UNIVERSITI PUTRA MALAYSIA

PHYSIOLOGY AND GROWTH OF TWO PROGENIES OF OIL PALM SEEDLING AFFECTED BY DIFFERENT PLACEMENTS OF COMPOUND FERTILIZER

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MASTER OF SCIENCE
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By

GAN CHUN HUNG

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

March 2013

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DEDICATION

To dedicate all the people who involved in my study especially my parents, brother, supervisory committee members, Associate Professor Dr Hawa ZE Jaafar, Professor Dr. Zaharah Abdul Rahman, Dr. Haniff Harun, Mr. Hafiz, Mr. Tay Wai Chian, Ms. Marzita, Mr. They Hock Kim and all the staffs in UPM and MPOB. Thanks for their generous assistance and helpful advice.

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

PHYSIOLOGY AND GROWTH OF TWO PROGENIES OF OIL PALM SEEDLING AFFECTED BY DIFFERENT PLACEMENTS OF COMPOUND FERTILIZER

By

GAN CHUN HUNG

March 2013

Chairman : Associate Professor Hawa ZE Jaafar, PhD

Faculty : Agriculture

This project was conducted to determine the effect of fertilizer placement to the growth, physiological and nutrient changes on two progenies of *Deli Avros* (PUP217 and PBC4324) of oil palm seedlings. The oil palm seedlings were cultivated in a polybag containing Rengam series soils. This experiment was conducted in a glass house in Ladang 2 of Universiti Putra Malaysia. Treatments were applied one month after cultivation to stabilize the crops. Four treatments with T0: No fertilizer placement; T1: broadcast fertilizer placement; T2: 15 cm deep fertilizer placement and T3: 30 cm deep fertilizer placement were tested in this study. The experiment is a 2 factorial experiment arranged in Randomize Complete Block Design (RCBD) with three replications. Physiological and growth data such as net photosynthesis (A), stomata conductance (g_s), transpiration rate (E), chlorophyll content, plant height, bole diameter, leaf number, total leaf area, specific leaf area,

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total biomass, leaf biomass, bole biomass and root biomass, root shoot ratio, relative growth rate, root length, root number, root lifespan and root distribution were measured. From the result, it indicated that no significant interaction between progeny and fertilizer placement on photosynthesis rate, stomata conductance, transpiration rate, chlorophyll content, plant height, bole diameter, total leaf area, specific leaf area, total biomass, leaf biomass, bole biomass, root biomass, root shoot ratio, relative growth rate, root length and root number except leaf number. It showed significant interaction between progeny and fertilizer placement. In leaf gas exchange parameter, the photosynthesis rate, stomata conductance, transpiration rate and chlorophyll content were influenced by fertilizer placements ($P \leq 0.05$). For the growth parameters, it was also found that applying different depths of fertilizer placement ($P \leq 0.05$) had increased plant height, bole diameter, total leaf area, total biomass, leaf biomass, bole biomass, root biomass, root shoot ratio and relative growth rate. So as plant height, bole diameter, total leaf area, specific leaf area (SLA), total biomass, leaf biomass, bole biomass, root biomass, root length and root number. They were only significantly influenced by the progeny ($P<0.05$). From the experiment, it can be concluded that deep fertilizer placement at 30 cm are as effective as broadcast application as shown by growth and leaf gas exchange parameters analysis, so that It is economic of treated plants and just keep sufficient nutrient placements needed.

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

PENGARUH PENEMPATAN BAJA KOMPAUN TERHADAP FISIOLOGI DAN PERTUMBUHAN DUA PROGENI ANAK KELAPA SAWIT

Oleh

GAN CHUN HUNG

Mac 2013

Pengerusi : Profesor Madya Hawa ZE Jaafar, PhD

Fakulti : Pertanian

Kajian ini dijalankan untuk mengkaji kesan kedalaman penempatan baja kompaun terhadap tindakbalas fisiologi dan pertumbuhan anak pokok kelapa sawit. Dua jenis progeni anak pokok sawit *Deli Avros* (PUP217 dan PBC4324) ditanam dalam polibeg yang mengandungi tanah jenis siri Rengam. Rawatan dimulakan sebulan selepas anak benih tersebut serasi dengan persekitaran rumah kaca. Terdapat empat jenis kedalaman penempatan baja digunanakan dalam kajian tersebut iaitu T0: kawalan; T1 : penempatan baja di permukaan tanah; T2: penempatan baja di 15 cm dari permukaan tanah dan T3: penempatan baja di 30 cm dari permukaan tanah. Kajian ini dilakukan dalam rumah kaca di Rumah Kaca Fakulti Pertanian Ladang 2, Universiti Putra Malaysia. Rekabentuk kajian ialah 2 faktorial ”Randomize Complete Block Design (RCBD)” dengan tiga replikasi setiap satu rawatan. Data pertumbuhan dan fisiologi seperti kadar fotosintesis (A), kekonduksian

