UNIVERSITI PUTRA MALAYSIA

MACRONUTRIENTS VARIABILITY IN LATERITIC SOIL AND EFFECTS OF ORGANIC AMENDMENT CONTENTS ON MANGO CV HARUMANIS

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By

NURHALIZA BT. MOHAMAD SHAHIDIN

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

August 2016

DEDICATIONS…

This thesis is dedicated to:

My beloved parents

Mohamad Shahidin bin Jafar
and
Faridah binti Othman

Sisters, brother and brothers in law

Nurhazami binti Mohamad Shahidin
Nur Hafizah binti Mohamad Shahidin
Mohamad Syafiq bin Mohamad Shahidin
Shahrizal bin Shahari
Muhammad Ar Maszizi bin Abd Aziz

My lovely nephews

Muhammad Syahmi Harith bin Shahrizal
Muhammad Izar Muqrish bin Ar Maszizi

and last but not least to my late supervisor

Assoc. Prof. Dr. Anuar bin Abdul Rahim

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

MACRONUTRIENTS VARIABILITY IN LATERITIC SOIL AND EFFECTS OF ORGANIC AMENDMENT CONTENTS ON MANGO CV HARUMANIS

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NURHALIZA BT. MOHAMAD SHAHIDIN

August 2016

Chairman: **Roslan Ismail, PhD**
Faculty: **Agriculture**

Mango (*Mangifera indica* L.) is one of the 16 fruits that have been highlighted for the agricultural development in the Third National Agricultural Policy (NAP3) by Malaysian Ministry of Agriculture in 1999. Currently, production of Harumanis mango was unable to cater the increasing demand in local and international markets. Cultivation of Harumanis mango on marginal soils such as lateritic soils is quite challenging as the information regarding mango cultivated on lateritic soil is very scarce since this cultivar is mostly cultivated on soil with pH greater than 7. Application of chemical fertilizer (CF) in mango cultivation area over the years has worsened the acidity problems of lateritic soil under humid tropical climate. Application of chicken manure (CM) compost into lateritic soil could reduce the level of soil acidity and enhances the soil chemical properties.

Three field experiments have been conducted from January 2014 until June 2015 in mango cultivation area located at Universiti Teknologi Mara (UiTM) Perlis Campus (N 06.45427°; E 100.28352°) cultivated with *Mangifera indica* L. cv. Harumanis (MA 128) aged 5 years old on lateritic soil (Terap Series). Experiment 1 was implemented with the objectives i) to determine variability of selected soil chemical properties in vertical and horizontal direction and ii) to evaluate correlation between the selected chemical properties of lateritic soil. The objective of experiment 2 was to assess temporal variations in chemical properties of lateritic soil and foliar of mango with respect to plant phenological stage (PPS) (day of sampling) and slope position. The experiment 3 was implemented to evaluate the effects of chicken manure (CM) compost application on the selected soil chemical properties and macronutrients concentration in mango leaf and its effects on mango yield. All data were analysed using Analysis of Variance (ANOVA) and means separation were conducted using Tukey's Honestly Significant Difference (HSD) test (p=0.05) using SAS Ver. 9.3. Pearson's correlation analysis was also conducted by SAS Ver. 9.3. Experiment 1 was divided into vertical and horizontal variability study of the selected soil chemical properties. Soil samples were collected from nine soil pits at 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm depth for vertical variability study. For the horizontal variability study in 0.29 ha study plot, 50 topsoil (0-

15 cm) samples were obtained by systematic sampling scheme. Results obtained in this study revealed that soil depth significantly ($p \leq 0.05$) affected soil pH, organic carbon (C), total nitrogen (N), carbon to nitrogen (C/N) ratio, available phosphorus (P), exchangeable potassium (K), magnesium (Mg) and aluminium (Al), and cation exchange capacity (CEC). Significant differences ($p \leq 0.05$) were also shown in clay and sand content by soil depth. Moderate variability indicated by coefficient of variation (CV) that ranged between 13.74% and 48.19% were found in organic C, total N, available P, exchangeable K, Ca, Mg and Al and base saturation in horizontal variability study. Soil organic C, total N and C/N ratio of topsoil in both vertical and horizontal variability study showed positive correlation greater than 70%. Exchangeable Al was negatively correlated ($r > 40\%$) with available P, exchangeable K and Ca in horizontal direction.

