Better Crops International

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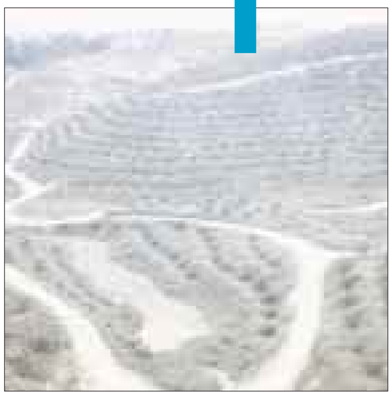

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Oil Palm Nutrition Management

Special Edition

Vol. 13, Issue 1,
May 1999

Better Crops International

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Our Cover: Oil palm production scenes... see page 9 for descriptions.
Photo source: Dr. T.H. Fairhurst and Dr. E. Mutert

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About This Special Issue

I am pleased to introduce this special issue of *Better Crops International* (BCI), in which the various aspects of oil palm production are highlighted. Our recognition of the importance of this world class crop is reflected in the fact that we have devoted 56 pages to this issue of BCI. Ordinarily, the magazine is 24 to 32 pages in length. Special thanks are due Dr. Ernst Mutert and Dr. Thomas Fairhurst, Director and Deputy Director of PPI/PPIC East and Southeast Asia Programs, for their leadership in compiling and organizing the material presented here. We trust you will find the information useful.

David W. Dibb, President
Potash & Phosphate Institute

Introduction to Oil Palm Production

By T.H. Fairhurst and E. Mutert

In this special edition of *Better Crops International*, we offer readers useful insights on oil palm agronomy provided by scientists working in some of the oil palm growing areas worldwide and outline some of the services available from PPI/PPIC.

Over the past 30 years, the worldwide area planted to oil palm (*Elaeis guineensis* Jacq.) has increased by more than 150 percent (**Figure 1**). Most of this increase has taken place in Southeast Asia, with spectacular production increases in Malaysia and Indonesia (**Figure 2**).

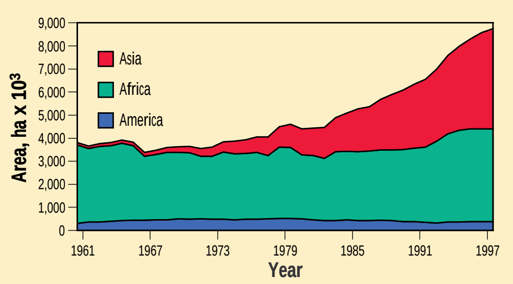

Figure 1. Expansion of the area planted to oil palm in Asia, Africa and America (FAO, 1999).

There are several reasons for this rapid expansion. Crude palm oil and kernel oil prices have been strong, due to the rapid increase in consumption of dietary oils and fats in the developing economies of China and India. This has encouraged investors to develop plantations on the large areas of suitable land found in peninsular Malaysia and the islands of Sumatra in Indonesia and Borneo, where part belongs to Malaysia (Sabah and Sarawak) and part to Indonesia (Kalimantan). So far, the expansion of oil palm in Southeast Asia has not been limited by unmanageable pest and disease problems.

(continued on page 4)

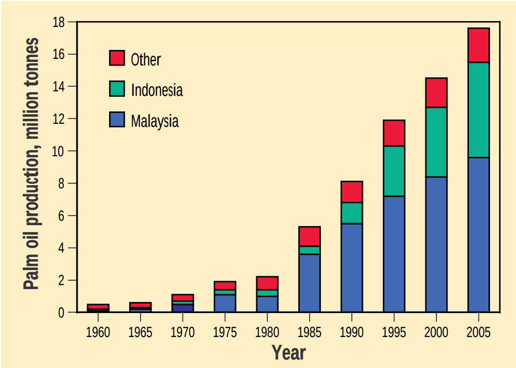

Figure 2. Development of oil palm production in Indonesia and Malaysia compared with the rest of the world, 1960-2005 (PPI/PPIC, 1998).

Crude palm oil and palm kernel oil are adaptable vegetable oils and now have a wide range of markets in the food and oleochemical industries (**Figure 3**). In addition, palm oil has been found a very healthy component of the human diet.

The oil palm remains a formidable competitor with other vegetable oil crops in terms of oil yield per hectare and resource use efficiency due to its unrivalled ability to transform solar energy into vegetable oil. For example, the oil yield from properly maintained oil palms is over six times larger than oil yields from commercially grown rapeseed (**Figure 4**). Additionally, the energy balance expressed by the ratio of energy output to input is wider for oil palm than other commercially grown oil crops (**Figure 5**).

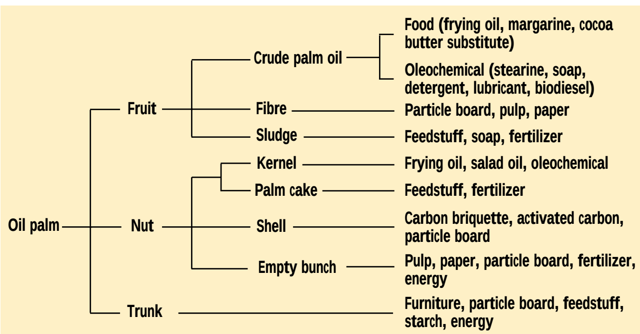

Figure 3. Uses of palm oils and biomass in food and manufacturing industries.

These characteristics will undoubtedly favour the oil palm as a renewable energy source in the future. On most soils, mineral fertilizers are required to sustain large yields and account for most of the energy used in production inputs.

These production indices help to explain why oil palm produces 22 percent of the world's vegetable oil on only 2 percent of the land planted to major vegetable oil crops (**Figure 6**).

Yields are higher in Southeast Asia compared to West Africa due to the effect of more favourable climatic conditions (solar radiation and rainfall distribution) on palm growth and yield (**Figure 7**). Over the past 30 years, yields have increased in both Southeast Asia and Central and South America due to the introduction of modern planting materials and improved field management techniques (particularly mineral nutrition and pest and disease control). The introduction of the pollinating weevil *Elaeidobius kamerunicus* in the 1970s ended the costly and inefficient process of hand pollination and resulted in sharp increases in yield in many oil palm producing regions. However, the proportion of total worldwide palm products...crude palm oil (CPO) and palm kernels...produced in Southeast Asia continues to increase (**Figure 8**) due to increases in the planted area and larger fruit bunch yields.

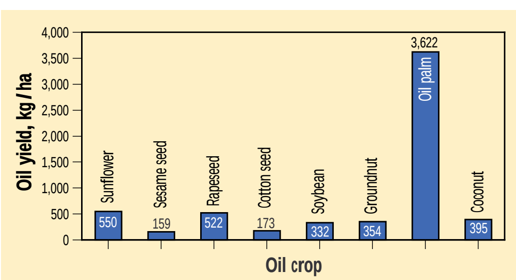

Figure 4. Oil yield (in oil equivalents) for major vegetable oil crops (after Mielke, 1991).

The nutrient demand of oil palm depends on the site's yield potential, which is determined by climatic conditions and the genetic potential of the planting material used. Thus in West Africa, nutrient demand is smaller than in Southeast Asia due to less favourable climatic conditions, particularly the effect of the prolonged dry season, on flowering.

Nutrients are removed in harvested bunches, immobilized in the palm trunk, and recycled through pruned leaves, male flowers, and leaf wash. Nutrients may also be recycled to the field in the form of empty fruit bunches, the principal residue resulting from the factory oil extraction process.

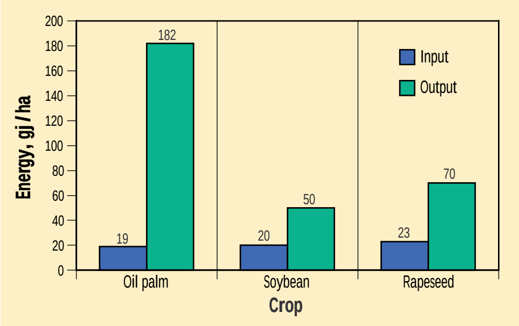

Figure 5. Resource use efficiency for oil palm, soybean and rapeseed (Wood and Corley, 1991).

Nutrient demand is small in the first year following field planting as the palm becomes established and develops a root system. However, there is a steep increase in nutrient requirements in years 3-4-5, but thereafter nutrient demand remains rather stable as shown for nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) in **Figure 9**.

The oil palm has the potential to play an important role in the drive for more sustainable farming systems in the next century. Some of the positive aspects of oil palm cultivation with regard to the environment are as follows:

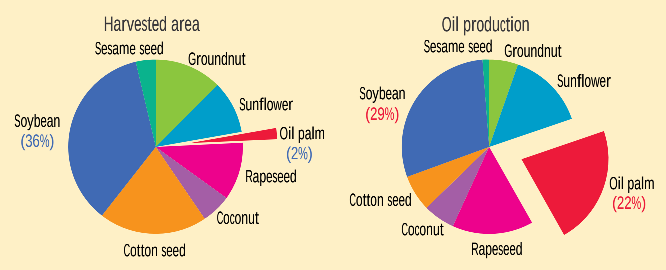

Figure 6. Harvested area and oil production for major vegetable oil crops (Mielke, 1991).

- Although oil palm is most efficiently grown as a monoculture, pesticide use is seldom required, provided proper ground conditions are maintained to supply the habitat necessary for the build-up of naturally occurring pest predators.
- As with other tree crops, the oil palm provides year-round ground cover which protects the soil from erosion.
- Well managed oil palms sequester more carbon (C) per unit area than tropical rainforests, and oil palm estates are predicted to become an important part of C offset management in the next century.
- About 25 percent of the harvested biomass may be returned to the field as a nutrient rich mulch, providing opportunities for growers to recycle nutrients and biomass from more fertile to less fertile parts of the estate.

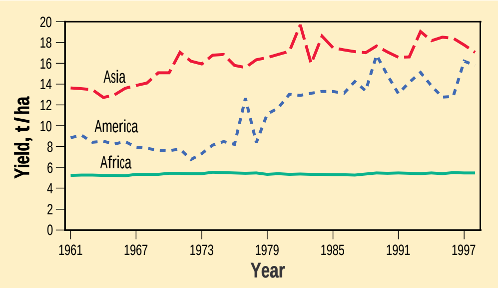

Figure 7. Fruit bunch yield in Latin America (excluding Brazil), Africa, and Asia (FAO, 1999).