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stomata (gs), kadar transpirasi (E), kandungan klorofil, dan ketinggian pokok, diameter batang, bilangan daun, keluasan daun dan jumlah berat kering, daun berat kering, batang berat kering, akar berat kering, spesifik keluasan daun, kadar nisbah akar daun, kadar relatif pertumbuhan, kepanjangan akar, bilangan akar, kepanjangan umur akar diukur. Keputusan menunjukkan tiada interaksi antara progeni and penempatan baja kepada fisiologi dan pertumbuhan anak kelapa sawait. Hanya bilangan daun dipengaruhi oleh interaksi progeni dan penempatan baja. Bagi aspek fisiologi, fotosintesis, kekonduksian stomata, kadar tranpirasi dan kandungan klorofil dipengaruhi oleh penempatan baja ($P \leq 0.05$). Ketinggian pokok, diameter batang, keluasan daun dan jumlah berat kering, daun berat kering, batang berat kering, akar berat kering, spesifik keluasan daun, kadar nisbah akar daun, kadar relatif pertumbuhan, kepanjangan akar, bilangan akar, kepanjangan umur dipengaruhi oleh penempatan baja ($P \leq 0.05$). Begitu juga ketinggian pokok, diameter batang, keluasan daun dan jumlah berat kering, daun berat kering, batang berat kering, akar berat kering, spesifik keluasan daun, kepanjangan akar dan bilangan akar dipengaruhi oleh progeni ($P \leq 0.05$). Dari kajian ini, kesimpulan bahawa kesan kedalaman penempatan baja pada 30cm adalah sama berkesan seperti penempatan baja atas permukaan tanah yang boleh di lihat di dalam analisis pertumbuhan dan pertukaran gas anak pokok kelapa sawit supaya penempatan nutrien sesuai dan cukup sahaja.

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I certify that a Thesis Examination Committee has met on the 22 March 2013 to conduct the final examination of Gan Chun Hung on his Master of Science thesis entitled “Physiology and Growth of Two Progenies of Oil Palm Seedling Affected by Different Placements of Compound Fertilizer” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the University 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 fulfillment of the requirement for the degree of Master of Science. The members of the supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Unversiti Putra Malaysia or at any other institution.

GAN CHUN HUNG

Date: 22 March 2013

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TABLE OF CONTENTS

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LIST OF TABLES

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LIST OF FIGURES

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LIST OF ABREVIATIONS

%	Percent
o	Degree
‘	Minute
*	Significant at 0.05 probability level
**	Significant at 0.01 probability level
≤	Smaller Than
=	Equal to
A	Net Photosynthesis
ANOVA	Analysis of varians
ATP	Denosine triphosphate
Ca	Calcium
cm	Centimeter
cm^2	Centimeter cubib
CO_2	Carbon dioxide
CH_2O	Carbohydrates
^oC	Degree Celcius
DMRT	Duncan Multiple Range Test
E	Transpiration Rate
g	Gram
g_s	Stomatal Conductance
Ha	Hectares

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K	Potassium
Kg	Kilogram
L	Liter
MAT	Month after treatment
Mg	Magnesium
mg	Miligram
mm	Milimeter
N	Nitrogen
n	Number of samples
n.s	Not significant
P	Phosphorus
R:S	Root and shoot ratio
SAS	Statistical Analysis System
SED	Standard Error Deviation
SLA	Specific leaf area
T0	No compound fertilizer was placed into treatment
T1	Compound fertilizer was placed on the surface
T2	Compound fertilizer was placed in the depth of 15cm
T3	Compound fertilizer was placed in the depth of 30cm
V1	*Dura Deli x Avro* (Ulu Balang)
V2	*Dura Deli x Avro* (Bangi)