The experimental design used in experiment 2 was Randomized Complete Block Design (RCBD) with repeated measurement. Two independent variables in this experiment were plant phenological stage (PPS) (day of sampling); first flowering (0 day), fruiting (90 days), flushing (180 days), end of flushing (270 days) and second flowering (360 days); and slope position; upper, middle and lower. A total of 60 topsoil (0-15 cm) samples and 48 leaf samples were collected. The study results showed that soil pH, total N, available P, CEC, base saturation and exchangeable bases (K, Ca and Mg) as well as N, P, K, Ca and Mg content in the leaf were significantly ($p \leq 0.05$) affected by single factor of PPS (day of sampling). Slope position single factor were also significantly ($p \leq 0.05$) affected the exchangeable Ca, Mg and Al, CEC and base saturation as well as N and K content in the leaf. It was found that leaf N content was the only variable exhibited significant ($p \leq 0.05$) interaction effects between PPS (day of sampling) and slope position.

The fertilizer treatments in experiment 3 consisted of a uniform rate (3.5 kg tree^{-1}) of NPK Blue fertilizer (12:12:17:2) in combination with five rates of CM compost (0, 4, 8, 12 and 16 kg tree^{-1}) with five replications which was laid out in Latin Square Design. Fertilizer was applied in two split application using pocket method in 15 cm depth. Soil and leaf sampling were conducted on 90, 180 and 270 days after the first fertilization. Yield parameters data were collected before and after fertilizer treatments, in year 2014 and 2015, respectively. The experiment results revealed that soil pH and exchangeable K, Ca and Mg in 0-15 cm and 15-30 cm soil depth has increased significantly ($p \leq 0.05$) after nine months of fertilization. However, there was no significant ($p > 0.05$) effects of the fertilizer treatments in CEC for both soil depths. Significant ($p \leq 0.05$) effects were found in leaf Ca content whereas, N, P, K and Mg content in the leaf and yield parameters were not significantly ($p > 0.05$) affected by the fertilizer treatments. The greatest increment in soil pH and exchangeable bases (K, Ca and Mg) was shown by the treatment of 16 kg tree^{-1} CM compost combined with 3.5 kg tree^{-1} CF.

Based on the findings, variability of selected soil chemical properties in vertical and horizontal direction in the respected area occurs due to the combined effects of undulating landform, soil management practices (application of fertilizer and pesticides), clay content and non-uniform availability of soil nutrients. It was found that PPS (day of sampling) and slope position single factor has resulted in variation of the selected soil chemical properties and macronutrients content in leaf of Harumanis mango. Application

of different rates of CM compost combined with CF has significantly ($p \leq 0.05$) enhanced the soil chemical properties in the study area. The recommended rate for increasing soil pH, exchangeable bases (K, Ca and Mg) and fruit yield on lateritic soil (Terap Series) of the respected area is combination of 16 kg tree^{-1} CM compost with 3.5 kg tree^{-1} CF.

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

KEPELBAGAIAN MAKRONUTRIEN DALAM TANAH LATERIT DAN KESAN KANDUNGAN PEMBAIK PULIH ORGANIK TERHADAP MANGGA CV HARUMANIS

Oleh

NURHALIZA BT. MOHAMAD SHAHIDIN

Ogos 2016

Pengerusi: **Roslan Ismail, PhD**
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Mangga (*Mangifera indica* L.) merupakan salah satu daripada 16 buah-buahan yang telah ditonjolkan untuk pembangunan pertanian dalam Dasar Pertanian Negara yang ke-3 (NAP3) oleh Kementerian Pertanian Malaysia pada tahun 1999. Pada masa kini, pengeluaran mangga Harumanis tidak dapat menampung permintaan yang semakin meningkat dalam pasaran tempatan dan antarabangsa. Penanaman mangga Harumanis di tanah marginal seperti tanah laterit agak mencabar kerana maklumat berkenaan penanaman mangga di tanah laterit adalah sangat terhad oleh kerana kultivar ini kebanyakannya ditanam di tanah dengan pH melebihi 7. Aplikasi baja kimia (CF) di kawasan penanaman mangga sejak sekian lama telah memburukkan lagi masalah keasidan tanah laterit di bawah iklim tropika yang lembap. Aplikasi kompos tahi ayam (CM) ke dalam tanah laterit dapat mengurangkan tahap keasidan tanah dan meningkatkan sifat kimia tanah.