Although primarily an estate crop, the oil palm has been successfully adapted to suit the needs of smallholders and has proved a powerful tool for poverty alleviation in developing countries. For example, approximately 2.5 and 1.3 million ha have been developed as

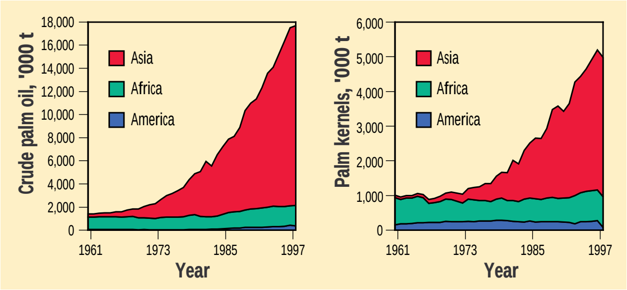

Figure 8. Regional production of CPO and palm kernels in Asia, Africa, and America (FAO, 1998).

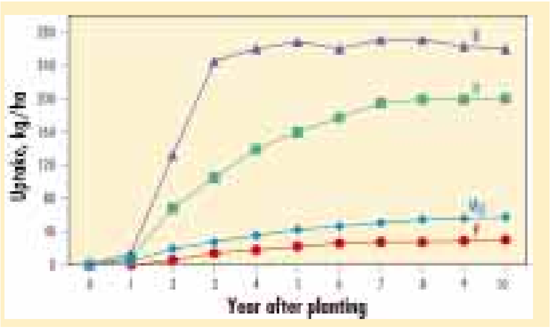

Figure 9. Nutrient uptake in oil palm (Ng, 1977).

smallholder projects, respectively, in Indonesia and Malaysia, bringing improved standards of living to 12 million people. **BCI**

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Twenty-Two Tips for Practical Oil Palm Planters

By E. Mutert and T.H. Fairhurst

Nursery phase

1. Select a suitable source of soil for bag filling (i.e., loamy soil, but not peat or "heavy" clay soil).
2. Select an appropriate irrigation system, based on the characteristics of the water supply (e.g., silt load, quantity available).
3. Incorporate sufficient phosphorus (P) fertilizer in the soil to be used for bag filling.
4. Maintain a properly designed program of nursery fertilizer application and apply fertilizers carefully to avoid leaf scorch. Do not over apply fertilizer.
5. Install a system of open drains to prevent standing water after irrigation events. Install shade (shade netting) in the pre-nursery and in the main nursery (nipah fronds) as required.
6. Cull out all seedlings showing abnormal traits (e.g., runt, narrow leaf, erect type, and fused pinnae).
7. Plan nursery planting so that seedlings are ready when land clearing has been completed. Avoid planting "over-aged" seedlings.




(At top left) A section through a "cut back" seedling ready for planting shows that flower initiation has already begun. Planting shock will cause these potential female flowers to abort.
(At top right) Response is reduced when potash fertilizer is incorrectly applied in a narrow band around the base of the tree.
(At bottom left) Correctly applied potash fertilizer.
(At bottom right) Properly spread urea is uniformly distributed across the application zone.

New development and immature phase

8. Prepare the field for planting properly. Planting points should be properly lined and each point cleared of debris. Avoid planting palms amongst tree stumps and logs that remain after land clearing.
9. Establish a full, vigorous stand of legume cover plants such as *Pueraria phaseoloides*, *Calopogonium mucunoides*, or *Centrosema pubescens* before planting. On low fertility status soils, apply sufficient mineral P and potassium (K) fertilizer to produce rapid canopy development (i.e., 115 to 300 kg P_2O_5/ha and 35 to 60 kg K_2O/ha).
10. Apply sufficient P fertilizer in the planting hole (i.e., 0.05 to 0.1 kg P_2O_5/palm). Mix the P fertilizer with the topsoil before packing the soil around the seedling.
11. Plant seedlings at the correct depth. In mineral soil, the bole should be level with the surrounding soil. In peat soil, use the "hole-in-hole" method after compacting the peat with heavy machinery. Always compact the soil around the seedling during planting as this helps reduce the incidence of planting shock.
12. Install a network of main and field drains to avoid the occurrence of standing water, which results in the appearance of nitrogen (N) deficiency symptoms.
13. Apply sufficient mineral fertilizer for rapid vegetative growth and canopy closure and a short immature phase (i.e., 24 months to first harvest). Wherever possible apply empty bunches as mulch around each planted point at 150 kg/palm.
14. Maintain a proper upkeep program of circle weeding to minimize competition between palms and the legume cover plants and other competitive creeping weeds such as *Mikania cordata* and *Merrimia umbellata*. Carry out regular rounds of supply planting to avoid the occurrence of vacant points due to dead or diseased palms.

Mature phase

15. Clear all palm circles of debris and establish clean circles before commencing harvest. Carry out a census to establish the number of productive and healthy palms.
16. Upgrade main and harvest roads to allow vehicular access to all fields, even during wet weather.

(At left) Properly planted supply palm.
(At right) Applying 0.5 kg ground magnesium limestone (GML) in planting hole on peat soils.

17. For the first three years, harvest bunches without removing the subtending frond to maximize green, productive frond retention during the phase of steep yield ascent.
18. Make optimal use of nutrients contained in empty fruit bunches and pruned fronds by proper recycling and spreading.

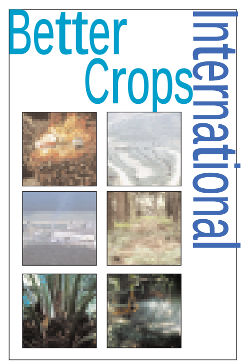
Severe planting shock due to careless planting.

19. Maintain a program of balanced fertilization, based on the results of soil testing and leaf analysis.
20. Establish a simple fertilizer monitoring system using six whole fields as plots and including the following six treatments: Standard Estate Practice (for a particular leaf sampling unit), half N, half K, double N, double K, double N and K.
21. Introduce an independent monitoring unit to evaluate field conditions against agronomic standards defined in field handbooks (e.g., upkeep, fertilizer application, harvesting, and pruning...see page 52).
22. Introduce a computerized database system (e.g., OMP7...see page 52) to store, analyse and retrieve agronomic data. **BCI**

Dr. Mutert is Director and Dr. Fairhurst is Deputy Director, PPI/PPIC East and Southeast Asia Programs.

More About Our Cover Photos

(Top left) High yields are the product of a high number of large fruit bunches per palm. Both of these factors are strongly influenced by palm nutrition and canopy management (planting density and pruning).
(Top right) On steeply sloping land, palms should be planted on terraces to improve access for harvesters and prevent soil erosion.
(Middle left) An aerial view of an oil palm estate and factory.
(Middle right) Properly arranged frond stacks and a well established mixture of ground cover plants under a mature palm stand.
(Bottom left) Leaf sampling teams must be properly trained to identify Frond 17.
(Bottom right) Mechanised fertilizer application is feasible where labour is in short supply and terrain is not too steep.



Management of Phosphorus, Potassium and Magnesium in Mature Oil Palm

By Ian Rankine and T.H. Fairhurst

Phosphorus

Function

Phosphorus (P) is an essential element for plant growth and is particularly important for root growth during the establishment and early growth stages. The chemistry of P in soil is complex and is influenced by many factors, making the interpretation of soil analysis difficult.

Stunted palm due to P deficiency.

The amount of 'available' P in soil depends on the method used to extract P from the soil for measurement. Therefore, where different methods have been used, soil test results should not be compared.

Soil P analysis is best interpreted by referring to a response curve which shows the relationship between the amount of available P in the soil and crop response to applied fertilizer P.

Deficiency Symptoms

- Unlike nitrogen (N), potassium (K) and magnesium (Mg), there are no easily recognizable leaf P deficiency symptoms in oil palm. However, P deficient plants may be stunted with short fronds, and the palm trunk may have a pronounced pyramid shape.
- Other species act as proxy indicators for P deficiency. For example:
  - a) A purplish discoloration on the leaf blade of *Imperata cylindrica* (alang-alang) indicates P deficiency. Leaves of legume cover crops (*Pueraria phaseoloides*) are small, plants are difficult to establish, and root nodulation is sparse when P is deficient.
  - b) When *Melastoma malabathricum* and *Dicranopteris linearis* exclude other inter-row species by their competitive advantage, soil P status may be low.
- In general, a response to P fertilizer is likely when the amount of available P in the soil is less than 15 mg/kg (Bray II method).

Common Causes of P Deficiency

- Areas where topsoil has been removed or lost due to soil erosion (e.g., hill tops, exposed slopes).
- Insufficient phosphate fertilizer applied, especially in plantations that

(At left) On steep land, platforms should be installed to reduce the loss of P fertilizer due to surface run-off and erosion. (At right) The fertilizer should have been sprinkled evenly over the edge of the palm circle.

have produced large yields in the past.
- Applied fertilizer P is fixed by aluminium (Al) and iron (Fe) compounds in low pH (acid) soil and is not available to palm roots for uptake.

Prevention of P Deficiency

- Apply phosphate fertilizer in the nursery, at transplanting, and throughout the immature phase to build up soil P reserves.
- Maintain soil and palm P status with annual applications according to leaf and soil analysis results.
- Install erosion control measures such as bunds, platforms and terraces to reduce losses of native and applied phosphate in surface run-off water and eroded soil.
- Soil P status can be improved by applying large amounts (up to 1 t/ha) of rock phosphate (RP) to legume cover crops during the immature phase.
- A yield of 25 tonnes fresh fruit bunches (FFB)/ha contains about 11 kg P. This is equivalent to 84 kg RP/ha or 0.5 to 0.7 kg RP/palm.

Treatment

- On acid (pH less than 5.5) oil palm soils, P is usually applied in the form of RP. More readily available sources such as triple superphosphate (TSP) and diammonium phosphate (DAP) may be used where a rapid response is required (e.g., where acute deficiency symptoms have been identified).
- Indicative P fertilizer recommendations are given below.