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CHAPTER 1

INTRODUCTION

A goal of fertilizer placement in palm oil plants is to maximise root-nutrient contact, especially at the early stages of crop root development, without causing emergence or establishment problems. In order to optimise yield, it is important to place fertilizer in the region that will have the highest density of fine roots, or in a location that the fertilizer will move to this region. An effective placement and timing of fertilizers can maximise both the yield and nutrient use efficiency, thereby increase the net profit for the producer. With the advances in technology, the placement and timing options have increased in the past few decades. A large number of researches have been conducted in the past 25 years on the effects of various placement and timing methods on crop yield, quality, emergence, fertilizer uptake, weeds, and water quality. On the other hand, there is a lack of empirical evidence on oil palm seedling root growth and fertilizer placement. In order to increase the production of the oil palm seedlings, fertilization is used to speed up the growth process.

Fertilizer is the most expensive input in oil palm cultivation and it is estimated to be about 65% of cultivation cost (Chan and Yusof, 1998). For example, at the nursery stage, a large number of replanting oil palm seedlings need a large amount of fertilizer in order to provide sufficient nutrients to oil palm seedlings. The increase cost of fertiliser at the nursery stage inevitably increases the cost in production. The present study aims to find a solution on how to reduce

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fertilizer usage in order to minimise production cost. The fertility status of soils and the soil ability to supply nutrient to the oil palms seedling are important to ensure healthy seedlings. Various factors affect the nutrient supplying characteristics of soils on the growing plants, differently but interdependently. These include soil nutrient interaction, root-nutrient interaction, soil pH, soil water status, soil ecology (environmental), soil morphology and also oil palm seedling morphology and physiology.

The present research focuses on the assessment of the fertility status of soils and the measurement of the parameters that contribute to the nutrients availabilities, mobility and the soil supplying properties relative to the oil palm seedlings. Such informative background is valuable to the successful manipulation of fertilization strategy for the purpose of enhancing productivity.

Efficient and effective application of fertilisers to the oil palm seedlings can enhance productivity. One way to ensure effective and efficient fertilizer application is by keeping losses of applied fertilizer to a minimum. It is believed that root growth in the sub-soiled channels would be stimulated in this way and that yield would be increased as a result of deep fertilizer placement and better growing condition. Nutrient loss can occur in various ways, but surface run off (Kee *et al.*, 2004), volatilization, leaching and denitrification are the major pathways. Broadcast is the cheapest means of fertilizer application in plantation industry, but it can also increase run-off losses in fertilizer.

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Therefore, the general objective of this study is to determine the effect of fertilizer placement on the growth and physiological changes of oil palm seedling. The study hypothesises that the placement of fertilizer at different depths will enhance growth due to increased efficiency of nutrient use and improved physiological aspect.

In order to meet the objective, the experiment was carried out in this study to:

1. determine changes in gas exchange and chlorophyll content of oil palm seedling affected by fertilizer placement;
2. characterise growth characteristics and growth responses of oil palm seedling under different depths of fertilizer placement;
3. identify the relationship between root growth and growth responses of oil palm seedling under different depths of fertilizer placement in rhizotron and,

CHAPTER 2

LITERATURE REVIEW

2.1 Oil palm seedlings

In normal practices, oil palm seedlings are kept in nurseries for about ten to twelve months before they are transplanted in the field. With good management, oil palm can bear its first harvest in about 24 to 36 months after field planting. Seedling stage is the most important stage for oil palm. As a perennial crop that has 20 - 25 years of life span, good establishment during this stage can ensure higher yield for future harvest. Oil palm seeds of poor quality will result in a reduction of yield by as much as 25 percent per year throughout a life span of oil palm. Because of this, discarding of seedlings that have abnormalities is a common procedure in nurseries. About 28 – 30 percent from total seedlings is culled. By doing this, it will ensure that stunted and abnormal palms will not take the space of the good ones in future field establishment. For new areas, oil palm planting needs an extra 28 – 30 percent from the expected usage and this depends on the type of soil and the number of palm per hectare coverage. For instance, for inland soil, about 185 germinated seeds per hectare are needed if field stand of 148 per hectare is sought. Meanwhile, for alluvial soil with field stand of 136 palms per hectare, orders of 173 seeds per hectare are needed to fulfil the planting scheme (Imran *et al*., 2002).