Tiga kajian lapangan telah dijalankan bermula dari Januari 2014 sehingga Jun 2015 di kawasan penanaman mangga yang terletak di kampus Universiti Teknologi Mara (UiTM) Perlis (N 06.45427°; E 100.28352°) ditanam dengan *Mangifera indica* L. kultivar Harumanis (MA 128) berumur 5 tahun di tanah laterit (Siri Terap). Eksperimen 1 telah dilaksanakan dengan objektif i) untuk menentukan kepelbagaian sifat kimia tanah yang dipilih dalam arah menegak dan mendatar dan ii) untuk menilai hubungan antara sifat kimia tanah laterit yang dipilih. Objektif eksperimen ke-2 adalah untuk menilai kepelbagaian masa terhadap sifat kimia tanah laterit dan daun mangga berdasarkan peringkat fenologi tumbuhan (PPS) (hari persampelan) dan kedudukan cerun. Eksperimen 3 telah dijalankan untuk menilai kesan pembaik pulih organik terhadap sifat kimia tanah yang dipilih dan kepekatan makronutrien dalam daun mangga dan kesannya terhadap hasil mangga. Kesemua data dianalisis dengan menggunakan Analisis Varians (ANOVA) dan pemisahan purata dijalankan menggunakan ujian Tukey HSD (p=0.05) menggunakan SAS versi 9.3. Analisis korelasi Pearson juga telah dijalankan menggunakan SAS versi 9.3.

Eksperimen 1 telah dibahagikan kepada kajian kepelbagaian sifat kimia tanah dipilih secara menegak dan mendatar. Sampel tanah telah dikumpulkan daripada sembilan lubang tanah pada kedalaman 0-15 sm, 15-30 sm, 30-45 sm dan 45-60 sm untuk kajian kepelbagaian secara menegak. Bagi kajian kepelbagaian secara mendatar dalam plot kajian seluas 0.29 hektar, sebanyak 50 sampel tanah atas (0-15 sm) diperolehi secara skim persampelan sistematik. Keputusan yang diperolehi dalam kajian ini mendedahkan bahawa kedalaman tanah memberi kesan secara bererti ($p \leq 0.05$) terhadap pH tanah, karbon (C) organik, jumlah nitrogen (N), nisbah karbon kepada nitrogen (C/N), fosforus (P) tersedia, tukar ganti kalium (K), magnesium (Mg) dan aluminium (Al), dan keupayaan pertukaran kation (CEC). Kesan secara bererti ($p \leq 0.05$) juga ditunjukkan dalam kandungan tanah liat dan pasir dengan kedalaman tanah. Kepelbagaian sederhana yang ditunjukkan oleh pekali variasi (CV) yang berada dalam julat antara 13.74% dan 48.19% telah ditemui dalam C organik, jumlah N, P tersedia, tukar ganti K, Ca, Mg dan Al, dan ketepuan bes dalam kajian kepelbagaian secara mendatar. Organik C, jumlah N dan nisbah C kepada N tanah atas dalam kajian kepelbagaian secara menegak dan mendatar menunjukkan korelasi positif melebihi 70%. Tukar ganti Al menunjukkan korelasi negatif ($r > 40\%$) dengan P tersedia, tukar ganti K dan Ca dalam arah mendatar.

Reka bentuk eksperimen yang digunakan dalam eksperimen 2 adalah reka bentuk rawak blok lengkap (RCBD) dengan pengukuran berulang. Dua pemboleh ubah bebas dalam eksperimen ini adalah PPS (hari persampelan); pembungaan pertama (0 hari), peringkat berbuah (90 hari), peringkat pembentukan daun baru (180 hari), peringkat akhir pembentukan daun (270 hari) dan pembungaan kedua (360 hari); dan kedudukan cerun; atas, tengah dan bawah. Sebanyak 60 sampel tanah atas (0-15 sm) dan 48 sampel daun telah dikumpul. Hasil kajian menunjukkan bahawa pH tanah, jumlah N, P tersedia, CEC, ketepuan bes dan tukar ganti bes (K, Ca dan Mg) serta kandungan N, P, K Ca dan Mg dalam daun terkesan secara bererti ($p \leq 0.05$) oleh faktor tunggal PPS (hari persampelan). Faktor tunggal kedudukan cerun juga memberi kesan secara bererti ($p \leq 0.05$) terhadap tukar ganti Ca, Mg, dan Al, CEC dan ketepuan bes serta kandungan N dan K dalam daun. Didapati bahawa kandungan N dalam daun merupakan satu-satunya pembolehubah yang menunjukkan kesan interaksi secara bererti ($p \leq 0.05$) antara PPS (hari persampelan) dan kedudukan cerun.

