UNIVERSITI PUTRA MALAYSIA

PROPERTIES, CLASSIFICATION AND SUITABILITY OF MALAYSIAN SOILS DERIVED FROM GRANITE-GNEISS AND POTENTIAL OF BASALT TO IMPROVE GROWTH OF RUBBER **(Hevea brasiliensis Müll. Arg.)**

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By

MOHD SHAFAR JEFRI BIN MOKHATAR

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

November 2017

DEDICATION

TO MY FAMILY

TO WHOM THEIR TRUE LOVE AND SUPPORT WERE BEHIND MY SUCCESS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Wan Mohamed Noordin Wan Daud, PhD
Faculty : Agriculture

Soils planted with rubber in Malaysia are usually highly weathered soils and known as acidic soils, characterized by low fertility. Recently, the use of basalt to alleviate soil acidity has attracted soil scientists and agronomists in some parts of the world. This study was conducted to characterize soils developed on granite-gneiss and to evaluate the potential of ground basalt as soil amelioration in relation to growth and nutrition of rubber. The study area was located at Geliar, Jeli, Kelantan (05.70497° N, 101.80118° E). Six soil profiles at different slope position were identified, described and sampled, whereby the areas were already planted with immature rubber. Soils developed on very hilly terrain (20°-25°) and hilly (12°-20°) have better drainage and more weathered compare to soil developed on flat area (0°-2°). In terms of clay mineralogy, it is dominated by kaolinite, as shown in XRD diffractogram at reflections 7.2 Å, 3.58 Å and 3.4 Å, followed by gibbsite at 4.82 Å and 4.32 Å. Goethite (4.18 Å), haematite (2.69 Å and 2.51 Å), and quartz (3.3 Å) also detected in the soil profile. Feldspar (3.25 Å) and mica (10 Å) present in high water table soil profile as shown by weak peak in diffractogram. Pedon I, Pedon II, Pedon III and Pedon VI can be classified as Lanas Series Red Variant deep phase. Pedon V can be classified as Lanas Series deep phase (yellow) and Pedon IV can be classified as Local Alluvium Complex. According to USDA soil taxonomy, Pedon I, Pedon II, Pedon III, Pedon V and Pedon VI can be classified as fine clayey, kaolinitic, isohyperthermic, Typic Kandiudults. All soils on high sloping area can be classified as Haplic Acrisol (Clayic) according to World Reference Base for Soil Resources. Pedon IV situated on flat area can be classified as loamy, mixed, isohyperthermic, Fluvaquentic Endoaquepts and Gleyic Cambisol (Geoabruptic) according to Soil Taxonomy and World Reference Base for Soil Resources, respectively. For soil suitability classification for rubber cultivation, soils on Pedon I, Pedon II, Pedon III and Pedon VI can be categorized into Class III, while soil on Pedon V can be categorized into Class II and Pedon IV can be categorized into Class IV. From growth data collected, steeper area (25°) would be more favorable for rubber growth during immature stage. For nursery trial, two types of soil were selected from six profiles along catena. Both types of soil were subjected to different rates of ground basalt, 0, 40, 80, 160 and 240 g/polybag. The experiment was carried out as randomized complete block design (RCBD) with three blocks. The girth and height were measured for a year. After a year, soil chemical properties and nutrients in leaf tissue were analyzed. The results showed that incorporation of basalt at 240 g/tree had improved soil fertility. Increase of soil pH results in decreasing Al concentration. Basalt applications enhance growth of immature rubber in terms of height and girth. Nutrients content in the tissue also increased with basalt application and increases with increasing rate applied. Effect of ground basalt application on growth was evident after three months and continued to increase over time. This study shows that the logistic growth curve model in the form of $y = A/(1+be^{-ct})$ [where y and t were the plant parameters and months after transplanting, respectively, while A, b and c were regression constants] was biologically fit in describing the growth in terms of each of the parameters (stem girth and plant height) versus months after transplanting. At each ground basalt rate applied, the model had F value with high approximate probability level at $\alpha = 0.0001$. For confirmation of study in nursery, a field trial was carried out. The experiment was carried out as complete randomized design (CRD), consisting of four rates of basalt (0, 179, 358 and 538 g/plant) and three replications. The field trial and the nursery have similar trend where application of basalt have enhanced fertility of the soil and growth of the rubber. Highest growth showed by plant with highest relative growth rate of height and girth with value of 16.76 cm/month and 0.681 cm/month respectively. Results showed that cation exchange capacity of the soil increased up to 22% and 45% with the application of 538 g/tree of basalt, after six months and a year. Basalt rate at 538 g/tree would be suitable to be used in field planting. From all data gathered in this study, it can be concluded that slope position influenced the soil formation, fertility, suitability and subsequently the growth of immature rubber tree. In order to improve fertility of highly weathered soils and enhancing early growth of rubber tree, ground basalt could be applied as a soil amendment in rubber plantation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SIFAT, KLASIFIKASI DAN KESESUAIAN TANAH MALAYSIA TERBENTUK DARI GRANIT-GNEISS DAN POTENSI BASALT UNTUK MENINGKATKAN PERTUMBUHAN GETAH (*Hevea brasiliensis* Müll. Arg.)