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Figure 2.1. Oil palm seedlings

2.2 Progeny *Deli Avros*

Deli Avros was developed from 38 consignments of seeds imported from various parts of Africa in 1921 – 1922 (Jalani *et al*., 2002). One of the consignments came from the “Djongo” palm in the Eala Botanic Gardens, Bogor and was planted at Aek Pancur in 1922. In Malaysia, Deli Avros material known as BM119 was planted in Banting in 1959.

Jalani *et a.l* (2002) reported that Deli Avros population is precocious and gives high early yields. The palm of Deli Avros is tall and its growth is vigorous. Economically, Deli Avros produces considerably good values for fresh fruit bunch, oil to bunch, oil to yield and total economic products.

2.3 Soil fertility management

Soil fertility management is an excellent reference for environmental and agricultural professionals. It can be defined as “efficient use of all nutrient sources”. The primary challenges in sustaining soil fertility include reducing nutrient losses, maintaining or increasing nutrient storage capacity, promoting

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recycling of plant nutrients, and applying additional nutrients in appropriate amounts. In addition, cultural practices that support the development of healthy, vigorous root systems result in efficient uptake and use of available nutrients. Efficient nutrient management programmes supply plants adequately to sustain maximum crop productivity and profitability while minimising environmental impacts of nutrient use. The quantity of nutrient required by crops varies depending on crop characteristics (crop, yield level, and variety or hybrid), environmental conditions (moisture and temperature), soil characteristics (soil type, soil fertility and landscape position), and soil and crop management.

2.4 Fertilizer placement

The methods of fertilizer placement can have substantial effects on the efficiency of the applied nutrients (Follett *et al*., 1981). Fertilizer placement options generally involve surface or subsurface applications before, at, or after planting. Placement practices depend on the crop and crop rotation, degree of deficiency or soil test level, mobility of nutrient in the soil, degree of acceptable soil disturbance and availability of equipment.

2.4.1 Broadcast fertilizer application

Nutrients are applied uniformly on the soil surface before planting and they can be incorporated by tilling or cultivating. Broadcast applications are particularly well adapted to heavy rates of nutrient application which might be used to increase soil levels of a nutrient. Broadcast applications have the added advantage of allowing combined applications of fertilizers and herbicides.

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However, they are usually considered to be somewhat less efficient than those methods which place nutrients in a specific position in, or on the soil. In no till cropping systems, there is no opportunity for incorporation; thus, broadcast N applications will reduce N recovery by the crop due to enhanced immobilisation, denitrification and volatilisation losses.

2.4.2 Subsurface / Seed band fertilizer application

Solid and fluid fertilizer placement can occur at numerous locations near the seed, depending on the equipment and crop. Commonly, fertilizer is applied 1 to 2 inches directly below the seed or 1 to 3 inches to the side and below the seed, depending on the equipment. These applications are generally used to enhance early seedling vigour, especially in cold and wet soils. Usually, low nutrient rates are applied to avoid germination or seedling damage. This application produces relatively high concentrations of nutrients in soil compared to broadcast application. This may result in higher efficiency of nutrient use for a variety of reasons including slowed nutrient reactions with the soil, placement below the zone of residue concentration, better penetration of the residue in the case of surface banding, and nutrient placement in soil zones that may remain moist longer. Therefore, nutrient absorptions are enhanced.

2.5 Fertilizer usage

2.5.1 The necessity for using fertilizers

The growing pressure on land due to population increase warrants intensive crop production. In order to sustain yield in an intensive system, irrespective of

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soil management technologies being adopted, it becomes imperative to use chemical fertilizer to augment the soil capacity to supply plants nutrients under such systems. Fertilization then becomes inevitable especially in lands under continuous cropping and where the harvested portions are continually removed from the farmlands.

Perennial crops like oil palms continually fix the absorbed nutrients taken up from the soil system to build their plant structure while they grow and return only little of the fixed nutrients through dead fronds falls. Such fixed nutrients (especially nitrogen and phosphorus) are organically held in plant body structure and are totally removed from the soil until the plants die and decompose to release the nutrients. The process of nutrient removal by growing crops and the subsequent yields removal is considered as nutrient mining of the soil.