Rawatan baja dalam eksperimen 3 terdiri daripada kadar baja NPK biru (12:12:17:2) yang seragam (3.5 kg pokok^{-1}) dengan kombinasi lima kadar kompos tahi ayam (0, 4, 8, 12 dan 16 kg pokok^{-1}) dengan lima replikasi yang disusun dalam reka bentuk Latin Square. Aplikasi baja adalah secara berasingan iaitu dua aplikasi dengan kaedah poket pada kedalaman 15 sm. Persampelan tanah dan daun dijalankan pada hari ke 90, 180 dan 270 selepas aplikasi baja yang pertama. Data parameter hasil sebelum dan selepas rawatan pembajaan pada tahun 2014 dan 2015 telah dikumpulkan. Keputusan eksperimen menunjukkan bahawa pH tanah dan tukar ganti K, Ca dan Mg pada kedalaman 0-15 sm dan 15-30 sm telah meningkat secara bererti ($p \leq 0.05$) selepas sembilan bulan pembajaan. Walau bagaimanapun, tiada kesan secara bererti ($p > 0.05$) rawatan pembajaan dalam CEC untuk dua kedalaman tanah. Kesan secara bererti ($p \leq 0.05$) dijumpai dalam kandungan Ca dalam daun manakala, kandungan N, P, K dan Mg dalam daun dan parameter hasil tidak dipengaruhi secara bererti ($p > 0.05$) oleh rawatan pembajaan. Peningkatan terbesar dalam pH tanah dan tukar ganti bes (K, Ca dan

Mg) ditunjukkan oleh rawatan 16 kg pokok^{-1} kompos tahi ayam dengan kombinasi 3.5 kg pokok^{-1} baja kimia.

Berdasarkan dapatan, kepelbagaian sifat kimia tanah yang dipilih dalam arah menegak dan mendatar dalam kawasan kajian berlaku disebabkan kesan kombinasi bentuk muka bumi yang beralun, amalan pengurusan tanah (penggunaan baja dan racun perosak), kandungan tanah liat, dan ketidakseragaman nutrien tanah yang tersedia. Didapati bahawa faktor tunggal PPS (hari persampelan) dan kedudukan cerun menyebabkan kepelbagaian dalam sifat kimia tanah dan kandungan makronutrien dalam daun mangga Harumanis. Aplikasi kompos tahi ayam dengan kadar yang berbeza dengan kombinasi baja kimia telah meningkatkan sifat kimia tanah secara bererti ($p \leq 0.05$) dalam kawasan kajian. Kadar yang disyorkan untuk meningkatkan pH tanah, tukar ganti bes (K, Ca dan Mg) dan hasil buah pada tanah laterit di kawasan berkenaan adalah kombinasi 16 kg pokok^{-1} kompos tahi ayam dengan 3.5 kg pokok^{-1} baja kimia.

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I certify that a Thesis Examination Committee has met on 30 August 2016 to conduct the final examination of Nurhaliza bt Mohamad Shahidin on her thesis entitled "Macronutrients Variability in Lateritic Soil and Effects of Organic Amendment Contents on Mango cv Harumanis" 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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Date: 28 February 2017

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment 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
ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CF	Chemical fertilizer
CM	Chicken manure
CV	Coefficient of Variation
cv.	Cultivar
DOA	Department of Agriculture
EDA	Exploratory Data Analysis
FAMA	Federal Agricultural and Marketing Authority
HSD	Honestly Significant Difference
ICP-OES	Inductive Coupled Plasma Optical Emission Spectrometer
MOA	Ministry of Agriculture
MADA	Muda Agricultural and Development Authority
ME	Mean error
NAP3	Third National Agricultural Policy
PPS	Plant phenological stage
SAS	Statistical Analysis Software
SD	Standard Deviation
UiTM	Universiti Teknologi Mara
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Background of study

Mango (*Mangifera indica* L.) is one of the 16 fruits that have been highlighted for the agricultural development in the Third National Agricultural Policy (NAP3) of Malaysia (MOA, 1999). *Mangifera indica* L. cv. Harumanis (MA 128), a premium mango cultivar is widely cultivated in Perlis and possesses high market demand in both local and international markets including Japan, Singapore and Hong Kong. This mango cultivar was introduced in Perlis since early 1980s.

In general, it was estimated that more than 8,000 ha land in Peninsular Malaysia has been cultivated with various mango cultivar which are mainly in Kedah, Perlis and Perak (DOA, 2009). As in year 2015, 150 metric tons of Harumanis mango was produced from 60 ha production area by Perlis Department of Agriculture (DOA). However, current production of Harumanis mango was unable to cater the increasing demand.