Oleh

MOHD SHAFAR JEFRI BIN MOKHATAR

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Tanah-tanah yang ditanam dengan getah di Malaysia biasanya tanah yang sangat terluluhawa dan dikenali sebagai tanah berasid, dicirikan oleh kesuburan rendah. Baru-baru ini, penggunaan basalt bagi mengurangkan keasidan tanah telah menarik perhatian saintis dan agronomis di beberapa bahagian dunia. Kajian ini dijalankan bagi mencirikan tanah terbentuk dari granit-gneiss dan menilai potensi basalt sebagai pembaik tanah berkaitan pertumbuhan dan pemakanan getah. Kawasan kajian terletak di Geliar, Jeli, Kelantan (05.70497° N, 101.80118° E). Enam profil tanah di posisi cerun berbeza dikenalpasti, dicirikan dan diambil sampel, di mana kawasan ini telah ditanam dengan getah tidak matang. Tanah yang terbentuk di kawasan yang sangat berbukit (20 ° -25 °) dan berbukit (12 ° -20 °) mempunyai saliran yang lebih baik dan lebih luluhawa berbanding dengan tanah yang terbentuk di kawasan rata (0 ° -2 °). Dari segi mineralogi tanah, ia didominasi oleh kaolinit, seperti yang ditunjukkan dalam difraktogram XRD pada pantulan 7.2 Å, 3.58 Å dan 3.4 Å, diikuti oleh gibbsite pada 4.82 Å dan 4.32 Å. Goethite (4.18 Å), haematit (2.69 Å dan 2.51 Å) dan kuarza (3.3 Å) juga dikesan dalam profil tanah. Feldspar (3.25 Å) dan mika (10 Å) terdapat dalam profil yang mempunyai paras tanah air yang tinggi dikesan dengan puncak lemah di difraktogram. Pedon I, Pedon II, Pedon III dan Pedon VI diklasifikasikan sebagai Fasa Dalam Siri Lanas Varian Merah. Pedon V diklasifikasikan sebagai Fasa Dalam Siri Lanas (kuning) dan Pedon IV diklasifikasikan sebagai Kompleks Alluvium Setempat. Menurut Taksonomi Tanah USDA, Pedon I, Pedon II, Pedon III, Pedon V dan Pedon VI boleh diklasifikasikan sebagai fine clayey, kaolinitic, isohyperthermic, Typic Kandiudults. Semua tanah di kawasan cerun boleh dikelaskan sebagai Haplic Acrisol (Clayic) menurut Pangkalan Rujukan Dunia untuk Sumber Tanah. Pedon IV yang terletak di kawasan rata boleh dikelaskan sebagai loamy, mixed, isohyperthermic, Fluvaquentic Endoaquepts dan Gleyic Cambisol (Geoabruptic), masing-masing mengikut Taksonomi Tanah dan Pangkalan Rujukan Dunia untuk Sumber Tanah. Bagi pengkelasan kesesuaian tanah untuk penanaman getah, tanah di Pedon I, Pedon II, Pedon III dan Pedon VI boleh dikategorikan sebagai Kelas III, manakala tanah di

