UNIVERSITI PUTRA MALAYSIA

EFFECTS OF ORGANIC-BASED AND FOLIAR FERTILIZERS ON THE GROWTH, YIELD AND QUALITY OF COCOA (*Theobroma cacao* L.)

NOORDIANA NORDIN

EFFECTS OF ORGANIC-BASED AND FOLIAR FERTILIZERS ON THE GROWTH, YIELD AND QUALITY OF COCOA (*Theobroma cacao* L.)

By

NOORDIANA NORDIN

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

January 2007

EFFECTS OF ORGANIC-BASED AND FOLIAR FERTILIZERS ON THE GROWTH, YIELD AND QUALITY OF COCOA (*Theobroma cacao* L.)

NOORDIANA NORDIN

MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

2007

DEDICATION

To beloved Abah and Mak

Tn. Haji Nordin bin Mohamed
Pn. Hajjah Hasnah binti Ahmad

To my soul mate

Abdul Rahman bin Mohamed

And my little prince

Ammar Hasif bin Abdul Rahman

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

EFFECTS OF ORGANIC-BASED AND FOLIAR FERTILIZERS ON THE GROWTH, YIELD AND QUALITY OF COCOA (*Theobroma cacao* L.)

By

NOORDIANA NORDIN

January 2007

Chairman : Associate Professor Syed Omar Syed Rastan, PhD

Faculty : Agriculture

Malaysian cocoa industries are facing many problems when cocoa in the country is grown on problem soils such as Ultisols and Oxisols. These soils are generally acidic, low in basic cations and also low in soil cation exchange capacity. Poor cocoa yield that was far behind the targeted yield of 1.5 tonnes contribute to reducing in Malaysian cocoa export. A combination of chemical and organic fertilizers have been shown to maintained the physical, chemical and biological of soil despite maximizing continuous production. Foliar fertilizer reduces the imbalance nutrients condition during critical growing stages. The general objective of this study was to evaluate the effect of different types of fertilizers on the cocoa growth production and the quality of cocoa beans. Thus, the specific objectives of this study were to see the effects of fertilizer treatments (organic-based and foliar fertilizers) on (i) soil fertility improvement; (ii) the growth of (matured tree and seedlings) and (iii) yield and beans quality of cocoa grown on Segamat Series. A field experiment was undertook to study the effects of organic-based and foliar fertilizers on the soil fertility improvement, the growth, yield and beans quality of cocoa grown on Segamat series. Experimental plots were prepared in Malaysian Cocoa Board (MCB) Experimental Farm with five treatments and four replications. The number of pods (successful cherelles) was recorded every month, starting 2 months after treatments. Total number of harvested mature pods was recorded from October 2004 until June 2005. The potential calculated yield was then estimated using the collected data of number of pods (successful cherelles) and harvested pods. Five pods were sampled out from each plot to determine pod and bean quality indicated by dry weight of husk, length and diameter of pods, weight of harvested pods, average number of beans/pod, single dry bean weight and pod index. A pot experiment was conducted under glasshouse conditions using cocoa seedlings of clone KKM 22 and PBC 130 grown in Segamat Series soil with five treatments. The experiment was conducted to determine the effect of organic-based and foliar fertilizers (as measured by plant height, stem diameter, and weight of root and top) on the growth of cocoa seedlings. The experiment was conducted for 20 weeks starting in August 2005 until January 2006. Root:shoot ratio and plant height showed no significant response to treatments except the stem diameter, root biomass and shoot (plant top) dry weight. Results showed that application of fertilizers gave no significant difference on the growth, yield or quality of cocoa. Therefore, further soil and leaf analysis had been carried out to