Mango can grow on a wide variety of soil types ranging from high pH soils to low pH soils though it grows best on soil with pH between 5.5 and 6.5. Although mango can adapt to numerous types of soil, the physical and chemical properties of the respective soil could resulted in different growth rate and yield production and subsequently affected the fertilizer requirement. Lateritic soils which are categorized as marginal soil are commonly used for rubber (*Hevea brasiliensis*) cultivation. However, due to the abundance source of lateritic soils in the northern part of Peninsular Malaysia, mango was also cultivated on this types of soil. The lateritic soil series includes Changlun, Chuping, Gajah Mati, Jitra, Melaka, Pokok Sena and Terap Series. Each of the soil series are characterized by different soil depth to the subsoil laterite layer which results in different soil physical and chemical properties.

Lateritic soils experience nutrients imbalance in which nutrient status was indicated by low to medium level (Wong, 2009). Due to its poor nature, lateritic soil does not able to supply sufficient amount of nutrients as for optimum growth of mango. High acidity of lateritic soil also hinder nutrition uptake which subsequently affected growth rate and yield. Low organic matter content in lateritic soil has resulted in low level of essential nutrients needed for crop growth as well as low cation exchange capacity (CEC) (Kheoruenromne, 1987). Lateritic soils are known to have high level of exchangeable Al due to its low pH which in turn affected the nutrient uptake and growth of roots and in certain extent results in occurrence of Al toxicity.

Growth and yield production of mango on lateritic soil was restricted due to the above mentioned soil properties, thus, making it less suitable for agriculture. Hence, application

of chemical fertilizer (CF), mainly nitrogen (N), phosphorus (P) and potassium (K) was initially carried out for mango cultivation in order to supply macronutrients needed. However, continuous application of CF without organic amendments in mango cultivation area in long term could alter the soil physical and chemical properties and resulted in depletion of beneficial microorganisms' population within soil as well as leads to soil acidification. In addition, the acidic soil condition can cause nutrients imbalance and suppress the availability of nutrients to the crops even though nutrients are abundant in the soils. Considering the long term consequences of CF usage, application of CF must be reduced and substituted with other natural resources which can promotes better soil health as well as to minimize the process of soil acidification and to ensure efficient nutrient supplies for optimal crop growth. Hence, application of organic matter amendments into the soil needs to be implemented in order to enhance the soil physical and chemical properties.

Various sources of organic materials are available for soil amendments such as animal manure and compost. Animal manures such as cow manure and chicken manure (CM) are widely used as soil amendments which are proven containing high concentration of major essential elements and high organic carbon (C) content. Organic amendments are widely used in agriculture practices and the impacts are globally discussed. Mylavarapu and Zinati (2009) stated that application of organic fertilizer benefits the soil by improving the soil physical and chemical properties as it contributes to aggregate stability, enhancing water holding capacity (Naeini and Cook, 2000), increases soil CEC, improve soil fertility and supplies mineral nutrients required by the crops (Simpson, 1986). Besides that, application of organic fertilizer also enhances the availability of nutrients to the crop as resulted from microbial activity (Zinati et al., 2004), which leads to a better nutrition to the plant and optimum yield production (Mylavarapu and Zinati, 2009).

Mangifera indica L. cv. Harumanis is mostly cultivated on soil with pH greater than 7. However, cultivation of Harumanis mango has been expanded on marginal soil such as lateritic soil with low soil pH. Previous research study on mango cv. Harumanis cultivated on high pH soils have been done by Razi (1992; 1996). However, there is limited research and scarce information on management practices of Harumanis mango cultivated on lateritic soils. Therefore, this study was undertaken to study the variability of macronutrients (N, P, K, Ca and Mg) in soil and mango leaf (N, P, K, Ca and Mg) under acidic soil condition. Besides that, this study aims to evaluate the effects of fertilizer management on soil and leaf nutrients concentration as well as yield of Harumanis mango on lateritic soils.

1.2 Objectives of study

The main objectives of this study were:

1. To determine variability of selected soil chemical properties in vertical and horizontal direction and correlation among the chemical properties in lateritic soil cultivated with Harumanis mango.

2. To determine temporal variability of chemical properties in lateritic soil and macronutrients concentration in mango leaf based on plant phenological stages (day of sampling) (flowering, fruiting, flushing and end of flushing) and slope positions (upper, middle and lower).

3. To evaluate the effects of CM compost application on soil chemical properties, macronutrients concentration in mango leaf and yield of Harumanis mango.

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LIST OF PUBLICATIONS

Nurhaliza, M.S., Roslan, I., Siti Zaharah, S., and Hun, K.S. (2015). Temporal changes of nutrient concentrations in lateritic soil under Harumanis mango cultivation. Poster. Proceedings of the Soil Science Conference of Malaysia. Putrajaya, Malaysia. 7-9th April 2015. pp. 172-175.

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