2.5.2 Concept in fertilizer use

In crop production, the idea of fertilizer use is to increase, modify or sustain crop yields. Fertilization in this study is a procedure or a technique for supplying plant nutrients in the form of chemical fertilizer into soil-nutrient-plant system. If the growing plants do not have adequate supply of the nutrients considered to be essential from the soil upon which they are growing, such plants will not be able to accomplish their vegetative growth potential and yields may be hampered. Deficiency of each nutrient has its attending symptom peculiar to it that makes physical diagnosis possible. Thus, supplying such nutrients through chemical fertilization removes deficiency and hence, enhances plants growth.

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2.5.3 Nutrient use uptake

This concept has to do with the extent of recovery of applied fertilizer nutrient by plants. It is expressed as the percentage of ratio of the amount of labelled nutrient recovered by plant to the amount of the labelled nutrient applied in fertilizer. Since the only target of fertilizer application is the crop, researchers have worked in various manipulative ways possible to ensure the efficient uses of applied nutrients by the growing crops. Thus, they have explored various factors and processes that could influence the potential use of applied nutrients. Factors like fertilizer types, the amount, form and solubility of fertilizer and the application methods and timing of application are subjects of research interest in relation to plant nutrients. The effects of soil, crop type, variety, season, climate and the environment have been researched upon with regards to nitrogen, phosphorus and potassium fertilizer uses.

2.6 Shoot-root relationships

The relationship between shoot and roots is of prime importance in understanding the normal pattern of growth and development of a plant and its response to the climatic and edaphic environment. The shoot and root systems are physiologically interdependent, the former providing photosynthesis and hormonal materials for the growth and the development of the latter. Similarly, the root system provides mineral nutrients, water and hormones that are essential for the growth and development of the shoot. This type of interdependent was characterised as a 'functional equilibrium' between the shoot and root activities (Brouwer, 1963; 1965 and 1983).

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Shoot and root growth is very closely coordinated during the vegetative phase of growth and displays algometry whereby they grow in constant proportion as they increase in size (Bray, 1963; Ryle *et al.*, 1981; Hunt, 1990). The ratio of shoot and root (S/R) allocation of dry weight is a central feature of growth especially in relation to the response of the plant to the environment. Shoot to root ration is a very sensitive index as it readily responds to nutrient concentration, temperature, water supply and level of irradiance (Larigauderie *et al*., 1991).

Shoot to root ratio will depend on both internal and external conditions which influence the activity of the supplying organ and the requirements of the dependent organs. The shoot and root specific activities are the rates of photosynthesis and nutrient uptake per unit shoot or root mass respectively, and depend directly on the environmental conditions (Johnson and Thornley, 1987). Plants sense their local environment and this is expressed via the change in S/R and so, the changes and the balance of growth can be considered in terms of the changing relationship between sources (where metabolites are synthesised or nutrients are absorbed) and sink (where they are utilised to create new tissues or maintain the existing tissues).

The highest rate of growth would be expected when there is minimum diversion of metabolites to the roots which is compatible with them providing adequate water, nutrients and growth substances to shoots. Greater root growth would seem to dissipate metabolites which could increase the photosynthetic area since roots are a major sink for assimilation, requiring about twice the amount to

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produce the same unit dry matter as do the shoots (Passioura, 1983). The growth and maintenance of roots are costly as shown in many estimates which indicated that nearly half of the assimilated photosynthetic is exported from leaves to below ground organs (Farrar, 1985).

2.7 The importance of root study

A study on roots in the field is probably justified only when there is reason to believe that the amount of below ground material is likely to be statistically and functionally different to that which might be predicted by the allocation of a fixed amount of photosynthate to a below ground compartment using allometric model, or where there is a need to achieve basic understanding of the system (Atkinson, 1996).

The main reasons for studying roots are:

a. Ecological Significance: In many situations, there is little basic relevant information especially in relation to natural vegetation, such as in the amount of root and distribution of roots weight with depth. This information is needed to answer questions such as, "Why do particular plant species grow in the places they do?"
b. Resource Capture: Roots represent the principal means whereby plants extract resources such as nutrients and water from soil. Current expenditure on irrigation systems and fertilizers attests to the importance of nutrient and water to crop production. An understanding of roots will help to eliminate wastage and adverse environmental effects.