Condition of palms	Application rate, kg/palm P_2O_5	RP
Replacement of nutrients removed	0.15 to 0.2	0.5 to 0.7
Deficiency symptoms observed	0.5 to 0.75	1.7 to 2.5

Fertilizer Management for Efficient Use

- Spread single and compound P fertilizers evenly over the outer edge of the weeded circle and the inter-row space. Most of the fertilizer is applied over the inter-row, but some is applied inside the weeded circle to allow for easy field checking.
- Phosphorus is not mobile in the soil. Therefore, little applied P is lost due to leaching, except in very sandy soils. However, surface-applied P fertilizers are easily lost in run-off and erosion. The installation of

soil erosion controls such as platforms, terraces and bunds increases the efficiency of P fertilizer use. It may be more efficient to apply single P fertilizers over the frond stack where the soil is protected from erosion and the oil palm root density is large.

Application Frequency

- One to 2 rounds/year.

Notes

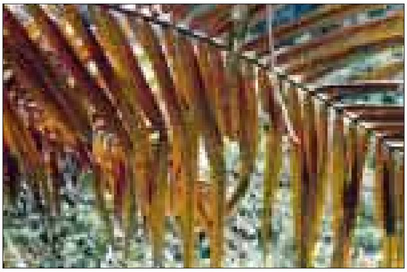
- Phosphorus may contribute to the eutrophication of waterways and algae blooms when P fertilizer is applied on slopes where soil conservation has not been implemented.
- Rock phosphate applied in the palm circle helps to counter the acidifying effect of N fertilizers (e.g., ammonium sulfate and urea) and replaces calcium (Ca), which has been leached due to past large applications of K and Mg fertilizers.

Potassium

Function

Potassium is an essential element for plant growth. It is important for proper stomata function in the leaf. Therefore, K-deficient palms are more susceptible to drought conditions.

Potassium is also important for the transport of assimilates from photosynthesis, enzyme activation, and oil synthesis. It is difficult to predict the response to applied K based on the amount of exchangeable K in the soil.



A frond on a mature palm showing severe K deficiency symptoms.

Potassium affects bunch size, bunch number, and is an important factor in disease resistance.

Potassium deficiency is common on peat and sandy soils and is usually the largest single nutritional factor that determines yield.

Deficiency Symptoms

- Potassium deficiency appears in oil palm as orange spotting, confluent orange spotting, diffused mid-crown yellowing, and white stripe.
- Diffuse or mid-crown yellowing occurs on acid sands and peat soils, particularly after prolonged periods of dry weather. In severe cases, old fronds will suddenly become desiccated and die.
- White stripe is probably caused by an imbalance involving excess N and insufficient K and boron (B).
- Potassium deficiency first appears on older leaves because K is remobilised from the older to younger fronds. Small, initially rectangular spots appear on the frond pinnae and turn bright orange as the spots join to form a reticulate mass. The spots transmit light when held up to a bright light source.
- Chlorotic spots frequently become necrotic and may become the site

of secondary pathogenic infection before frond desiccation.

- Potassium deficiency has been associated with the occurrence of vascular wilt disease, cercospora leaf spot, ganoderma basal stem rot, and the physiological disorders which cause bunch and plant failure.
- Excess K may induce B and Mg deficiency and is reported to decrease the oil to bunch ratio.

Correct application of K fertilizer to the edge of the palm circle.

Common Causes of K Deficiency

- A concentration of exchangeable K in the soil less than 0.15 cmol/kg.
- Potassium deficiency is common in palms planted on:
  - a) Peat soils.
  - b) Sandy soils (low pH) derived from sandstone and granite.
  - c) Acid soils with small, pH-dependent cation exchange capacity.
- Inadequate application of mineral K fertilizer to balance the removal of K from a large yield of fruit bunches over a period of several years. Potassium deficiency may be a problem when insufficient fertilizer K is applied to high yielding clonal oil palms.
- Potassium deficiencies often appear in high yielding progenies when full fruiting begins if insufficient K fertilizer is applied during the immature phase.

Prevention of K Deficiency

- Apply sufficient K fertilizer.
- Recycle K contained in empty bunches or bunch ash (if empty bunches are incinerated).
- Apply empty bunches to sandy soil to build up soil nutrient retention capacity.
- A large amount of K is removed from the field in fruit bunches. A yield of 25 tonnes fresh fruit bunches (FFB)/ha contains about 93 kg K. This is equivalent to 186 kg muriate of potash (MOP)/ha or 1.2 to 1.5 kg MOP/palm.

Treatment

Indicative K fertilizer recommendations are given below.

Condition of palms	Application rate, kg/palm K_2O	MOP
Replacement of nutrients removed	0.7 to 0.9	1.2 to 1.5
Deficiency symptoms observed	1.8 to 3.0	3.0 to 5.0

Fertilizer Management for Efficient Use

- Single and compound K fertilizers are evenly spread over the outer rim of the circle and the surrounding inter-row space. Single K fertilizers can be applied irrespective of weather conditions.
- The large application rates required on sandy textured soils should be

applied in several rounds (e.g., 5 kg MOP/palm in four applications of 1.25 kg/palm).

Application Frequency

- Two to 3 rounds/year (3 to 4 rounds/year on sandy and peat soils).

Notes

- Larger applications may be required on peat soils, sandy soils, and replant areas where little fertilizer has been applied previously.
- The most commonly used K fertilizer is MOP, but langbeinite ($K_2SO_4 \cdot 2MgSO_4$) may also be used where a supply of both K and Mg is required. Langbeinite (Sul-Po-Mag/K-Mag)...22 percent K_2O, 18 percent MgO, 22 percent sulfur (S)...provides a source of K, Mg and S.

Magnesium

Function

Magnesium is the central element in chlorophyll and is therefore essential for efficient photosynthesis. It is also important in phosphate metabolism, plant respiration, and the activation of enzymes.

Deficiency Symptoms

- Initial symptoms appear as olive green to ochre patches on the distal end of the older frond pinnae, particularly those exposed to full sunlight.
- Newly emerged fronds do not normally exhibit deficiency symptoms.
- In cases of more severe deficiency, the fronds become ochre to bright yellow and may eventually become desiccated.
- **A clear diagnostic feature of Mg deficiency is the absence of chlorosis on sections of pinnae shaded from direct sunlight.**
- Chlorotic areas may be invaded by secondary fungal infection (e.g., *Pestalotiopsis gracilis*), which produces purplish spots on the margins and distal ends of frond pinnae.

A young field palm showing Mg deficiency on lower fronds.

Common Causes of Mg Deficiency

- Magnesium deficiency symptoms may be caused by insufficient availability and/or uptake of Mg, but may also be caused when there is an imbalance between Mg, and other cations, e.g., K^+, NH_4^+.
- Magnesium deficiency is often detected in very high rainfall areas (greater than 3,500 mm/year).
- Magnesium deficiency is likely when the amount of soil exchangeable Mg is less than 0.3 cmol/kg.
- Palms planted on sandy textured soils with shallow topsoil (e.g., erod-

ed areas on sloping land).

- Inadequate application of Mg to high yielding palms or to palms on Mg-deficient soils.

Magnesium deficiency in mature frond. Symptoms have not appeared on shaded pinnae.

Prevention of Mg Deficiency

- Check the ratio of exchangeable Ca:Mg and Mg:K in soil analysis data. Nutrient imbalances are likely where the Ca:Mg ratio exceeds 5:1 (e.g., volcanic soils) or Mg:K ratio exceeds 1.2:1.
- A yield of 25 tonnes FFB/ha contains about 20 kg Mg. This is equivalent to 123 kg kieserite ($MgSO_4{\cdot}H_2O$)/ha or 0.75 to 1.0 kg $MgSO_4{\cdot}H_2O$/palm, or 184 kg $K_2SO_4{\cdot}2MgSO_4$/ha or 1.2 to 1.5 kg $K_2SO_4{\cdot}2MgSO_4$/palm.

Treatment

Indicative recommendations for Mg fertilizer are given below.

	Application rate, kg/palm		
Condition of palms	MgO	$MgSO_4{\cdot}H_2O$	$K_2SO_4{\cdot}2MgSO_4$
Replacement of nutrients removed	0.20 to 0.27	0.75 to 1.0	1.1 to 1.5
Deficiency symptoms observed	0.54 to 0.81	2.0 to 3.0	3.0 to 4.5

- On very acid soils, dolomite may be used to provide the basic requirement for Mg. However, kieserite and Sul-Po-Mag/ K-Mag are the preferred sources of more readily plant available Mg.

Fertilizer Management for Efficient Use

- Split large applications of soluble Mg fertilizer (kieserite, Sul-Po-Mag/K-Mag).
- Apply single and compound fertilizers containing Mg over the outer edge of the weeded circle. Dolomite is more effective when dusted over the frond stack to maximise the contact between the particles of dolomite and the soil.
- Response to the application of fertilizer Mg may be increased by an application of empty fruit bunches (EFBs)...30 tonnes EFB/ha; particularly where topsoil has been eroded.

Application Frequency

- Two to 3 rounds/year (3 to 4 rounds/year in sandy soils).

Notes

- Sul-Po-Mag/K-Mag (22 percent K_2O, 18 percent MgO, 22 percent S) provides a source of K, Mg and S.
- Kieserite (27 percent MgO, 23 percent S) provides a source of Mg and S. **BCI**

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Some Nutritional Disorders in Oil Palm

By H.R. von Uexküll and T.H. Fairhurst

Prevention of Oil Palm Disorders with Legume Cover Crops

Except for peat soils, the proper approach to oil palm development begins with the establishment of leguminous cover plants (LCP), immediately following land clearing (**Photo 1**). The LCPs help prevent soil erosion and surface run-off, improve soil structure and palm root development, increase the response to mineral fertilizer in later years, and reduce the danger of micronutrient deficiencies (**Photo 2**). They also help prevent outbreaks of *Oryctes* beetles, which nest in exposed decomposing vegetation. Both phosphorus (P) and potassium (K) fertilizers are needed to maximize the LCP's symbiotic nitrogen (N) fixation potential of approximately 200 kg N/ha/yr and are applied to most soils at 115 to 300 kg P_2O_5/ha and 35 to 60 kg K_2O/ha. Young palms are severely set back where grasses are allowed to dominate the inter-row vegetation (**Photo 3**), particularly on poor soils where the correction of nutrient deficiencies is difficult and costly.