Pedon V boleh dikategorikan sebagai Kelas II dan Pedon IV boleh dikelaskan sebagai Kelas IV. Dari data pertumbuhan, kawasan curam (25°) lebih baik bagi pertumbuhan getah diperingkat tidak matang. Bagi percubaan nurseri, dua jenis tanah dipilih dari enam profil di sepanjang catena. Kedua jenis tanah tertakluk kepada kadar basalt berlainan, 0, 40, 80, 160 dan 240 g/polibeg. Eksperimen dijalankan sebagai reka bentuk blok lengkap rawak (RCBD) dengan tiga blok. Ukur lilit dan tinggi diukur selama setahun. Selepas setahun, sifat kimia tanah dan nutrien dalam tisu daun dianalisis. Keputusan menunjukkan penambahan basalt pada 240 g/pokok meningkatkan kesuburan tanah. Peningkatan pH tanah mengurangkan kepekatan Al. Aplikasi basalt meningkatkan pertumbuhan getah dari segi ketinggian dan lilitan. Kandungan nutrien dalam tisu meningkat dengan penggunaan basalt dan kadar yang diguna. Kesan aplikasi basalt kisar pada pertumbuhan terbukti selepas tiga bulan dan terus meningkat dari masa ke semasa. Kajian ini menunjukkan bahawa model keluk pertumbuhan logistik dalam bentuk $y = A/ (1+be^{-ct})$ [di mana y dan t masing-masing adalah parameter pokok dan bulan selepas menanam, manakala A, b dan c adalah konstan regressi] sesuai secara biologi dalam menerangkan pertumbuhan dalam konteks setiap parameter (ukur lilit batang dan tinggi pokok) versus bulan selepas menanam. Pada setiap kadar basalt kisar yang diberi, model mempunyai nilai F yang tinggi dengan tahap kebarangkalian pada $\alpha = 0.0001$. Untuk pengesahan kajian di nurseri, percubaan lapangan dijalankan. Eksperimen dijalankan sebagai reka bentuk rawak lengkap (CRD), terdiri dari empat kadar basalt (0, 179, 358 dan 538 g/pokok) dan tiga replikasi. Percubaan lapangan sama seperti di nurseri yang mempunyai trend sama di mana aplikasi basalt meningkatkan kesuburan tanah dan pertumbuhan getah. Pertumbuhan tertinggi dengan kadar pertumbuhan relatif bagi ketinggian dan ukur lilit dengan nilai 16.76 cm/bulan dan 0.681 cm/bulan. Keputusan menunjukkan bahawa kapasiti pertukaran kation tanah meningkat sehingga 22 % dan 45 % dengan penggunaan 538 g/pokok basalt, selepas enam bulan dan setahun. Kadar basalt pada 538 g/pokok sesuai untuk digunakan dalam penanaman. Dari data dikumpulkan, disimpulkan bahawa kedudukan cerun mempengaruhi pembentukan tanah, kesuburan, kesesuaian dan pertumbuhan pokok getah tidak matang. Bagi meningkatkan kesuburan tanah terluluhawa dan meningkatkan pertumbuhan awal pokok getah, basalt boleh digunakan sebagai pindaan tanah di ladang getah.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement of the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AA	Auto Analyzer
AAS	Atom Absorption spectrophotometer
Al	Aluminium
ANOVA	Analysis of variance
C	Carbon
C.E.C	Cation exchange capacity
Ca	Calcium
CGR	Crop growth rate
CIRP	Christmas Island rock phosphate
Cmol	Centi mol
Co	Cobalt
CRD	Complete randomized design
Cu	Copper
FAO	Food Agriculture Organization
Fe	Iron
GML	Ground magnesium limestone
GR	Growth rate
H_2O_2	hydrogen peroxide
H_2SO_4	sulfuric acid
HCl	Hydro chloric acid
IAN	Instituto Agronomico do Norte
IRSG	International Rubber Study Group
IUSS	International Union of Soil Science
K	Potassium
KT	Kota Tinggi
LTC	Latex timber clone
Mg	Magnesium
Mn	Manganese
MRB	Malaysia Rubber Board
N	Nitrogen
Na	Sodium
NH_4OAc	Ammonium acetate
NR	Natural rubber
P	Phosphorus
pH	Potential of Hydrogen
RCBD	Randomized complete block design
RGR	Relative growth rate
RISDA	Rubber Industry Smallholders Development Agency
RRIM	Rubber Research Institute of Malaysia
SAS	Statistical Analysis System
Si	Silicon
UNESCO	United Nation Educational Social Cultural Organization
USDA	United States Department of Agriculture
WRB	World Reference Base
XRF	X-Ray Fluorescence

