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INFLUENCE OF SOIL EXCHANGEABLE CATIONS ON GROWTH, NUTRIENT UPTAKE AND PHYSIOLOGY OF OIL PALM SEEDLINGS

AHMAD AFANDI BIN MURDI

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By

AHMAD AFANDI BIN MURDI

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

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Dedicated to Suhaili, Amirul Haziq
Nur Hanisa and Nur Hasya

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

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Chairman : Associate Professor Ahmad Husni Mohd Hanif, PhD

Faculty : Agriculture

Increasing the efficiency of nutrient uptake can significantly reduce the cost of production, since fertilizer cost is about 30% of total cost of oil palm production. Despite many agronomic trials on the response of oil palm to various fertilizers, there were few published information on the multidisciplinary study of physiological responses with cations e.g. potassium (K), calcium (Ca) and magnesium (Mg). Therefore, this study is necessary to increase efficiency in the oil palm nutrient management system through multidisciplinary aspects of soil and plant physiology. The trial was conducted in the nursery of the Malaysian Palm Oil Board (MPOB) Research Station in Lahad Datu, Sabah. Oil palm seedlings were grown in polybag filled with two types of soil i.e Semporna Family which contain high exchangeable Ca or Lumpongan Family with low exchangeable Ca. Semporna soil was tested at 3^2 levels of K and Mg and Lumpongan was tested at 3^3 levels of K, Ca and Mg with three replicates. Among the parameters studied were vegetative measurements, relative chlorophyll content and leaf relative water content. Destructive samplings of whole plants were done and seedlings were separated into rachis, pinnae, stem and roots. The tissues were then used to determine K, Mg and Ca concentrations and uptake. Soil samples were taken at the beginning and the end of trials and subsequently analysed for cations content. Leaf gas exchange parameters were measured using a portable infrared gas analyser two weeks before the final destructive sampling. Pre-treatment analysis showed that the exchangeable K, Mg and Ca in Lumpongan soil were 0.35, 6.74 and 6.07 cmol (+) kg^{-1} respectively. Meanwhile, in Semporna soil the exchangeable K, Mg and Ca were 0.17, 1.22 and 33.50 cmol (+) kg^{-1}. Application of cation fertilizers significantly increased respective exchangeable cations in both soils. There were non significant increases in seedling dry matter components with regards of cations treatments in both soils. The concentration and uptake of K in seedling components were increased significantly by K fertilizer in both soils. Magnesium fertilizer was not recommended on Lumpongan soil but 6.69 g of Mg per seedling are needed to sustain the growth of seedling in Semporna soil. The seedling recovery efficiency for K and Ca in Lumpongan soil was about 3.65 and 1.21%, respectively. Meanwhile, in Semporna soil the recovery efficiency for K and Mg was about 4.56 and 2.54%, respectively. This study showed that total cation in oil palm seedling leaves was largely determined by soil exchangeable calcium rather than K or Mg. The proportion of individual tissue cation to total cations was fairly constant, i.e about 29% if the soil exchangeable calcium is high (> 25 cmol (+) kg^{-1}). This was considered sufficiently balance for oil palm nutrient requirement. However, excessive amount of exchangeable Mg in soil (> 4.75 cmol (+) kg^{-1}) such as Lumpongan soil resulted in an imbalance proportion of individual tissue cation to total cation. The oil palm seedling vegetative growth, leaf tissues turgidity and chlorophyll content exhibited less sensitivity to cation treatments as indicated by non significant difference in both soils. Excessive amount of Ca in Semporna soil contributed to low shoot to root ratio of the seedlings by 7 to 9% as compared to Lumpongan soil. The photosynthesis rate on Lumpongan and Semporna soils ranged from 8.52 to 9.45 µmol $m^{-2}s^{-1}$ and 7.07 to 8.66 µmol $m^{-2}s^{-1}$, respectively. This implies that, cations treatments did not significantly reduce the photosynthesis rate. It was also concluded that the stomata conductance and intercellular CO_2 concentrations of seedlings in both soils were adequate to support leaf gas exchange as indicated by non significant different between treatments. In conclusion, combinations of K1 (35.11 g K) + Mg0 (0 g Mg) + Ca1 (14 g Ca) and K2 (70.22 g K) + Mg1 (6.69 g Mg) were recommended for sustaining optimum growth, nutrient uptake and physiological requirement in oil palm seedlings grown in Lumpongan and Semporna soils, respectively. These combinations take into account the total dry matter production, uptake, recovery efficiency and physiological characteristics of oil palm seedlings at each cation levels.