Nitrogen Deficiency – Nitrogen deficiency is frequently observed on young palms grown in areas with non-LCP inter-row vegetation (**Photo**

Photo 1. (At top left) Properly established legume cover plants.
Photo 2. (At top right) During the time frame planting to maturity a full cover crop of *Pueraria phaseoloides* provides 150 to 200 kg N/ha/year and prevents soil erosion.
Photo 3. (At bottom left) Young palms planted without legume cover plants.
Photo 4. (At bottom right) Nitrogen deficiency in palms planted without legume cover plants.

4). Severe N deficiency is rarely seen on old palms. Nitrogen deficiency is expressed in uniformly pale, yellow green leaflets and a sharply reduced growth rate. Midrib tissues become bright yellow. Unlike magnesium (Mg) deficiency, the symptoms are equally pronounced on both upper and lower rank pinnae. Nitrogen deficiency may also be caused by poor drainage.

Phosphorus Deficiency – Phosphorus deficiency does not produce leaf symptoms in oil palm. However, the trunks of affected palms are narrow and tapered (**Photo 5**). The presence of Straits rhododendron (*Melastoma malabathricum*) (**Photo 6**), the tropical bracken fern *Dicranopteris linearis* (**Photo 7**) and alang-alang (*Imperata cylindrica*) (**Photo 8**) all indicate low soil fertility and past soil degradation (**Photo 9**).

Potassium Deficiency – Potassium is the nutrient required by oil palm in largest amounts, and deficiency symptoms develop on most soils unless K fertilizer is applied. Continued K deficiency leads to a progressive decline in yield and plant health. A number of different symptoms indicate K deficiency or an imbalance of K with other elements. The most typical and widespread form of K deficiency is known as "confluent orange spotting" (**Photo 10**). The first signs of K deficiency are pale green spots on the pinnae of older fronds. In a more advanced stage, the rectangular spots become orange-yellow and transmit light when held up to the sky. Later, the tips of leaf pinnae start to dry up. In very severe cases, entire older fronds may dry up. Some palms show symptoms similar to K deficiency known as "genetic orange spotting"

Photo 5. (At top left) The trunk of P deficient palms is small and stunted.
Photo 6. (At top right) *Melastoma malabathricum* indicates low soil pH and soil infertility.
Photo 7. (At bottom left) Inter-row dominated by the tropical bracken fern *Dicranopteris linearis*.
Photo 8. (At bottom right) Phosphorus-deficient alang-alang leaves.

Photo 9. (At top left) Alang-alang leaves show P deficiency on eroded soil.
Photo 10. (At top right) Typical orange spotting symptoms indicate K deficiency.
Photo 11. (At bottom left) Genetic orange spotting in a young mature palm.
Photo 12. (At bottom right) Potassium-deficient cover crop leaf (*Pueraria phaseoloides*) in oil palm.

caused by an inherited defect (**Photo 11**). Potassium deficiency symptoms are also easy to identify in legume cover plants (**Photo 12**).

"White stripe" is a condition related to K deficiency. "White stripe" is a complex physiological disorder, frequently observed on young, vigorously growing palms. An imbalance among N, K, and boron (B) is believed to be involved in most cases. In such cases where affected pinnae are long and soft, an N/K imbalance appears to be the main cause. White stripe symptoms may also be found in combination with confluent orange spotting symptoms. In such cases the symptoms are due to an N/K imbalance and low B status of the leaf. The pinnae shown in **Photo 13** contained N, K and B concentrations of 2.92 percent, 0.78 percent, and 5 mg/kg, respectively.

Boron Deficiency – Boron deficiency is expressed in a range of leaf symptoms. However, in all cases the distal end of leaflets at the tip of the frond are most affected. Pinnae are misshapen, stiff and brittle. "Hook leaf" is one typical symptom of B deficiency (**Photo 14**).

Magnesium Deficiency – Severe Mg deficiency results in the development of bright orange color in older fronds (**Photo 15**). The orange discoloration is very pronounced on the upper rank pinnae exposed to sunlight, whilst lower rank and shaded pinnae remain green (**Photo 16**). Leaf veins also stay green for a longer period. Older fronds dry up and die under conditions of severe Mg deficiency. Planters should be able to distinguish between Mg and K deficiency and a healthy leaf (**Photo 17**).

Manganese Deficiency – Manganese (Mn) deficiency is not common, but has been reported on soils with high exchangeable Mg status and

Photo 13. (At top left) "White stripe" symptoms are widely observed in fast-growing, young (up to 6 years) palms where there is an imbalance among N, K and B.

Photo 14. (At top right) Close-up of hooked leaves indicating B deficiency in oil palm.

Photo 15. (At bottom left) Severe Mg deficiency in a young oil palm.

Photo 16. (At bottom right) Close-up of an oil palm leaf showing Mg deficiency. Shaded lower pinnae remain green, but exposed upper rank pinnae turn orange-yellow.

insufficiently compacted peat soils where palms are suffering from drought. Manganese deficiency shows as a yellowing of interveinal areas (**Photo 18**). In contrast to Mg deficiency, the symptoms are found on young rather than on older fronds. The symptoms are equally pronounced on upper (sun exposed) and lower (shaded) rank pinnae. Manganese deficiency can occur on peat and very sandy soils and is sometimes associated with high leaf Mg status.

Zinc Deficiency – Zinc (Zn) deficiency is not common in oil palm but may be induced under high soil P status and occurs on ultrabasic and ultramafic soils with high soil pH. It is also believed to be a factor involved in the "Peat Yellows" condition found on peat soils. Zinc deficiency has also been reported on shallow peat soils overlying sand, particularly where large amounts of soluble P fertilizer have been applied. It appears as small, narrow white streaks on lower and mid-crown fronds (**Photo 19**). A different condition that produces blotchy leaf symptoms has also been identified tentatively as Zn deficiency.

Iron Deficiency – Iron (Fe) deficiency is very rare in oil palm and occurs where soil pH is very high (i.e., more than 7.5). The deficiency has been observed where palms are grown over coral outcrops or on spots where white ant hills have been levelled. It is easily identified, as symptoms appear first on the youngest fronds, which appear droopy and show diffuse blotchy yellowing and white freckles (**Photo 20**).

Copper Deficiency – Copper (Cu) deficiency is common on deep peat soils and occurs also on very sandy soils. It appears initially as whitish-yellow mottling of younger fronds. As the deficiency intensifies, yellow, mottled, interveinal stripes appear and rusty, brown spots develop on

Photo 17. (At top left) Magnesium (bottom in photo) and K (center in photo) deficient oil palm leaves compared with normal leaf.
Photo 18. (At top right) Manganese deficiency in oil palms is very rare.
Photo 19. (At bottom left) Zinc deficiency in oil palm.
Photo 20. (At bottom right) Iron deficiency in oil palm fronds.




the distal end of leaflets. Affected fronds and leaflets are stunted and leaflets dry up (**Photo 21**).

On sandy soils, palms recover rapidly after a basal application of 50 g $CuSO_4$ (**Photo 22**). On peat soils, lasting correction of Cu deficiency is difficult, as applied $CuSO_4$ is rendered unavailable. A promising method to correct Cu deficiency on peat soil, developed by the authors, is to mix $CuSO_4$ with clay soil and to form tennis-ball sized "copper mudballs" that are placed around the palm and that provide a slow-release source of available Cu.

Crown Disease – Crown disease is probably caused by a genetic disorder that tends to affect young palms (**Photo 23**). In most planting material, palms recover completely from crown disease. Nitrogen fertilizer should not be applied to palms affected by crown disease since this increases the chance of opportunistic pathogenic invasion of affected tissue.

Little Leaf – This syndrome has not been fully explained but has often been confused with B deficiency. The growing point is damaged, sometimes by *Oryctes* beetle. Small, distorted leaves that resemble B deficiency are then produced (**Photo 24**). This is often followed by secondary pathogenic infections in the spear that may lead to spear rot and palm death. **BCI**

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Photo 21. (At top left) Use of peat soil for poly-bag filling may result in severe Cu deficiency of the seedlings. For oil palm nurseries, only mineral soil should be used.

Photo 22. (At top right) Young oil palm recovering from Cu deficiency after an application of $CuSO_4$.

Photo 23. (At bottom left) Crown disease in oil palm.

Photo 24. (At bottom right) Little leaf syndrome.

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Agronomic Management of Oil Palms on Deep Peat

By E. Mutert, T.H. Fairhurst and H.R. von Uexküll

The special soil physicochemical characteristics of deep tropical peat soils and their environments are documented in order to explain the need for adequate drainage, compaction and nutrition in oil palm development on these "problem soils." Successful techniques of land preparation, nursery establishment, and planting procedures are presented together with fertilizer recommendations and yield response on peat soils in comparison to mineral soils.

Worldwide, there are approximately 25 million ha of peat land in oil palm growing countries (**Table 1**). Some of this land is considered suitable for oil palm development due to its rather homogeneous soil features, its constant availability of water, and its flatness – all in support of uniform yield characteristics in oil palm.

Table 1. Global distribution of peat lands in oil palm growing regions (after Andriesse, 1988; Driessen, 1978).

Region	Million ha
Malaysia	2.4
Indonesia	16.0
Others	0.6
Asia	**19.0**
Zaire	1.0
Guinea	0.5
Others	0.6
Africa	**2.1**
Brazil	1.0
Others	2.8
Central & South America	**3.8**
Total	**24.9**

The availability of modern 'heavy' equipment and improvements in knowledge and understanding of oil palm nutrition have now made the development of deep peat technically feasible. However, considerable expenditure for road construction, drainage, soil compaction, soil preparation, and mineral fertilizer, as well as practical experience and knowledge of peat and peat management, is required for successful oil palm development on these "problem soils."

More than 76 percent of the world's tropical peat lands are found in Malaysia and Indonesia. About 90 percent of this area is located on the islands of Borneo and Sumatra, but so far only 200,000 to 300,000 ha have been developed for oil palm.

(At left) Palms tend to lean over when planted in unconsolidated peat. To avoid this, the "hole-in-hole" method must be used.
(At right) Well-established oil palm on peat soil due to proper water management and use of proper planting techniques.

What is peat? Peat soils consist of partly decomposed biomass and develop in depressions or wet coastal areas when the rate of biomass production from adapted vegetation (i.e., mangroves, swamp forest) is greater than the rate of decomposition. This is due to the presence of a permanently high water table that prevents aerobic decomposition of plant debris (Andriesse, 1988; Driessen, 1978).