CHAPTER 1

INTRODUCTION

Brazilian rubber tree or *Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg. is the main source of natural rubber. Although there are many other plants that have been exploited for rubber, such as guayule, *Manihot*, *Funtumia*, *Cryptostegia* and Russian dandelion, especially in times of high prices, in the long run, none could be more economic compared to *Hevea* (Imle, 1978). It has become one of the important commodity crops that have contributed much to the nation's economy as this country is one of the largest producer and consumer of natural rubber in the world (Mooibroek and Cornish, 2000; Shafar et al., 2012). Malaysia has a strong agriculture base *via* being the world leader in the production of several industrial, commercial crops, such as rubber, oil palm, cocoa, pepper, and tropical timber (Shamshuddin et al., 2015; Noordin and Shafar, 2017a).

With the global economic growth, world rubber consumption is expected to increase in tandem. It is forecasted that by the year 2020, 33.9 million tonnes of world rubber will be needed compared with 24.53 million tonnes in the year 2010. It is expected that 45.4% of 33.9 million tonnes will be from natural rubber (NR) (Suarni and Ang, 2011). With the increasing demand due to the expansion of the automobile industry worldwide, it can be concluded that production of natural rubber need to be boosted.

In addition, Noordin (2013) reported that among the factors for Malaysia's declining rubber production are decreasing areas under rubber due to substitution with oil palm plantation, shortage of skilled tappers, poor adoption of modern technologies especially among the smallholders, areas with low tree productivity, and immature areas with high yielding clones not yet in production. As a result of limited suitable planting areas, rubber trees have been planted in low – nutrient soils and dry areas (Noordin, 2013; Shamshuddin et al., 2015; Noordin and Shafar, 2017a).

Agriculture is one of the main land use in Malaysia and has been a significant contributor in economic development of the country as a source of food, employment, export earner and raw materials for agro based industries (Aminuddin et al., 1990; Arshad et al., 2007; Noordin and Shafar, 2017a). Total land area cultivated with rubber is estimated to be 1,078,630 hectares (Malaysian Rubber Board, 2017). The rubber growing areas of Peninsular Malaysia are mainly confined to an elongated north south strip along the west coast. Scattered concentrations are also found on the east coast. Rubber is cultivated on a wide range of terrain ranging from level to steep topography and on a wide variety of soils (Noordin, 1981b; Paramananthan, 1981).

Topography has been one of the criteria used in classifying certain areas into rubber zone. Another factor that influences plant growth is soil suitability. In the tropics, parent material plays the most important role in determining clay mineralogy, soil type and fertility status (Tavernier and Eswaran, 1973). Some detailed information on pedogenesis of shale-derived soil (Noordin, 1975), marine and riverine alluvial (Noordin, 1980a), and igneous and metamorphic rocks (Paramananthan, 1977) has been reported.

