seperti GML dan kieserite ($MgSO_4$) telah dijalankan.

Eksperimen ini dijalankan menggunakan susunatur Randomized Completely Block. Terdapat 7 rawatan dengan 6 replikasi. Rawatan tersebut terdiri daripada T1- NPK tanpa sumber Magnesium; T2- NPK+ Kieserite dengan kadar standard; T3- NPK + GML dengan kadar standard; T4-NPK+ MRSG dengan kadar yang disyorkan; T5- NPK+ MRSG (1/2 dari kadar standard); T6- NPK+ MRSG(dua kali ganda dari kadar standard); T7- NPK+ MRSG (kadar yang sama dengan Ca yang terdapat dalam GML). Parameter tanah yang diuji pada 0, 3, 6 dan 9 bulan adalah Ph, EC, kadar tukarganti kation, karbon, nitrogen, sulfur, and mikronutrient tertentu. Parameter tanah yang diukur adalah pH, EC, kation tukarganti, karbon, nitrogen, sulfur dan mikronutrien terpilih, manakala parameter tanaman yang ditentukan adalah trait pertumbuhan, berat basah dan kering akar dan bahagian atas tumbuhan, makronutrien (Ca, Mg, P dan K) serta mikronutrien (Zn dan Mn).

Hasil kajian menunjukkan rawatan T7 yang mengandungi 36 gram Mg memberikan respon positif yang signifikan kepada tanah.dalam peningkatan pH, kalsium tukarganti, magnesium dan sulfur tertinggi. Nilai terendah bagi kesemua parameter tersebut adalah daripada rawatan kawalan. Nilai aluminium dalam tanah adalah rendah memandangkan nilai pH tanah di kawasan ladang adalah melebihi Oleh itu, ketoksikan Al tidak menjadi satu ancaman kepada pertumbuhan kelapa sawit di kawasan terbabit. Rawatan

GML mampu meningkatkan pH tanah dan meningkatkan pertumbuhan kelapa sawit. Didapati bahawa kieserite memberi kesan signifikan terhadap kesuburan tanah, terutama dalam penignkatan nilai magnesium dan sulfur.

Didapati bahawa MRSG memberikan kesan positif terhadap kesuburan tanah, dengan peningkatan nilai Mg, Ca dan nilai pH. Selain itu, aplikasi MRSG tidak mendatangkan kesan negatif terhadap aktiviti mikrob di dalam tanah. Hasil penambahbaikan kesuburan tanah, pertubuhan anak pokok kelapa sawit adalah sebaik yang ditanam pada tanah yang dicampur GML atau kieserite. Oleh itu, MRSG dapat menggantikan kieserite sebagai sumber Mg, di mana ia merupakan satu kaedah dalam pengurangan kos penghasilan minyak kelapa sawit.

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I certify that a Thesis Examination Committee has met on 24 August 2017 to conduct the final examination of Arolu Fatai Ayanda on his thesis entitled "Effect of Magnesium Rich Synthetic Gypsum Application on Ultisol Properties and Growth of Oil Palm Seedlings" 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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LIST OF ABBREVIATIONS

AA	Auto-analyzer
AAS	Atomic absorption spectrophotometer
Al	Aluminium
ANOVA	Analysis of variance
As	Arsenic
Avail.p	Available Phosphorus
Ca	Calcium
CEC	Cation exchange capacity
Chl	Chlorophyll
CNS	Carbon Nitrogen Sulphur
Cu	Copper
FFB	Fresh Fruit Bunches
GML	Ground magnesium limestone (dolomite)
Ha	Hectare
HSD	Honest significant difference
ICP-OES	Inductively coupled plasma optical emission spectroscopy
K	Potassium
Mg	Magnesium
MgO	Magnesium oxide
Mn	Manganese
MRSG	Magnesium rich synthetic gypsum
N	Nitrogen
P	Phosphorus
Pb	Lead
RCBD	Randomized complete block design
RDW	Root dry weight
RT SURF	Root Surface
RT LENG	Root Length
RT TIP	Root Tip
RT VOL	Root Volume
SDW	Shoot dry weight
Tons/ha/yr	Tonnes per hectare per year
XRD	X-ray Diffraction
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 General Introduction

In Malaysia, Ultisols and Oxisols are very common especially in the upland areas occupying about 72 % of the country's land area. These soils contain kaolinite, gibbsite, goethite, and hematite in the clay fraction. The soils are very highly weathered due to their existence under tropical environment with high rainfall and temperature throughout the year, resulting in leaching of plant nutrients and accumulation of sesquioxides (Anda et al., 2008). The soils by nature are devoid of basic cations (Ca and Mg) and available P (due to fixation by the oxides) and hence, their productivity is generally considered as low. The soils are mainly utilized for oil palm cultivation with great success due to excellent soil management practices which ensures that essential macro nutrients required for normal plant growth that is deficient is provided. One of such essential nutrient required for crop growth and yield development is magnesium.