Ombrogenous peat usually develops in shallow depressions where it soon rises like an hourglass above the water table. As the area develops, it becomes increasingly dependent on nutrient deposition from the atmosphere, contained in rain and dust, which results in the formation of very acid peat soils of low fertility status.

Topogenous peat is formed in flood plains and is usually enriched by the influx of nutrients from through-flow and the deposition and sedimentation of minerals during temporary flooding and, therefore, is less acid and more fertile.

Thus, the properties of peat soils...mostly classified as Tropofibrists and Tropohemists in the USDA soil order of Histosols...in contrast with mineral soils, are characterized by:

- Very low bulk density (100 to 200 kg/m^3 compared with 1,400 to 1,800 kg/m^3 for most mineral soils)
- Low nutrient content, except for nitrogen (N)
- Poor nutrient retention capacity, especially for potassium (K)
- Rapid fixation of water soluble copper (Cu) and zinc (Zn) compounds by humic and fulvic acids and polyphenolic compounds
- Low to very low pH (pH 2.8 to 4.5)
- Very large content (up to 98 percent) of organic matter (OM)...a fire hazard when dry
- Very large water holding capacity

Land Preparation

The spongy character of peat is a major reason for shrinkage following drainage at the beginning of peat soil preparation for oil palm planting.

The development of a functional water management system – involving drainage but also maintenance of a water table close to the surface to prevent excessive drying – is a prerequisite step for successful oil palm establishment on peat.

The system should be meticulously planned following a thorough field survey during the dry season and inspections during periods of flood.

During monsoon rains, the system must be able to accommodate a greater volume of flow, as oil palm roots will be affected by reduced aeration in stagnant water.

During periods of drought, water must be conserved to prevent

Table 2. Dimensions for drains in oil palm established on deep peat (Gurmit Singh, 1983).

	Width, m		
Drain type	Top	Bottom	Depth, m
In-field	1.0 - 1.2	0.5 - 0.6	0.9 - 1.0
Collection	1.8 - 2.5	0.6 - 0.9	1.2 - 1.8
Main	3.0 - 6.0	1.2 - 1.8	1.8 - 2.5

irreversible drying of peat and drought stress on newly planted oil palms. Thus, a gate with removable wooden blocks is required at each palm block to maintain the water level between 50 to 80 cm from the peat surface.

Wherever possible, main drains are installed along existing (natural) drainage lines. Collection drains are installed on the lower side of each 200 m wide block so that in-field drains run down the slope towards collection drains and bridges are not required to connect the harvest road with harvest paths. In-field drains are installed at eight row intervals, or 59 m apart, where plant density is 160 palms/ha. Poorly drained patches may require additional in-field drains (dimensions are given in **Table 2**). Initial deep drainage is required to induce physical shrinkage and 'self compaction' of the peat material which may be as much as 1 m in the first year.

The aim is to compact the soil mechanically after the peat has shrunk following drainage and thereafter control the rate of subsidence by manipulating the water table.

Properly compacted peat has excellent capillarity and water holding capacity, will improve anchorage for the oil palm (less leaning and "falling over" of palms at maturity), increases the supply of nutrients, reduces the risk of fire, termite and white ant attacks, and supports more rapid growth and larger yields of fruit bunches.

A field can only be considered ready for planting after all drains have been installed and the planting path and planting circles have been cleared and compacted. "Less costly" alternatives invariably result in failure.

Figure 1. (Clockwise) (1) Excavator with punch attachment, (2) compacting, and (3, 4) preparing a planting hole-in-hole (courtesy of PT Group Plantations, Indonesia).

Much misguided effort is invested in the difficult task of establishing legume cover plants (LCP) on infertile, very acid peat soils where there is no benefit from biological nitrogen fixation (BNF). Peat soils are not prone to erosion, additional organic matter is not required, and the LCP may increase the risk of fire during dry periods.

However, since slash and burn is not permitted, it may be necessary to establish LCP to increase the rate of decomposition of stacked woody vegetation after land clearing and reduce the number of potential breeding sites for rhinoceros beetles (*Oryctes rhinoceros*).

Nursery and Planting

Because of its physicochemical properties, peat soil is quite unsuitable for use in oil palm nurseries, and mineral soils should be used instead.

Since frond length tends to be shorter in palms grown on peat

Table 3. Generic fertilizer recommendations for palms planted on deep ombrogenous peat where bunch ash is not available.

Nutrient:	N	P	K	Cu	Zn	B
Fertilizer (source):	Urea	RP	KCl	$CuSO_4$	$ZnSO_4$	Borate
Rate:	kg fertilizer/palm					
Planting hole	0.25			0.02	0.02	–
Month 3	0.25	–	0.5	–	–	–
Month 6	0.50	0.50	0.5	0.20	0.10	–
Month 9	0.50	0.50	0.5	–	–	0.10
Total Year 1	1.25	1.25	1.5	0.22	0.12	0.10
Year 2	1.50	1.50	3.5	0.20	0.06	0.10
Year 3	1.50	1.50	5.0	0.10	0.05	0.10

(especially ombrogenous peat) than on mineral soils, higher planting densities (commonly 160 palms per ha) are usually required to achieve an optimum leaf area index (LAI).

In order to establish palms properly on deep peat, a "triple hole" procedure is recommended. First, the peat is compacted by 0.5 to1.0 m at each planting point using the tracks and bucket of a swamp excavator (Rasmussen *et al*., 1982). The peat is then compacted at each planting point using a specially constructed attachment (see **Figure 1**).

Palms are then planted into a "hole-in-hole-in-hole". If the land is properly prepared, one machine can prepare up to 1,000 holes per day (about 6 ha).

Proper planting in a recessed and compacted hole is a key step in oil palm development on deep peat, and no compromise should be allowed in this operation.

Fertilization

Adequate fertilization is essential to successful palm oil production on deep peat.

An ameliorative application of finely ground reactive rock phosphate (RRP) together with bunch or wood ash or burnt lime (quick lime) in and around the planting hole results in an increase in the availability of N, phosphorus (P), K, and other plant nutrients by increasing the rate of peat decomposition and mineralization.

Where bunch ash or wood ash is not available, plant nutrients have to be supplied entirely from mineral fertilizers (**Table 3**).

Nitrogen. Peat soils contain large amounts of N. As mentioned earlier, the application of alkaline, high pH material such as bunch ash, wood ash, burnt lime, or rock phosphate (RP) increases the rate of decomposition and the mineralisation of N. Thus, an annual application of 0.6 kg N per palm (e.g., 1.25 kg urea per palm) is usually sufficient during the first year in the field.

Phosphorus. Annual rates of 300 to 400 g P_2O_5 per palm are usually sufficient during the immature growth period. Because of the high acidity in peat soils, fine ground RRP (1.0 to 1.25 kg RRP per palm per year) is the preferred source of P.

Potassium. Potassium is commonly the most deficient nutrient on peat soils. Rates of 2 to 4 kg K_2O per palm applied as KCl or appropriate combinations of KCl and Sul-Po-Mag/K-Mag are required in 3 to 4 split applications to avoid large leaching losses. Where bunch ash is available – which indirectly would contribute to the supply of N, P and micronutrients as described above – 6 kg bunch ash per palm per year is usually sufficient to meet the crop demand during the development phase.

Magnesium. "Indigenous" magnesium (Mg) deficiency in peat soil is not common, but Mg fertilizer may be required to correct Mg deficiency induced by large applications of K (Turner and Bull, 1967).

Calcium. While addition of calcium (Ca) as a nutrient is usually not required, Ca as a component of burnt lime is recommended to increase the rate of peat decomposition. Calcium uptake may thus depress Mg and K uptake.

Copper. Copper is absorbed by the humic and fulvic acids present in organic matter. Therefore, Cu is the most widely deficient micronutrient in deep acid peat soils. Copper deficiency was identified as the cause of "mid-crown chlorosis", which results in reduced vegetative growth and very small fruit bunch yields (Ng and Tan, 1974; Ng *et al.*, 1974; Turner and Bull, 1967). Accordingly, response to Cu (as $CuSO_4$) – both as foliar and basal applications – is large, provided the deficiency is corrected in the first two years after planting.

However, correction of Cu deficiency by these methods requires frequent sprays (1 to 2 per month) or a large basal application.

A promising and innovative technique presently being tested in Borneo provides a low cost but persistent slow release source of Cu. Copper mud balls are prepared by mixing $CuSO_4$ and wet clay soil in a ratio of 1:1 or 1:1.5. Two partially dried mud balls (each 0.75 to 1.0 kg) are inserted into the peat close to the seedling and are expected to supply sufficient Cu for each palm during the first 2 to 3 years after planting (von Uexküll, pers. comm.).

Table 4. Development of annual palm oil yields on a tropical peat soil compared to a typical mineral soil in Malaysia (after Ng et al., 1990).

	CPO, t/ha	
Year after planting	Peat soil*	Class I clay**
3	0.75	–
4	2.34	1.43
5	4.14	3.33
6	5.36	4.54
7	6.56	5.26
8	6.40	5.26
Total	25.55	19.82

*Average of 200 ha. **Malaysian average on class I clay soils.

Boron. The supply of boron (B) in most peat soils is insufficient to meet the requirements of vigorously growing oil palms. In most cases, the use of compound fertilizer containing NPK plus trace elements (micronutrients) or annual applications of 0.1 kg sodium tetraborate per palm will prevent the occurrence of B deficiency.

Table 5. Annual fertilizer nutrient application for immature and mature oil palms established on tropical peat soils in W. Malaysia* (after Ng *et al.*, 1990).

	kg/ha/year						
Phase	N	P_2O_5	K_2O	MgO	CaO	B_2O_3	$CuSO_4$
Immature	50-100	65-80	140-260	–	140-230	6-12	1-2
Mature	120-160	50-70	550-700	0-10	300-400	13-18	3-5

*158 palms per ha planted at the age of 14 to 15 months.

Zinc. To prevent Zn deficiency, often related to a complex nutritional disorder called "peat yellows", a quality compound fertilizer containing Zn and other micronutrients should be used during the immature phase.

Yield Performance. Large yields, comparable to those obtained on mineral soils, are obtained from palms planted on deep peat soils, provided correct water and nutrient management techniques have been used.