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

PENGARUH TUKARGANTI KATION TANAH TERHADAP TUMBESARAN, PENGAMBILAN NUTRIEN DAN FISIOLOGI ANAKBENIH SAWIT

Oleh

AHMAD AFANDI BIN MURDI

Jun 2007

Pengerusi : Profesor Madya Ahmad Husni Mohd Hanif, PhD

Fakulti : Pertanian

Peningkatan kecekapan pengambilan nutrien akan turut menurunkan kos pengeluaran, ini kerana kos pembajaan merangkumi 30% daripada keseluruhan kos pengeluaran sawit. Meskipun, banyak penyelidikan agronomi yang telah dilaksanakan berkaitan gerakbalas sawit ke atas berbagai jenis baja, tetapi sedikit yang diterbitkan berkaitan kajian fisiologi sawit terhadap kation seperti Kalium (K), Kalsium (Ca) dan Magnesium (Mg). Oleh itu, kajian ini penting untuk meningkatkan kecekapan pengurusan nutrien sawit melalui pendekatan multidisiplin berkaitan tanah dan fisiologi pokok. Kajian dijalankan di tapak semaian Stesen Penyelidikan Lembaga Minyak Sawit Malaysia (MPOB) di Lahad Datu, Sabah. Anakbenih disemai di atas dua jenis tanah iaitu yang mengandungi Ca tukarganti yang tinggi (Famili Semporna) dan tanah rendah kandungan tukarganti Ca (Famili Lumpongan). Tanah Semporna diuji dengan kadar 3^2 K dan Mg manakala tanah Lumpongan dengan kadar 3^3 K, Ca dan Mg sebanyak tiga ulangan. Di antara parameter yang

diukur ialah pengukuran tampang, kandungan klorofil dan kandungan bandingan air laidaun. Keseluruhan pokok diagihkan mengikut bahagian pelepah, laidaun, batang dan akar. Seterusnya penentuan kandungan dan pengambilan K, Ca dan Mg. Sampel tanah diambil sebelum dan selepas kajian, seterusnya dijalankan penganalisaan kandungan kation. Pengukuran pertukaran gas daun dilakukan menggunakan alat “infrared gas analyser” dua minggu sebelum pengambilan sampel terakhir. Analisis awal tanah Lumpongan menunjukkan kandungan tukarganti K, Mg dan Ca adalah 0.35, 6.74 dan 6.07 cmol (+) kg^{-1} manakala, di tanah Semporna kandungan tukarganti K, Mg dan Ca adalah 0.17, 1.22 dan 33.50 cmol (+) kg^{-1}. Penggunaan baja kation meningkatkan kandungan setiap tukarganti kation secara ketara di kedua-dua tanah. Rawatan kation menunjukkan peningkatan pengeluaran bahan kering setiap komposisi anakbenih yang tidak ketara di kedua-dua tanah. Kepekatan dan pengambilan K dalam komposisi anakbenih meningkat secara ketara hasil pembajaan K untuk setiap jenis tanah. Pembajaan Mg tidak disyorkan di tanah Lumpongan tetapi baja Mg 6.69 g sepokok diperlukan bagi menampung tumbesaran anakbenih di tanah Semporna. Kecekapan pengambilan semula bagi K dan Ca di tanah Lumpongan ialah 3.65 dan 1.21% manakala, di tanah Semporna kecekapan pengambilan semula untuk K dan Mg ialah 4.56 dan 2.54%. Kajian menunjukkan bahawa, jumlah kation pada anakbenih sawit terutamanya di dalam laidaun sangat dipengaruhi oleh kandungan tukarganti Ca dalam tanah berbanding tukarganti K atau Mg. Pembahagian peratus setiap kation dibanding jumlah kation adalah seimbang pada 29% sekiranya kandungan tukarganti Ca adalah tinggi (> 25 cmol (+) kg^{-1}), ianya dianggap mencukupi dan seimbang untuk keperluan nutrien sawit. Walau bagaimanapun, jika kandungan tukarganti Mg adalah tinggi (> 4.75 cmol (+) kg^{-1})