identify the actual problem of yield limitation by determining the concentration of macro- and micronutrients. It was discovered that manganese concentrations in soil and leaf samples for field experiment were 3-fold higher than the adequate range, possibly resulting in manganese toxicity, therefore cocoa was not grown on good soil. Manganese toxicity has been found out to be the possible reason of cocoa yield and quality limitation. The Segamat series contains mineral such as pyroxene which contributes to Mn. Initial status of Segamat series soil has indicated that Mn concentration was 113 – 150 mg/kg, which were beyond the adequate range of 20 – 40 mg/kg. An addition of Mn through fertilizer application has made the problem worst. It is recommended that enough lime should be applied to the soil since the present liming program (500 g/plant or 0.5 – 1 tan/ha/year, broadcast once a year) has indicated insufficient to increase the soil pH to an adequate range of 5.5 – 7.0 in order to obtain better yield and quality of cocoa grown on Segamat series soil.

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

KESAN BAJA BERUNSUR ORGANIK DAN BAJA DEDAUN KE ATAS PERTUMBUHAN, HASIL DAN KUALITI KOKO (*Theobroma cacao* L.)

Oleh

NOORDIANA NORDIN

Januari 2007

Pengerusi : Profesor Madya Syed Omar Syed Rastan, PhD

Fakulti : Pertanian

Industri koko Malaysia sedang berhadapan dengan masalah apabila cocoa di negara ini ditanam di atas tanah yang bermasalah seperti Ultisols dan Oxisols. Tanah ini umumnya berasid, kurang kation bes dan juga kadar pertukaran kation yang rendah. Hasil koko yang rendah iaitu di belakang hasil sasaran sebanyak 1.5 tan turut menyumbang kepada pengurangan eksport koko Malaysia. Gabungan baja kimia dan organik telah menunjukkan pengekalan keadaan fizikal, kimia dan biologi tanah walaupun pengeluaran maksimum secara berterusan. Baja dedaun mengurangkan keadaan nutrien yang tidak seimbang sewaktu tahap kritikal proses pertumbuhan. Objektif umum kajian ini adalah untuk menilai kesan baja yang berbeza jenis ke atas pertumbuhan, hasil dan kualiti koko. Seterusnya, objektif khusus kajian ini adalah untuk melihat kesan rawatan baja (baja berunsur organik dan baja dedaun) ke atas (i)

peningkatan kesuburan tanah; (ii) pertumbuhan (pokok matang dan anak pokok) dan (iii) hasil dan kualiti biji koko yang ditanam pada tanah Segamat. Eksperimen lapangan telah dijalankan untuk mengkaji kesan baja berunsur organik dan baja dedaun terhadap kejayaan perkembangan putik koko, hasil dan kualiti koko. Plot eksperimen telah disediakan di Ladang Percubaan Lembaga Koko Malaysia (LKM) dengan lima rawatan dan 4 replikasi. Bilangan buah (putik koko yang tidak layu) direkodkan pada setiap bulan, mulai 2 bulan selepas rawatan bermula. Jumlah keseluruhan buah koko matang yang dituai direkodkan mulai Oktober 2004 sehingga Jun 2005. Potensi hasil dikira dengan menganggarkan data terkumpul daripada bilangan buah (putik koko yang tidak layu) dan buah koko matang yang dituai. Lima biji buah koko disampel dari setiap plot untuk mengkaji kualiti buah dan biji koko seperti berat kering kulit koko, panjang dan ukur lilit buah koko, berat buah koko matang, purata bilangan biji/buah koko, berat kering biji koko dan indeks buah koko. Eksperimen berpasu telah dijalankan dalam rumah kaca menggunakan anak pokok koko klon KKM 22 dan PBC 130 yang ditanam dalam tanah siri Segamat dengan lima rawatan. Eksperimen dijalankan untuk mengkaji kesan baja organik dan baja dedaun (dengan mengukur tinggi pokok, ukur lilit batang, dan berat akar dan bahagian atas pokok) ke atas pertumbuhan anak pokok koko. Eksperimen telah dijalankan selama 20 minggu bermula Ogos 2005 hingga Januari 2006. Nisbah akar: pucuk dan tinggi pokok tidak memberikan tindakbalas bererti terhadap rawatan kecuali ukur lilit batang, berat akar dan berat kering bahagian atas pokok. Keputusan menunjukkan penggunaan baja-baja tidak memberi sebarang perbezaan bererti samada terhadap hasil mahupun kualiti koko. Oleh sebab itu, analisis sampel daun dan tanah yang selanjutnya telah dijalankan untuk mengenalpasti masalah sebenar hasil yang terhad dengan mengkaji kepekatan makro- dan mikronutrien. Didapati bahawa kepekatan mangan di dalam sampel daun dan tanah adalah 3 kali ganda lebih tinggi daripada julat yang memadai, berkemungkinan menyebabkan keracunan mangan, oleh yang demikian koko tidak ditanam di atas tanah yang baik. Keracunan mangan telah dikenalpasti sebagai punca yang menghadkan hasil dan kualiti koko. Tanah Segamat mengandungi mineral seperti pyroxene yang menyumbang kepada pembentukan mangan. Status tanah Segamat sebelum kajian bermula menunjukkan bahawa kepekatan managan adalah 113 – 150 mg/kg, yang mana melebihi julat yang berpatutan iaitu 20 – 40 mg/kg. Penambahan mangan melalui baja telah menjadikan masalah ini semakin buruk. Adalah disyorkan bahawa kapur yang mencukupi diberi kepada tanah siri ini memandangkan program pengapuran yang sedia ada (500 g/pokok atau 0.5 – 1 tan/ha/tahun, ditabur sekali setahun) telah menunjukkan kadar yang belum mencukupi untuk menaikkan pH tanah kepada julat yang bersesuaian iaitu 5.5 – 7.0 untuk mendapat hasil dan kualiti yang lebih baik bagi koko yang ditanam di tanah Segamat.