Based on larger scale tests that target a maximum exploitation of genetic yield potential, total cumulative yields of 25.6 tonnes crude palm oil (CPO) per ha were produced on a Tropofibrist (pH: 3.9; total N: 1.5 percent; available P: 15 mg/kg; exchangeable K: 0.15 cmol/kg; exchangeable Mg: 2.05 cmol/kg) in Malaysia between year 3 and year 8 following planting. This yield was almost 6 tonnes above the average CPO yield accumulated during the same period on class 1 clay soils (Ng *et al.*, 1990) (**Table 4**).

Obviously, such yield developments offer substantial economic incentives to oil palm growers on peat soils and more than compensate for the large investments required for efficient water management and road systems.

However, such impressive yields require adequate nutrient inputs during immature and mature phases of oil palm development (**Table 5**). **BCI**

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The Oil Palm – Fact File

Origin

Riverine region of tropical rain forests of West Africa.

Botany

Elaeis guineensis Jacq. Family of *Palmae*, subfamily *Cocoidae*. Monoecious (both male and female flowers produced on the same plant). Eight leaves (fronds) are produced in successive leaf spirals. Five spirals of leaves are retained on each mature tree (i.e., 40 leaves). Leaf production rate is between 1 to 3 leaves per month. The time between the initiation of a female flower and the production of a ripe bunch is about 44 months.

Cultivars

Dura x *pisifera* hybrids, referred to as *tenera* palms, are the most widely used planting material. Tissue cultured "clonal" palms are presently being developed world-wide.

Harvested part

Fruit bunches (sessile drupe) contain fruitlets. Bunch weight increases from about 5 kg (three years after planting) to about 50 kg (>15 year old palms). Each fruitlet contains oil in the mesocarp (45 to 55 percent oil) and kernel (50 percent oil). Palm oil extraction rate from fresh fruit bunches (FFB) ranges from 20 to 25 percent. Kernel extraction rate ranges from 4 to 6 percent.

Life cycle

Perennial. Wild palms have a life span of up to 200 years. Commercial palms have an economic life span of 20 to 30 years.

Phase	Duration
Nursery	10 to 12 months
Immature phase	24 to 30 months
Production:	
Steep ascent phase	Year 3 to 10
Plateau phase	Year 10 to 15
Declining phase	Older than 15

Maximum yield

46 tonnes FFB/ha, equivalent to 10.6 tonnes crude palm oil (CPO) and 0.9 tonnes palm kernel oil (PKO). Yields greater than 12 tonnes CPO/ha have been reported for clonal oil palms. Harvesting of FFB takes place every 7 to 14 days.

Nutrient removal in fruit bunches

	kg				
Yield	N	P	K	Mg	Ca
1 tonne FFB	2.94	0.44	3.71	0.77	0.81
25 tonnes FFB	74	11	93	19	20

Micronutrient requirements

Boron, copper (peat soils, sandy soils), zinc, iron (coral soils).

Planting density

Ranges from 120 to 148 palms/ha (to 160 palms/ha on peat), depending on planting material, soil, and climate. Wider plant spacing is used where growing conditions favour vegetative growth and vice versa. Palms are planted using a triangular spacing pattern. The most common spacing is 143 palms/ha, with palms planted on a 9 m x 9 m triangular spacing.

Climatic requirements

Low altitude (less than 500 m above sea level), 15º from the equator in the humid tropics. Evenly distributed rainfall of 1,800 to 2,000 mm/year, but will tolerate rainfall up to 5,000 mm/year, provided the soil is properly drained. Oil palm is sensitive to poor drainage and drought. Potential yield is reduced where there are more than three consecutive months with less than 100 mm rainfall per month. Irrigation may increase economic returns in areas with pronounced dry periods. More than 2,000 sunshine hours (i.e., low cloud cover during daytime).

Soil requirements

Adapted to a range of soil types. Tolerates low pH, but does not thrive at very high pH (greater than 7.5). Soil must be free draining. **BCI**

Fertilizer Use Efficiency in Oil Palm is Increased under Irrigation in Ecuador

By Francisco Mite, Manuel Carrillo and José Espinosa

Since the early 1960s, oil palm (*Elaeis guineensis* Jacq.) has been grown in Ecuador in response to the growing demand for vegetable oils for human and industrial consumption. Currently, the planted area comprises 113,000 ha, with an expected expansion of 10,000 ha per year over the next five years.

Approximately 20 percent of Ecuador's oil palm plantations are located in the region of Quevedo, Los Rios province. This area is prone to soil water deficits. An experiment was carried out to investigate the effect of irrigation and improved mineral nutrition on oil palm growth and yield.

Characteristics of the Experimental Site

The experiment was conducted at the Pichilingue Experiment Station, near Quevedo, Los Rios province. The site is 120 m above sea level with a mean annual rainfall of 2,021 mm. Rainfall exceeds requirements from January to April, but a water deficit occurs from May to December (**Figure 1**). The mean annual temperature at the site is 24.3º C with 914 sunshine hours.

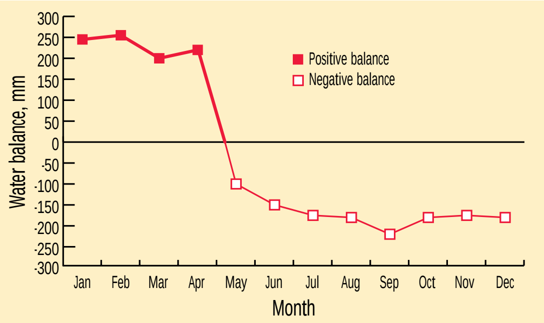


Figure 1. Balance between water availability and oil palm demand for the years 1992 to 1996 at Quevedo, Ecuador.

Soil at the experimental site is representative of the area and is classified as a Melanudand, a volcanic soil having a moist water regime with a dark surface horizon. Soil exchangeable cation and available phosphorus (P) status is very high (**Table 1**). The experiment was located in a 100 ha commercial field of palms planted to National Institute of Agronomic Research (INIAP) *tenera* material in 1991. The triangular planting density was 143 palms/ha.

Table 1. Chemical characteristics of the soil at the experimental site in 1991.

Depth, cm	pH	P (Olsen), mg/kg	K	Ca, cmol(+)/kg	Mg
0 to 10	6.3	24	0.51	10.9	1.3
10 to 25	6.7	7	0.42	7.7	1.0

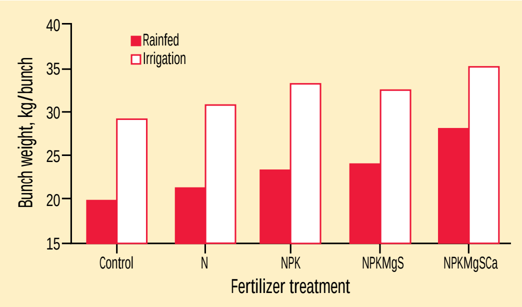
Table 2. Nutrient rates applied to the different treatments from 1992 to 1997.

Year	N	P_2O_5	K_2O	MgO	S	$CaCO_3$
	kg/palm/year					
1992	0.40	0.16	0.15	0.08	0.069	1.95
1993	0.40	0.16	0.15	0.08	0.069	1.95
1994	0.49	0.18	0.18	0.10	0.085	2.45
1995	0.98	0.50	1.40	0.25	0.223	6.85
1996	1.00	0.50	1.40	0.35	0.307	6.85
1997	1.60	0.50	2.00	0.35	0.307	6.85

Materials and Method

The effect of irrigation on fruit bunch yield at five levels of mineral fertilizer was measured from the onset of harvest in 1993 for a period of five years. The plots were arranged in a split plot design with the irrigation treatment as the main plot and fertilizer treatments as sub-plots. Nutrients in the fertilizer treatments included nitrogen (N), P, potassium (K), magnesium (Mg), sulfur (S), and calcium (Ca). The irrigated plots were supplied with 60 mm water three times during the dry season. Fertilizer treatments were comprised of a control, +N, +NPK, +NPKMgS, and +NPKMgSCa at amounts shown in **Table 2**. Fertilizer sources were urea, triple superphosphate (TSP), potassium chloride (KCl), magnesium sulfate ($MgSO_4$) and calcium carbonate ($CaCO_3$). Fertilizers were applied in a band in the weeded circle. Urea, KCl and $MgSO_4$ fertilizers were applied in two equal split applications in January and April. The TSP and $CaCO_3$ were applied in February.

Figure 2. Effect of irrigation and fertilizer application on bunch weight in the fifth year of harvest in Quevedo, Ecuador.



Results and Discussion

Harvesting commenced in 1993. The number of bunches per palm was increased under irrigation, but was not affected by the fertilizer treatments. There was, however, a significant positive interaction between the effect of irrigation and fertilizer application on bunch weight, particularly as the palms grew older (**Figure 2**). Bunch weight was increased under balanced fertilizer application for both irrigated and rainfed treatments, but bunch weight was 7 to 10 kg larger in the irrigated plots compared with the rainfed conditions (**Figure 2**).

Due mainly to the increase in bunch weight, cumulative yield was 26 to 33 t/ha higher under irrigation compared with rainfed conditions and, the cumulative yield increase was largest when all six nutrients were applied together (**Figure 3**).

Figure 3. Effect of irrigation and fertilizer application on cumulative yield (1993 to 1997) of fruit bunches in Quevedo, Ecuador.

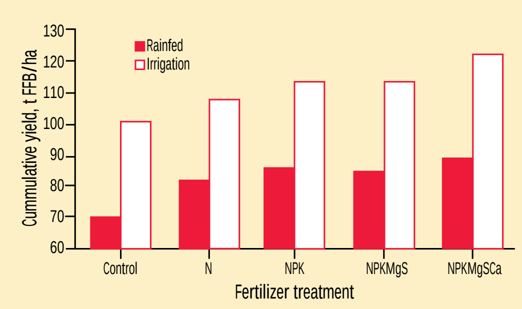


Photo 1. Inadequate nutrition during immature stage may be a cause of low yields later.

Conclusions

Adequate nutrition is essential during the growth and development stages of the oil palm since nutrient uptake establishes the plant's production potential (see graph of nutrient uptake on page 6). This fact is often neglected by producers. The trunk is a sink for nutrients accumulated by the plant during the immature stage. Later, when harvest begins, the trunk provides a buffer against nutrient removal in fruit bunches and the transient and temporary availability and supply of nutrients by the soil. Large yields can thereby be sustained because the palm can withstand stress without changing from reproductive to vegetative growth phase. Trunk size was larger in the complete nutrient application plot compared with the control (**Photos 1** and **2**). Low yields obtained by many oil palm growers in Ecuador may be attributed to inadequate nutrition during the immature stage of oil palm development.