sepertimana yang terdapat pada tanah Lumpongan akan menyebabkan ketidakseimbangan pembahagian kation berbanding dengan jumlah kation. Tumbesaran anakbenih sawit di kedua-dua tanah kurang mempamerkan kepekaannya terhadap rawatan kation. Ini dibuktikan melalui tumbesaran, ketegasan tisu laidaun dan kandungan klorofil yang tidak ketara perbezaanya. Kandungan Ca yang berlebihan seperti di tanah Semporna menyumbang kepada nisbah pucuk kepada akar anakbenih yang rendah di antara 7 hingga 9 % berbanding tanah Lumpongan. Kadar fotosintesis untuk anakbenih di tanah Lumpongan dan Semporna masing-masing pada 8.52 hingga 9.45 μmol $m^{-2}s^{-1}$ dan 7.07 hingga 8.66 μmol $m^{-2}s^{-1}$. Rawatan kation disifatkan tidak memberikan kesan yang ketara terhadap penurunan kadar fotosintesis anakbenih. Turut disimpulkan ialah, purata nilai konduktan stomata dan kepekatan CO_2 antara sel mencukupi bagi menampung pertukaran gas daun, sepertimana yang dibuktikan melalui perbezaan yang tidak ketara nilai keduanya melalui rawatan kation. Hasil kajian merumuskan bahawa, kombinasi K1 (35.11 g K) + Mg0 (0 g Mg) + Ca1 (14 g Ca) di tanah Lumpongan dan K2 (70.22 g K) + Mg1 (6.69 g Mg) bagi tanah Semporna disyorkan untuk menampung tumbesaran, pengambilan nutrien dan keperluan fisiologi anakbenih sawit. Kombinasi tersebut dipilih setelah mengambil kira pengeluaran berat kering, pengambilan semula dan ciri-ciri fisiologi anakbenih sawit bagi setiap tahap kation.

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I certify that an Examination Committee has met on 19th June 2007 to conduct the final examination of Ahmad Afandi Bin Murdi on his Master of Agricultural Science thesis entitle "Influence of Soil Exchangeable Cations on Growth, Nutrient Uptake and Physiology of Oil Palm Seedlings" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the student be awarded the degree of Master of Agricultural Science.

Members of the Examination Committee are as follows:

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

Mohamed Hanafi Musa, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Zakaria Wahab, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Zin Zawawi Zakari, PhD
Malaysian Palm Oil Board
(External Examiner)

HASANAH MOHD. GHAZALI, PhD
Professor and Deputy Dean
School of Graduates Studies
Universiti Putra Malaysia

Date: 24 October 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 Agricultural Science. The members of the Supervisory Committee are as follows:

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

Mohd Rafii Hj. Yusop, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Mohd Haniff Harun, PhD
Crop Physiology Group
Malaysian Palm Oil Board
(Member)

AINI IDERIS, PhD
Professor and Dean
School of Graduates Studies
Universiti Putra Malaysia

Date: 15 November 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.

AHMAD AFANDI BIN MURDI

Date : 4 October 2007

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CHAPTER I

INTRODUCTION

The primary objectives of oil palm agronomy research are to optimize yield and to reduce cost of production. Productions cost can be reduced by increasing the efficiency of nutrient uptake, since fertilizers cost is about 30% of total costs of production. In view of the very low nutrient content of most soils where oil palm is grown, adequate and balanced nutrient applications are required for optimal growth and high yield (Tarmizi *et al*., 2003). Therefore, basic studies are needed to understand the relationships between soil-fertilizer-plant in maintaining optimum nutrition and the mechanisms of oil palm response in terms of dry matter and nutrients allocation. Nutrient use efficiency can be achieved by balancing the external nutrient inputs.

Through intensive research and development, much knowledge and information have been obtained on nutrient management in oil palm. There are still areas where improvement can be made, such as by exploiting of cations nutrient such as potassium, magnesium and calcium. The main function of cation are to balance the charge of anions or each cation absorbed, so as to maintain a neutral charge balance, except when NH_4^+ is abundant (Henry and Boyd, 1996).