ACKNOWLEDGEMENTS

First and foremost, I wish to give special thanks and express my gratitude to my supervisor, Associate Professor Dr. Syed Omar Syed Rastan, and my supervisory committee, Professor Dr. Shamsuddin Jusop, without whom this Master's thesis would not have been made possible. They both introduced me into the field of soil science and fertility, and all their constructive comments, criticisms and suggestions have been of great help throughout this research.

I would like to express my sincere thanks to Mr. Nik Aziz Nik Mat, a member of my master research committee, for his constructive comments in my works and guidance in the experimental work. This research was made possible with the collaboration of the Malaysian Cocoa Board (MCB). Thanks are also due to staff and management of MCB Experimental Farm, Jengka in providing the cocoa trees, equipments required for the experiment and also labours for the tough work in the field. I would also like to thanks all staff of Land Mangement Department and particularly; Mr. Alias, Mr. Mahyudeen, Mr. Jamil and Mr. Zainuddin for their assistance and cooperation.

Financial support during my study was provided by the Ministry of Science, Technology and Innovation (MOSTI) for the financial support IRPA project number 01-02-04-0503-EA001and the South East Asia Research Centre for Agriculture (SEAMEO SEARCA) scholarship, for which I am sincerely grateful. I would also like to extend my sincere thanks to Diversatech (M) Sdn. Bhd. in providing the fertilizers required for the experiment.

My deepest gratitude is for my parent, Hj. Nordin Mohamed and Hjh. Hasnah Ahmad, my husband, Abdul Rahman Mohamad, for consistently providing an inspiring and conducive atmosphere. There were times when quiting seemed to be the best options, but their love made me carry on. My thanks to all my colleagues for their kind help. Finally, I would like to extend my deepest appreciation to all who have contributed in one way or another to the success of this thesis.

And above all, my thank are due to Allah, The Almighty, The Merciful, The Benevolent. His grace alone brings succour.