The vast majority of Malaysian acid soil is low in exchangeable magnesium and is inadequate for optimum plant performance (Shamshuddin et al., 1991). Mg-fertilizer (kieserite) is rather expensive, adding cost to oil palm production. Magnesium is an essential nutrient whose function in activation of enzymes for energy metabolism surpasses that of other mineral elements (Azham, 2003).

Several hundreds of enzymes require magnesium in other to function. Magnesium is an essential nutrient elements needed in oil palm for yield and development. It is an integral constituent of plant chlorophyll, thereby playing important role in photosynthesis; the outstanding photosynthetic capacity of oil palm makes it an efficient oil-producing crop. Magnesium also increases water and nutrient uptake, promoting a better nutrient-use-efficiency, transport of phosphate in the plant (Jones, 1979). The importance of magnesium in oil palm is such that Mg deficiency leads to fresh fruit bunch yield reduction; this can be attributed to disruption of various metabolic activities in plant. Interruption of protein synthesis, oil formation and reduction in starch accumulation are examples of essential metabolic activities disruption that accompany magnesium deficiency (Fairhurst and Hadter, 2003).

Magnesium deficiency symptoms are most commonly caused by inadequate uptake and/or availability of Mg, but may also be caused as a result of imbalance between Mg, and other cations (Rankine and Fairhurst, 1999). The relationship between magnesium, calcium, and potassium is antagonistic (Tinker and Smilde, 1963; Hagstrom, 1997), such that excess supply of these nutrients may cause a reduction in magnesium uptake by plant roots due to competition among the nutrients (Foster, 1986).

The oil palm requires large amounts of nutrients to sustain its growth and production so that high yield levels of 30 t/ha/year or more can be achieved and maintained. With the expertise available in the country, palm oil are produced in large amounts for the world .The problem of low productivity resulting from this nutrient deficiency in oil palm has made fertilizer use indispensable in oil palm cultivation (Goh and Hadter, 2003). The importance of fertilizers in oil palm cultivation cannot be over emphasized (Foster et al., 1986). Oil palm has an outstanding photosynthetic capacity which makes it an efficient oil producing crop. Oil palm constitutes about 84% of fertilizer nutrient consumption by industrial crops in Malaysia (Mohamed Ali Sabri, 2009). Oil palm seedlings are usually raised in a nursery where they are subjected to optimal growing conditions and given adequate care due to their susceptibility to pest and disease attack, and also mechanical damage (Piggot, 1990). Cost of seedlings production is high due to fertilizer cost.

As such, it makes a lot of sense to look for an alternative source of Mg. That is where magnesium rich synthetic gypsum (MRSG) comes in. It is a by-product obtained from an industrial process in the refining of rare earth in Gebeng, Pahang, which can be used to supply magnesium instead of using kieserite. MRGS contains about 73% gypsum ($CaSO_4.2H_2O$) and has high content of magnesium, calcium and sulphur, the macronutrients needed by oil palm during its growth.

Currently, research on MRSG application in oil palm cultivation is still lacking. In this study, MRGS plays a role as a source of Mg for oil palm seedlings. Investigation on growth performance of oil palm seedlings in soil treated with MRGS was determined in comparison those treated with kieserite or GML. Effects of MRSG application on the growth performance of oil palm seedlings had been investigated.

1.2 Problem Statements

Fertilizer is one of the most important inputs in the cultivation of oil palm, accounting for about 40% production cost (MPOB, 2016). About 90% of fertilizers in Malaysia are imported. Global economic crisis causing the depreciation of the Malaysian Ringgit against the US dollars results in significant increase in the prices of imported fertilizers. In recent years, the country spends high amount on purchase of Mg fertilizer (MPOB, 2009). The increase in price of kieserite and the dependence of Malaysia on a few global players (producers and exporters) who possess sufficient market power in terms of fertilizer price determination (Jamal and Yaghoob, 2014) has made it imperative to evaluate the locally available source to be used as fertilizer against the imported Mg-fertilizer in terms of their performance and cost effectiveness.

1.3 Objectives

The general objective of this study was to evaluate the performance of magnesium rich synthetic gypsum as a potential Mg source in oil palm fertilizer programme in Malaysia.

The specific of objectives were as follows:

i. To characterize and explain the formation of the soil cropped to oil palm in Bera, Pahang;
ii. To determine the effect of MRSG application on the chemical and biological properties of the soil;
iii. To evaluate the growth performance of oil palm seedlings due to MRGS application.

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