Therefore, each cation will assert an effect on the optimal ratio for optimal growth and maximum yield. The antagonistic interaction of K, Ca and Mg was clearly shown on Semporna soil families, where Ca constitutes more than 70% of the ratio of the three exchangeable bases, resulting in an imbalance uptake of Mg and K and consequently affects the growth and yield of oil palm (Afandi *et al*., 2002).

Cation, such as potassium plays an important role in cell extension, stomata regulation and other factors related to water stress. Accumulation of K produces a gradient of osmotic pressure that draws water into root. Plant deficient in K has less ability to absorb water and is subjected more to water stress. The effects of K on oil to bunch ratio in oil palms have been reported (Tarmizi, 2000).

Another essential cation is Mg which is associated with chlorophyll and its ability to converts light energy into biochemical energy during photosynthesis. Inadequate Mg in palms will reduce the oil to bunch ratio (Prabowo and Foster, 1998) and its relation to K in oil palms has been well studied (Chan and Rajaratnam, 1977; Breure, 1982).

Knowledge of some physiological aspects, such as photosynthesis, stomatal conductance and leaf relative water content of the oil palm is important for proper agronomic managements. Any limitations on physiological process, such as nutrient supply will reduce efficiency in the oil palm production system and affecting the dry matter production and yield. In general, the rate of dry matter production of crop is determined by physiological processes, such as photosynthesis, respiration, stomata conductance, translocation and transpiration. Therefore, understanding the physiological role of mineral nutrients is essential in order to increase fertilizer efficiency.

Despite many agronomic trials on the response of oil palm to various fertilizers, there is little published information on the interdisciplinary study of accumulation and partitioning of cation nutrients in relation to physiological responses during its growth. Measurements of photosynthesis in oil palm production system are necessary for comparing and understanding productivity at leaf, palm or community level as well as their response to environmental stress (Haniff, 2005).

The objectives of this study were: (i) To quantify K, Ca and Mg concentration and uptake in various parts of oil palm seedling and their relation to oil palm seedling growth, and (ii) To quantify physiology responses of oil palm seedlings in relation to K, Ca and Mg uptake.

CHAPTER II

LITERATURE REVIEW

The Performance of Oil Palm (*Elaeis guineensis* Jacq.) in Malaysia

Total area planted with oil palm in Malaysia in 2005 was about 4.05 million hectares. Sabah remained the largest oil palm planted state with 1.2 million hectares or 30% of total area. As the major crop for vegetable oil in the world, palm and kernel oils represent almost 28% of the total vegetable oil production in the global market. The performance of the Malaysian oil palm industry in 2004 and half yearly 2005 remained competitive compared with other crops.

The crude palm oil (CPO) production was increased to the highest level in the Malaysian oil palm industry's history, increasing by 4.7% or 0.63 million tonnes to 13.98 million tonnes from 13.35 million tonnes in 2003. Improvement in the oil extraction rate from 19.75% in 2003 to 20.03% in 2004 and expansion of mature area are the main contribution of the significant increased of CPO production. However, the fresh fruit bunches (FFB) yield per hectare decreased by 2.1% to 18.60 tonnes from 18.99 tonnes in 2003 due to dry period encountered in early 2004 (MPOB, 2005).

The oil palm sector had contributed significantly to the Malaysia's economy during the 1997/98 regional financial crisis. However, its future expansion is going to be limited by several factors such as depletion of prime soils for planting, shortage of workers and rising costs of labour and material (Afandi *et al*., 2002).

In Sabah alone, there is a trend lately to develop area previously classified as marginal for agriculture including oil palm. As an example, there is a rapid increase in oil palm hectarage in the Keningau – Sook plain which is located at an altitude of about 370 m above sea level, and situated in a rain – shadow area with distinct dry season (Deratil *et al.*, 2001).

Yield Performance and Nutritional Requirements

The theoretical potential oil yield of oil palm has been estimated to be about 17 t ha^{-1} (Corley, 1985) however the recorded average oil yields in Malaysia is about 3.6 t ha^{-1} (Ng *et al.*, 2003). Due to its large production of FFB yield and oil per hectare per year, therefore oil palm required large demand for nutrients as compared to the other crops such as soybean, seed rape and sunflower. An attempt had been made to reach the theoretical potential oil yield of oil palm through tissue culture (Ng *et al.*, 2003).