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c. Soil Microbes: The root system represents the major pathway for the flow of carbon to the soil and soil organisms, especially those in the rhizosphere. As rhizophere organisms are responsible for much key process such as N immobilisation, NH_4 oxidation, denitrification and root nodulation, the supply of resources to the soil is potentially critical to the evaluation of soil carbon budgets. In addition, there is an increasing body of information on the effects of plant species on the soil microbial composition. This has gained additional attention and emphasis is given in the debate about the impact of raised atmospheric level of CO_2 and nitrous oxide.

d. Resource Allocation: Information on the relative allocation of resources below ground, above ground and on different types of root and mycorrhizas tells us about the coupling of the plant to its environment.

e. Plant Interaction: Roots represent one of the key means whereby plants of the same and other species interact. These interactions are now being seen both in relation to temperate and tropical multi-crop systems, as means of improving the efficiency of resource use.

f. Soil Structure: The roots and their associated micro flora have a major effect upon soil structure and stability of aggregates. The inputs of organic matter to the soil which they represent will influent key soil properties such as cation exchange capacity.

g. Anchorage: Roots are essential for plant stability and anchorage. While this is particularly important for tree crops, it has significant economic implications for many field crops; e.g., cereals.

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h. Root Products: Roots may be used as an energy source in tropical production systems. They may also be a source of pharmaceutical compounds or of food additives and flavourings.

i. Basic Biological Information: To obtain basic information on a part of the plant that consumes a significant proportion of total resources and to determine the one that has the physiological and developmental interest in its own right.

2.8 The root system of oil palm

Several studies have shown that both cultural practices and spatial variability in soil fertility affect root development and distribution (Bachy, 1964; Purvis, 1956; Taillez, 1971), and that root distribution must be considered when selecting fertilizer placement strategies (Sidhu *et al*., 2002). The root system and its distribution in the soil is thus an important factor affecting efficiency in fertilizer use in oil palm. A number of studies have shown that the greatest quantity of roots is found within 30cm of the soil surface (Purvis, 1956; Ng *et al.*, 1968). The seedling radicle grows at a rate of about 4.4mm/day, to a maximum length of about 50cm (Jourdan and Rey, 1997).

Four categories of roots were distinguished based on the differences in root diameter. Primary roots (6-10mm diameter) are adventitious and may be traced back to the palm bole. Some descend vertically into the soil to provide anchorage, but most descend at various angles and then bend horizontally to provide a framework supporting secondary, tertiary and quaternary roots.

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Secondary roots (2-4mm diameter) branch at right angles to the primary roots and mostly grow upwards the soil surface and then turn to grow horizontally. Tertiary roots (0.7-1.2mm diameter, <15cm length) arise at right angles to secondary roots. Unlignified quaternary roots (0.1-0.3mm diameter, <3cm length) arise at right angles to tertiary roots. Oil palm roots are usually infected by mycorrizal fungi (vesicular-abuscular mycorrhiza). The hyphae of these fungi ramify between the cells of roots and also extend into the soil where they play an important role in the uptake of nutrients, particularly phosphate.

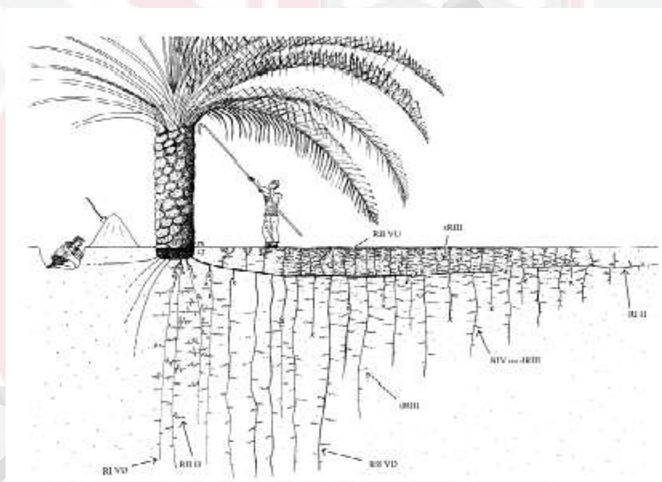

Figure 2.2. Adventitious root system of oil palm

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Figure 2.3. Root structure of oil palm seedlings