I certify that an Examination Committee has met on 26th January 2007 to conduct the final examination of Noordiana Binti Nordin on her Master of Science thesis entitled "Effects of organic-based and foliar fertilizers on the growth, yield and quality of cocoa (*Theobroma cacao* L.)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Hamdan Jol, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Ahmad Husni Mohd. Hanif, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Aminuddin Hussin, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Mohd. Aris Junus, PhD
Professor
Malaysian Agricultural Research and Development Institute
MARDI
(External Examiner)

____

HASANAH MOHD. GHAZALI, PhD
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 APRIL 2007

This thesis 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 are as follows:

Syed Omar Syed Rastan, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Shamshuddin Jusop, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

En. Nik Aziz Nik Mat
Senior Research Officer
Malaysian Cocoa Board
Jengka, Pahang
(Member)

____

AINI IDERIS, PhD
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 10 MAY 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

NOORDIANA NORDIN

Date: 20 March 2007

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Commercial cultivation of cocoa in Malaysia commenced in the early fifties when the United Cocoa Development Company successfully planted some 239 hectares in Terengganu. Later planting expanded to the East Malaysia, Sabah which became the leading state to grow monocrop cocoa in Malaysia. The high price of cocoa beans in world market and support from the government under the crop diversification program of Second Malaysia Development Plan has influenced the rapid expansion of the industry.

Although the average yields of many agricultural crops have increased dramatically in recent years, the average yield of cocoa has shown very little increase and in some areas, it has actually fallen. One of the problems related to the decrease in cocoa bean production over the years is low soil productivity which only achieve 0.98 t/ha in 2003 (Malaysian Cocoa Board, 2003). Most cocoa in the country is grown on highly weathered soils, known as Ultisols and Oxisols. The low soil productivity is due to acid reaction, low cation exchange capacity to retain nutrients and Al toxicity. Recently, the area under cocoa has decreased drastically to 50, 824 hectares. The decrease is attributed principally to poor prices for cocoa beans, poor maintenance and declining hectarage. Areas which are suitable for cocoa are replanted with other crops such as oil palm and rubber, while marginal soil is used in new cocoa development areas (Malaysia Agricultural Directory and Index, 2003).

The quality of the cocoa bean is important due to the natural variability which exists in cocoa. High residual acid content, very low chocolate flavour and bitter taste is usually associated with poor quality bean, which contributes to the lower prices of Malaysian cocoa beans compared to Ghana cocoa beans i.e. the normal commercial standard (Bakri *et al*., 1994). The quality of cocoa products can also be determined by shell content and the fat component of the dry nibs (Lockwood *et al*., 1994). There are several physical characteristics which affect the poor quality on cocoa beans to Malaysian industries. It includes strong acid taste of cocoa beans. All cocoa beans are acidic to a certain degree, most to an extent that is acceptable for chocolate manufacture, but when the amount of acids (the acids concerned are acetic and lactic) in the beans is excessive there will be an adverse effect on the flavour of the finished chocolate (Pilkington, 1994).

Bean weight is influenced by the type of planting material and by the rainfall during the development of the pod. As bean size falls, average shell content rises. Shell content is known to vary within genotype and independently of bean size. Shell percentage should be as low as possible, consistent with adequate protection of the nib from mould and insects as shell is removed in manufacture and is of very little value. The content of cocoa butter is usually expressed as a percentage of the dry nib or cotyledon. The change in fat content is probably affected by climatic factor. The beans develop during the monsoon gives normal size beans, shell percentage and fat content.

Another problem is poor yield of cocoa beans. This may be related to cherelles wilt problem. Young cocoa fruits or cherelles stop growing and turn yellow a week later and then blacken and shrivel, but remain on the tree. This phenomenon occurs during the first half of the pod development period and called cherelle wilt. The incidence of wilt increases from pollination to a peak at about 50 days, then falls off and rises to a second peak at 70 days. No further wilting takes place after 95 to 100 days. Many young pods or cherelles die because of the physiological condition of the tree, more pods being set than the tree's food reserves can support. Like all other tree crops, cocoa has its thinning mechanisms. Over 80 percent of cocoa pods may abort prematurely through cherelle wilt (Hadley and Pearson, 1994). Furthermore, trees supporting large numbers of pods often tend to produce smaller pods and beans. Since there is no specific diagnosis on the cause of cherelle wilt, there are many assumptions have been made including physiological disturbance, pest damage, diseases and imbalance nutrient supply.