The limiting factors that may restrict yields include inadequate rainfall, shallow soil depth, slope and poor drainage, which may reduce nutrient requirement estimates. Tarmizi *et al.*(1999) incorporated the environmental data, soil chemical and texture, foliar nutrient ratio, total leaf cation balance and other factors in the oil palm fertilizer recommendation system called “Oil Palm Efficient Nutrient System” or OPENS (*Figure 1*).

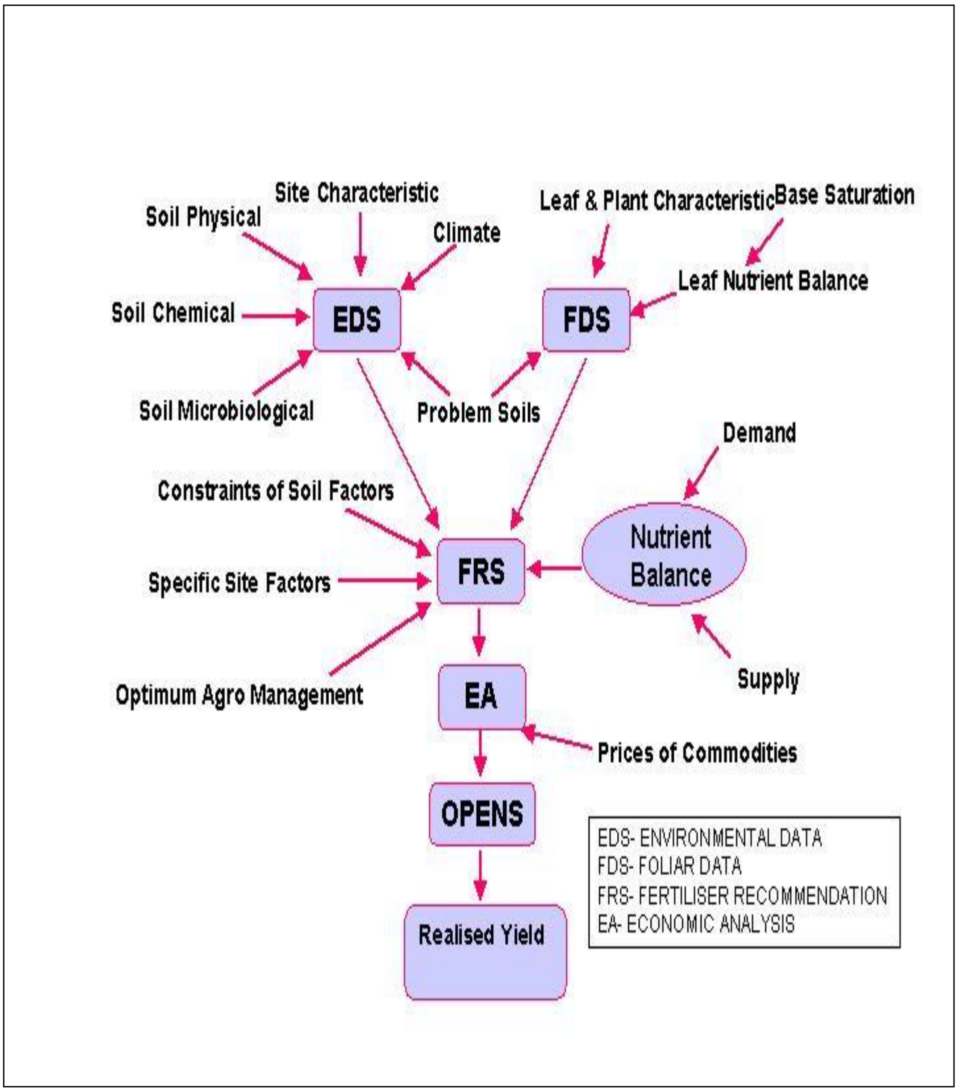

Figure 1: Oil Palm Efficient Nutrient System (OPENS)

The nutrient requirements will depend significantly on the maximum site yield potential if the agro-management practices, such as planting of cover crops, pruning intensity and planting density are standardized. This is because fertilizers increased dry matter production mainly by improving canopy efficiency (Squire, 1983).