Palm growth and production are limited by water deficits in many oil palm producing areas of Latin America. Since palms take up nutrients from the soil solution, low soil moisture availability limits nutrient uptake. Some growers suspected that low yields in the Quevedo oil palm area of Ecuador were partly explained by low soil moisture availability. This experiment documented for the first time the extent and impact of water deficits on yield and clearly demonstrates that proper water management in oil palm is important for obtaining large yields. The interaction between irrigation and nutrient application is evident from this experiment, as plots without irrigation and fertilizer produced an accumulated yield of 70.1 tonnes of fruit bunches in 5 years, while the irrigated and fertilized plots produced 122.8 tonnes during the same period (**Figure 3**).

Photo 2. Trunk size of oil palms was larger in the complete nutrient application plot.

Balanced nutrient application is important even in high soil fertility status volcanic soils found in many of the oil palm growing areas of Ecuador. However, irrigation is required in the dry season in order to achieve the maximum response to mineral fertilizer. The increase in cumulative yield under balanced fertilizer application and irrigation was equivalent to an additional two-years of production in the control plots. BCI

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Iron Deficiency of Oil Palm in Sumatra

By Sugih Wanasuria, Heru Setyobudi, I.B. Mayun, and B. Suprihatno

Symptoms of iron (Fe) deficiency in oil palm are described and a level of 50 mg Fe/kg dry wt. in leaf (frond) 17 is stated as critical for oil palm growth. Absorption of ferrous sulfate solutions through one root tip per palm was tested as an efficient and lasting means to overcome Fe deficiency in oil palm and is reported as applicable in oil palm estates of Riau, Sumatra, Indonesia.

Introduction

Iron deficiency is a worldwide problem in crop production on calcareous soils (Marschner, 1986). However, Fe deficiency is very rare in oil palm grown on acid tropical soils.

A growth disorder was observed in nine-year-old oil palms grown on a histic tropaquept with a 40 cm layer of peat over a thick sand underlay (40 to 150 cm) in two estates in Riau, Sumatra. This disorder was subsequently identified as severe Fe deficiency. These soils are acidic (pH H_2O: 4.5), very sandy (80 to 90 percent sand), and have very low levels of available plant nutrients [(e.g., available phosphorus (P), Bray II: <6 mg/kg; exchangeable calcium (Ca), magnesium (Mg) and potassium (K) <1.0, <0.4 and <0.2 cmol/kg, respectively]; and very low content of total Fe (0.05 percent). It was also noted that palms grown on peat soils (typic troposaprist) in adjacent areas were not affected.

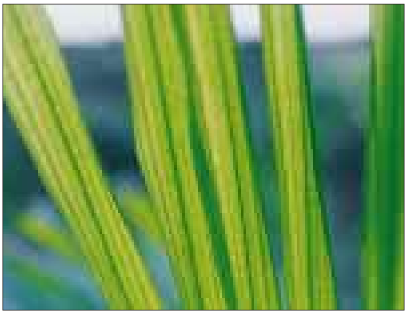


Photo 1. (Left) At the beginning, interveinal chlorosis is observed on the leaflets of the youngest fronds. At a later stage, the whole frond becomes white.

Photo 2. (Right) Chlorosis is at first shown by the three youngest fronds and is later shown by older fronds below them.

Description

The earliest visible symptom is interveinal chlorosis of the usually normal sized and shaped youngest fronds (leaves 1 to 3). At a later stage, the youngest fronds turn completely white, while many of the older fronds are yellow. This chlorosis is followed by breakage and drying up of the fronds, arrested plant growth, and death. The process above is


Photo 3. (Left) Severe symptoms of Fe deficiency indicated by chlorosis on over nine of the youngest leaves.
Photo 4. (Right) The youngest leaves break at the base and dry up. At the final stage of Fe deficiency, the plant dies.

usually concluded within one year of the appearance of the first symptoms (**Photos 1** to **4**).

As a simple test, totally chlorotic young leaflets were painted once daily for three consecutive days using a 0.5 percent solution of ferrous sulfate. The result was a complete re-greening of the leaflets within seven days. Similar tests with other micronutrients such as copper (Cu) and zinc (Zn) as sulfate produced negative results.

Table 1. Total leaf Fe concentration of affected, treated and non-affected palms.

Category of palms		mg/kg oven dried matter – Frond 3	Frond 9	Frond 17
Affected palms	(a)	21	40	48
Treated palms	(b)	32	68	59
Non-affected palms	(c)	39	83	64

(a) Sick (Fe-deficient) palms
(b) Recovered palms (three months after Fe root absorption-treatment)
(c) Healthy palms

Table 2. Total Fe concentration in frond 17 of two groups of palms.

Group	mg/kg oven dried matter – Mean ± Std Dev	Range
Fe-deficient	44 ± 8	35 - 53
Non-affected	71 ± 16	47 - 119

Critical level

Leaf analysis confirmed the diagnosis of Fe deficiency in affected palms (**Table 1**).

After comparing analytical results from Fe-deficient and non-affected palms, the critical deficiency level of total Fe in frond 17 was found to be around 50 mg per kg dry weight (**Table 2**).

Table 3. Effect of various $FeSO_4 \cdot 7H_2O$ treatments on the severity of Fe deficiency of oil palm at 0, 3, 6, and 12 months after Fe application (MAA), presented as a rated scale from 0 to 100 percent.

Treatment	0 MAA	3 MAA	6 MAA	12 MAA
Control	67	78	93	100
Soil application (3,000 g)*	67	63	59	70
Foliar spraying (3 rounds of 6L)**	67	56	63	100
Root abs. (11.0 g $FeSO_4 \cdot 7H_2O$)***	67	0	0	0
Root abs. (16.5 g $FeSO_4 \cdot 7H_2O$)***	67	0	0	0
Root abs. (22.0 g $FeSO_4 \cdot 7H_2O$)***	67	0	0	0

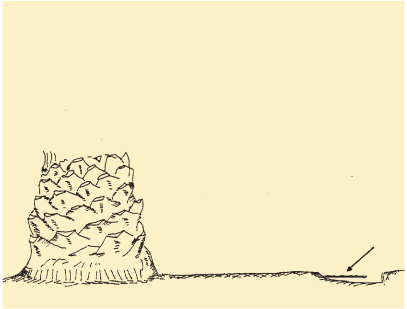
• Score 0 (0 percent): "Healthy" = no chlorosis on any leaves
• Score 1 (33 percent): "Light" = chlorosis on fronds 1 to 3
• Score 2 (67 percent): "Moderate" = chlorosis on fronds 1 to 9, white color of the three youngest fronds
• Score 3 (100 percent): "Severe" = chlorosis on more than 9 youngest leaves, breakage and drying up of the leaves
* Two applications of 1,500 g, monthly intervals
** 0.53 percent $FeSO_4 \cdot 7H_2O$ solution during the first 3 weeks (weekly intervals)
*** per 50 ml (stabilized with 0.6 g citric acid), 1 root per palm

Causes

Iron deficiency has been reported so far only in immature oil palm on deep peat in Sarawak, east Malaysia (Turner, 1981) and on the east coast of Riau (authors' observations, unpublished). This study suggests that the nature of the organic topsoil and absence of Fe in the sandy underlay of the histic tropaquept contributed to the insufficient Fe uptake by the affected palms.

Treatment

Three methods of Fe application were tested in a field trial with six treatments (control, soil application, foliar spraying, and three rates of root absorption), each with nine



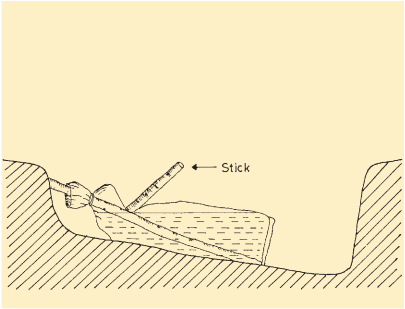


Figure 1a. (Left) To use the root absorption method, select one healthy primary root around the stem. Cut perpendicularly. Clean the root. The root should be hanging horizontally.

Figure 1b. (Right) After inserting the root into a plastic bag filled with the treatment solution, tie up the mouth of the bag. Then incline and place the root in a way that all the treatment solution can be absorbed very slowly.

Fe deficient palms selected as replicates using a completely randomized design. Industrial grade ferrous sulfate ($FeSO_4 \cdot 7H_2O$) containing 19 percent Fe was applied as the corrective agent (**Table 3**).

All root absorption treatments (50 ml per palm solutions contained in a plastic bag were applied to one pre-selected active root tip) were effective in correcting and preventing Fe deficiency for at least 12 months (**Table 3**).

Foliar sprayings during the first three weeks of the trial caused a regreening of chlorotic leaves 2 to 4 weeks after the first application. However, foliar application of Fe could not prevent the recurrence of chlorosis on newly emerging leaves, thus indicating that sprayings would have to be repeated regularly to ensure success.

Soil application by broadcasting $FeSO_4 \cdot 7H_2O$ on the palm circle was completely ineffective. Most likely the applied Fe (II) was transformed by oxidation and/or strongly adsorbed in the organic and mineral layers of the soil and thus became as unavailable for plant uptake as any inherent soil Fe.

The successful Fe applications through root absorption confirmed that Fe is "intermediately mobile" in plants, meaning that it is translocated to a certain degree in the phloem. Iron application on just one root tip resulted in the complete recovery of palms over a 12-month period and maintained Fe contents in leaves at levels of sufficiency.

Following the satisfactory results in the trials, the root absorption technique was used to apply 15 g $FeSO_4 \cdot 7H_2O$ + 1 g citric acid in 50 ml solution per palm (one time application on one root tip) on all the affected palms in the two estates. Observation one year thereafter showed that Fe deficiency symptoms had disappeared in all formerly affected palms, indicating that root absorption is an effective and lasting means to treat Fe deficiency in oil palm plantations. **BCI**

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Suitability of Soils for Oil Palm in Southeast Asia

By E. Mutert

Soil physical properties such as depth, texture and structure are important factors in determining suitability for large scale oil palm planting.