Competition between cherelles and new shoot to gain nutrient and water has been proven. Cherelle wilt will increase during the emergence of new shoots (Nichols, 1964). N, Ca, Mg and Mn are required in high rate at the early stage of cherelle development. Insufficient in Ca will cause the cherelle loose its tolerant towards fungus and cherelle wilt will continuously occurred even though the development of pods has completed (Shear, 1975). In plant nutrition, Ca is an extremely important mineral but only few soils contain adequate amount of Ca. Many soils of the humid tropics contain insufficient Ca to maintain a suitable degree of base saturation of the soil colloids. In such soils, exchangeable Al dominates the exchange sites of the clay, contributing the excessive soil acidity and soluble Al is toxic to many plants. The amount of Ca in the soil solution is dependent on the amount of exchangeable Ca present (Philip, 1998). The soil factors believed to be of the greatest importance in determining the availability of Ca to plants are the degree of saturation of exchange complex, the types of soil colloids and the nature of the complementary ions adsorbed by the clay.

Chemical properties of soil material provide a broad measure of the capacity of a soil to supply the nutrient requirements of cocoa on a continuing basis. Cocoa is not tolerant to low soil fertility, but can be established provided that there is a suitable management practice. Total N, organic P, the cation exchange capacity and the sum of exchangeable bases (within certain pH limit) are highly positively correlated with the organic matter content of the soil (Room and Ranjit, 1981). A weakly acid soil with pH 6.0 or above and a major fraction of Ca in the exchangeable bases, as well as high organic matter content are considered the favourable soil for cocoa.

The role of soil organic matter also lies in ameliorating non-nutritive stress such as Al toxicity. Organic fertilizers are derived from plants, animals and waste of plantation such as compost, green fertilizer, POME and waste from animals such as blood, urea and bones. Organic matter can improve soil structure and fertility (Ofori-frimpong and Rowell, 1999). With addition of organic matter, a sandy soil will be more fertile which increase soil water holding capacity and soil structure will be improved. There are a few functions of soil organic matter which include nutrients storage such as N, P, S, increase cation exchange capacity, provide energy for soil microorganisms' activities and stabilize the soil structure (Shamshuddin *et al*., 2004). High organic matter will increase soil aggregates stability.

Marginal soils with low fertility are mainly available for cocoa plantation while areas suitable have been replanted with other crops. Low yield in such soils associated with low quality of cocoa. Many attempts have been made to solve this problem, as the cocoa dry bean yield keep decreasing constantly. Poor cocoa beans quality contributes to the lower price of Malaysian cocoa beans. The current average yield/ha per year is 1.1 tonnes, which is still far behind the target yield of 1.5 tonnes. Economically, the most important current product of cocoa tree is in the cocoa beans which can be further processed into cocoa butter and other industrial products. The perfect management will produce bigger cocoa beans with average of 1 g per dry bean with thinner cotyledons.

There are a few ways of producing most of the best yield and quality of the crops which includes additional mineral fertilizers, especially in developing countries, the use of new varieties allowing for more or better harvests, of new agricultural techniques and other agrochemicals (herbicides etc.) (Eibner, 1985). Fertilizer recommendations for cocoa are not possible without adequate knowledge of the soils of the area and their responsiveness to applied fertilizers. This can only be achieved through soil testing and field experimentation. It is generally assumed that agricultural systems with perennial crops are more sustainable than systems with annual crops. Soil erosion is negligible and perennial crops have more closed nutrient cycling. Moreover, inorganic fertilizers are used more commonly in perennial crops so that soil fertility decline and nutrient mining are less likely to occur (Hartemink, 2005). The need for a more intensive and economic agricultural production has led to a balance of nutrients that would combine the positive characteristics of both organic-based fertilizers and foliar fertilizers.