High-grade metamorphic complexes could be found in the northern part of Peninsular Malaysia. Regional metamorphism in this regions results in formation of schist and gneiss in various facies (Alexander, 1965; Hutchison, 2009). Soil taxonomy classification system has been widely used in classifying soil according to their similarity in selected properties (Lim and Chan, 1989; Paramananthan, 2000). In Malaysia, soils were classified until the lowest unit, soil series in classification system developed based on parent material. A group of soil derived from the same parent material has identical morphological/profile characteristics (Paramananthan, 2012; Noordin, 2013). From the taxonomic name, clarifications about favourable and adverse characteristics of the soils are easily known and proper crop management recommendation could be made.

Most of the soils in the tropics were classified as Ultisols and Oxisols. These types of soils were highly weathered and known as acid soils and infertile. Most of rubber cultivation was done on these types of soils. Native of forest species, *Hevea* nutrition requirement is quite low compared to other commodity crops such as oil palm and cocoa. However, with the production of the new clones with more vigour properties in terms of growth and high in latex production, more nutrients are needed by the plant (Shafar et al., 2012; Zahidin, 2015).

Mono-cropping system in plantation is common in order to achieve efficiency in terms of management. However, with extensive use of fertilizer, pesticides and herbicides, these practices will result in negative effects to the soil health after a few cycles of rubber cultivation. In India, it was reported that the use of ammonium sulphate fertilizer for a long period in rubber plantations have reduced the soil pH to a level below than 4 (Joseph, 2012). As time passes, the soil pH decreased significantly and this has been investigated and reported by several workers in different countries (Tichy et al., 1997; Kayser et al., 2000; Zhang et al., 2007; Li et al., 2016). Therefore, there is the need to improve soil pH and other properties that have been degraded.

Interdisciplinary approach which is termed as agrogeology or the use of rocks for crops, aims to study geological processes and natural rock and mineral materials that contribute to the maintenance of agro-ecosystems (Van Straaten, 2002, 2006). Liming has been one of agronomic practice in improving soil productivity in rubber plantation. In the absence of lime, silicates, which are rich in Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} but low in Fe^{3+} and Al^{3+} may be used to alleviate soil acidity (Van Ranst, 1995; Noordin, 2013). Furthermore, unlike lime, silicates such as basalt are not easily fixed in the top soil, and consequently, the sub-soil will also be neutralized resulting in deeper less acidic soil (Shamshuddin and Fauziah, 2010a; Noordin, 2013).

Recent findings on alleviating soil acidity revealed that it can be done by application of ground basalt. Apart from increasing the soil pH, it would also supply all macronutrients, except N (Gilman et al., 2002; Shamshudin and Anda, 2012). However, all those findings were made by using basalt from Australia. In Peninsular Malaysia, there are two places where basalt could be found, Kuantan and Segamat. These basalts are available and their potential use in agricultural production is unknown.

Effect of topography on soil pedogenesis and their influence on growth of immature new Latex Timber Clone, RRIM 3001 are not known. Ground basalt could be considered as new soil amendment practice in Malaysia and responses of rubber towards ground basalt application is still unknown. Application of ground basalt could enhance early growth of rubber tree. Furthermore, fertilizer recommendation for new clone grown on soils at different slope could be done precisely. Precision agro-management could save the cost of fertilizer application and time by reducing immaturity period of rubber tree. Thus, this study was conducted with the following objectives:

General Objective: To characterize and evaluate soil developed on granite-gneiss for rubber cultivation and evaluate the potential of ground basalt as soil amelioration in relation to growth and nutrition of new Latex Timber Clone, RRIM 3001.

Specific Objectives:

1. To evaluate the effects of slope on the characteristics of a soil developed on granite-gneiss in Jeli, Kelantan, Malaysia.
2. To investigate the effects of different slope on growth of immature rubber.
3. To study the growth enhancement of immature rubber by ground basalt application under nursery condition.
4. To evaluate the growth and nutrition of immature rubber by ground basalt application under field condition.

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