2.9 Review of the research regarding deep fertilizer placement

The treatments they tested were rock phosphate (RP) and single superphosphate (SSF) in Bands (1.2m of with in the soil surface), furrows (0.2m deep in the tree rows) or broadcast in the planting holes. The studies have indicated that the eucalyptus root system tended to proliferate around places where the P fertilizer was applied. As an alternative way to guarantee high eucalyptus growth, it has been suggested that low solubility fertilizer could be broadcast and association with a high solubility source could be applied in localised form as in furrows (Barros *et al*., 1990). Fertilizer application increased tree stem volume and overall biomass compared to control pots (no-phosphate fertilizer). The rock phosphate (RP) and single superphosphate (SSF) produced better results when they were applied in furrows due to enhanced absorption of P by the plants that resulted in an increase in dry matter production. The placement in furrows in highest plant recovery rate of the P fertilizer applied. The combination of SSF, places in the planting hole and RP applied in the furrow produced the highest stem volume and shoot dry matter. The results showed that considering the experiment period, the combined use of low and high solubility form of P fertilizer in localised placement may attend the high initial demand of P by the seedling and provide a long term P availability to allow high productivity (Fernandez *et al*., 2000).

The treatment were nutrient placement depths of 15 and 30-cm were compared to broadcast or no application of P and K fertilizers using two corn hybrids at two plant densities. Corn root and shoot responses to 15-cm banded applications of P and K were evaluated. In the result, deeper placement is encouraged on the basis that essential nutrients are placed in more favorable zones for root uptake. Significant and positive corn growth responses to the 30-cm placement depth of P and K were observed. However, overall, results do not indicate that deeper placement of P and K should be used in place of broadcasting (Kline, 2005).

2.10 Rengam series soil

The soils of the Rengam Series were first established in Simpang Rengam near Kluang in Johore (Paramananthan, 2000). The source name is Simpang Rengam Village, Johore, Peninsular Malaysia (Paramananthan, 2000). Rengam Series is probably the most widespread soils in Peninsular Malaysia. They can be found in all states of the Peninsular except Perlis. This type of soils is not found in Sabah and Sarawak. The Rengam Series is a member of Rengam family, which is a fine, kaolin tic, isohyperthermic, and red-yellow Tipik

Lutualemkuts. It typifies this family which is developed over coarse grained acid igneous rocks. The soils have moderately developed medium sub-angular blocky structures and are friable, and they consistently get firmer with depth. They occur on undulating, rolling and hilly terrain and are derived from granitic parent material (Paramananthan, 2000).

Normally, this soil is suitable for the plantation of a wide range of crops such as oil palm, rubber, fruit trees, pines and cash crops on the gentler slopes. The commonest crops grown in this soil are oil palm and rubber. This is because Rengam soils are well drained and their permeability is good. However, a proper fertilizer programme is needed in order to obtain good yields.

In chemical aspects, they have CEC clay of less than 16 mols (+) kg^{-1} clay in all sub horizons between 25 and 100cm depth. Refer to Table 2.3; pH for topsoil is 4.96 with 0.06cmol (+) kg^{-1} soil of potassium exchangeable.

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Table 2.1. Physical and chemical characteristics of Rengam soils

Horizon	Horizon	Bt_1	Bt_2	Bt_3
Depth (cm)	0-18	18-30	30-72	72-140
Clay %	32	34	36	40
Silt %	6	8	5	4
Fine sand %	12	11	10	10
Coarse sand %	50	47	49	46
Organic carbon %	1.14	0.64	0.66	0.46
Total nitrogen %	0.11	0.07	0.05	0.05
C / N ratio	10.4	9.1	13.2	9.2
pH H_20 (2:5)	4.96	4.97	4.98	4.95
Total P in ppm	72	65	58	58
Available P in ppm	5.1	4.5	2.8	2.8
Exchangeable cations – 1N – NHOAc – pH7				
cmol (+) kg^{-1} oil				
Calcium	0.25	0.14	0.08	0.12
Magnesium	0.13	0.07	0.04	0.05
Potassium	0.06	0.04	0.04	0.04
Cation exchange capacity - 1N - NHOAc – pH7				
cmol (+) kg^{-1} soil	4.5	3.5	3.8	3.2
cmol (+) kg^{-1} clay	14.1	10.3	10.5	8
Based saturation%	8	7	4	7

Source: Paramananthan, 2000

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