It it estimated that more than 95 percent of oil palms are grown on acid, low fertility soils. This becomes evident from topsoil characteristics of eight representative soil types commonly used for oil palm in Southeast Asia (**Table 1**).

Table 1. Topsoil (0 to 30 cm) characteristics of eight soil types commonly used for oil palm in Southeast Asia.

Pedon	Soil type	pH, H_2O	Corg, %	Ntot, %	P Bray II, mg/kg	Exchangeable Ca (cmol(+)/kg)	Mg	K	Al	Clay (%)	Silt	Sand
1	Terric Troposaprist	3.8	24.5	1.1	35	0.85	1.56	0.24	9.50	55	32	13
2	Typic Sulfaquept	4.1	2.5	0.2	18	0.18	0.20	0.32	12.50	72	21	7
3	Typic Hapludox	4.4	1.1	0.1	6	0.28	0.25	0.16	0.60	37	9	54
4	Xanthic Kandiudox	4.3	1.8	0.2	15	0.86	0.48	0.24	3.20	63	5	32
5	Typic Paleudult	4.4	1.2	0.1	12	0.16	0.03	0.09	1.40	18	8	76
6	Typic Hapludult	4.1	1.4	0.1	8	0.76	0.18	0.15	1.80	20	19	61
7	Typic Kandiudult	4.9	0.8	0.1	5	0.19	0.10	0.05	0.80	33	7	60
8	Typic Melanudand*	4.8	6.4	0.5	8	1.86	0.25	0.07	0.80	18	53	29

*12 percent allophane was present in the less than 2 mm soil mineral fraction.

The soils are illustrated in **Figure 1**. All of these soils have a pH less than 5.0, six of the eight have low to very low contents of nitrogen (N), available phosphorus (P), and exchangeable potassium (K). Half of them have low to very low contents of exchangeable magnesium (Mg) when evaluated for fertility parameters with regard to oil palm (**Table 2**).

With the exception of P and Mg on the Terric Troposaprist soil, oil palms planted on these soils are expected to respond to applications of N, P, K, and Mg.

While soil amendments such as empty fruit bunches (EFB) and fertilizers can be applied to correct nutrient shortages, soil physical limitations such as impenetrable layers and poor water retention are difficult to rectify. Thus, physical properties such as depth, texture and structure of the soil are major criteria for assessing suitability for large scale oil palm planting. Terrain is of great importance. In order to avoid greater cost of establishment, problems with harvesting, and losses from run-off and erosion, areas exceeding slopes of 15 percent should be not extensive.

Table 2. Soil fertility evaluation for oil palm.

Property	V. low	Low	Mod.	High	V. high
pH	<3.5	4.0	4.2	5.5	>5.5
Org. C, %	<0.8	1.2	1.5	2.5	>2.5
Total N, %	<0.08	0.12	0.15	0.25	>0.25
Total P, mg/kg	<120	200	250	400	>400
Avail. P, mg/kg	<8	15	20	25	>25
Ex. K, cmol(+), kg	<0.08	0.20	0.25	0.30	>0.30
Ex. Mg, cmol(+), kg	<0.08	0.20	0.25	0.30	>0.30
ECEC, cmol(+), kg	<6	12	15	18	>18
Deficiency	likely	possible	—	—	induced
Hidden hunger	—	—	likely	—	possible
Fertilizer response	definite	likely	possible	—	possible

Source: after Goh Kah Joo, 1997
Methods and Extractants
pH: H_2O, 1:2.5; Organic C: Walkley & Black; Total N: Kjeldahl; Total P: 25% HCl; Available P: Bray II; Exchangeable K, Mg, and CEC: Leaching with 1M ammonium acetate at pH 7.0.
cmol(+)/kg = meq/100g
mg/kg = parts per million (ppm)

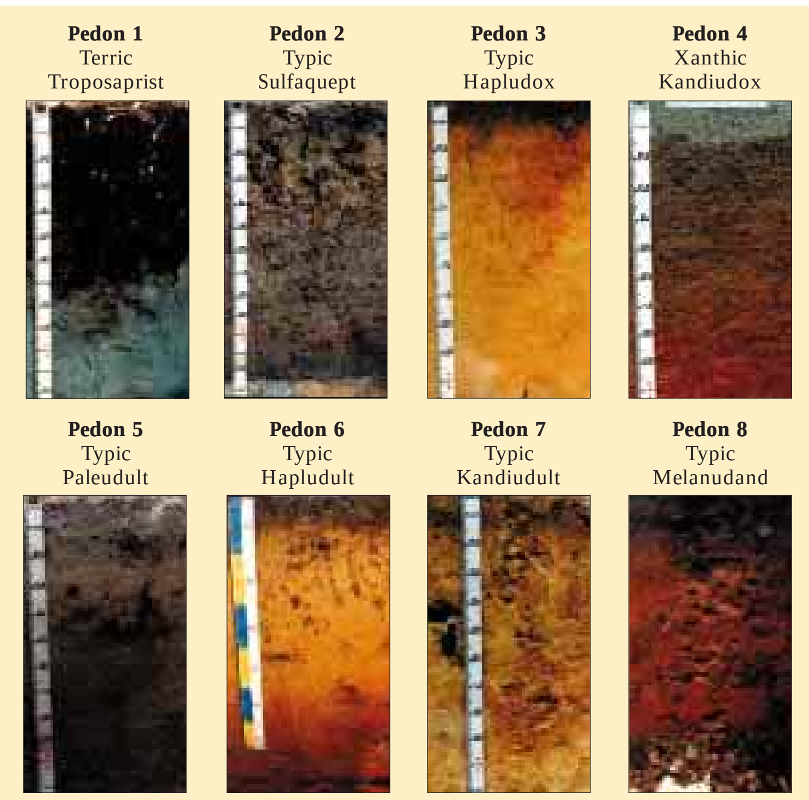

Figure 1. Eight representative soil types commonly planted to oil palm in Southeast Asia.

Table 3. Suitability characteristics of eight soil types commonly used for oil palm in Southeast Asia.

Pedon	Soil type	Parent material	Terrain	Drainage	Constraints	Advantage	Treatment
1	Terric Troposaprist	Marine clay	Flat	Poor	Poor anchorage; subsidence; K deficiency	Constant water availability	Hole in hole planting; water management
2	Sulfaquept	Estuarine clay	Flat	Imperfect	Acidity; stagnant water	Constant water availability	Keep water > 20 cm below surface
3	Typic Hapludox	Granite	Steep (30%)	Well drained	P fixation; moisture stress; erosion; P, K deficiency	No stagnant water	P placement; mulch (EFB); terraces
4	Xanthic Kandiudox	Reworked materials	Gentle rolling	Well drained	High clay content; low fertility	Good moisture retention	Mulch (EFB); fertilization
5	Typic Paleudult	Subrecent terrace	Undulating	Imperfect	Moisture stress; low fertility; K, Mg deficiency	Easy to work	Mulch (EFB); fertilization
6	Typic Hapludult	Colluvium	Undulating	Moderately well	Low fertility; P, K, Mg deficiency	Sufficient moisture	Mulch (EFB); fertilization
7	Typic Kandiudult	Granite	Rolling	Well drained	Low fertility; N, P, K, Mg deficiency	Easy to work	Mulch (EFB); fertilization
8	Typic Melanudand	Volcanic ash	Gentle rolling	Well drained	K deficiency	Excellent structure	Fertilization, particularly K

Although the majority of oil palm roots are found within the first 60 cm of the soil, firm anchorage of adult palms of more than 8 m height can only be assured in a deep soil (greater than 90 cm). Thus, a soil suitable for oil palm permits extensive root development, firm anchorage, and...due to its clay loam texture and friable consistency...stores sufficient water and plant nutrients. It provides adequate drainage during the wet season in flat to gently undulating terrain. As the oil palm is thought to have evolved in swampy, wet levees, a well drained alluvial soil as found in coastal areas of Southeast Asia is probably most suited.

However, a wide range of soils derived from igneous and sedimentary rocks, peat, and volcanic ash (which are of lower nutrient status) are commonly planted to oil palm in Southeast Asia (**Tables 1** and **3**).

At present, highly weathered and light textured soils (Pedon 5, 6, 7 in **Tables 1** and **3**) derived from granite and Pleistocene sediments and deep peat soils (see page 22 of this issue)...all of very low inherent fertility...are being successfully planted in oil palm expansion areas throughout Southeast Asia. **BCI**

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The Oil Palm Nursery: Foundation for High Production

By E. Mutert, Alfredo Sandoval Esquìvez, Aida Olivera de los Santos, and Elias Ortiz Cervantes

The nursery is the foundation for every successful oil palm plantation. It must produce healthy seedlings having the potential for sustaining large oil yields for 25 years or more.

Currently, all modern, commercial planting material consists of *tenera* palms or DxP hybrids, which are obtained by crossing thick-shelled *dura* with shell-less *pisifera*. Although common commercial pre-germinated seed is as thick-shelled as the *dura* mother tree, the resulting tree will produce thin-shelled *tenera* fruit. Only certified pre-germinated oil palm seed from established seed gardens should be used.

The near-future alternative to pre-germinated seed, once constraints to mass production are overcome, is tissue-cultured or "clonal" palms which provide "true copies" of high yielding DxP palms.

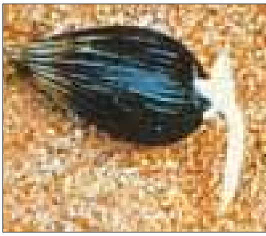

Photo 1. A seedling at approximately 21 days old, ready for planting. Shoot (plumule) and root (radicle), which is pointing downward, are clearly distinguishable.

Site Selection

Ideally, the nursery should be located on a level, well-drained area that is easily accessible and close to the centre of the future plantation. It is essential to have an uninterrupted supply of clean water and topsoil which is both well-structured and sufficiently deep enough to accommodate three rounds of on-site bag-filling. Approximately 35 ha can grow enough seedlings over a three-year period to plant a 5,000 ha plantation.

Type of Nursery

Double stage nurseries, compared to a single stage nursery, are preferred because they require less space and irrigation, and allow for more efficient upkeep and selection (culling). However, the double stage nursery involves transplanting pre-nursery seedlings to the main nursery, which if done improperly, may cause transplanting shock.

Each nursery should have lockable stores for parts, tools and equipment and for chemicals and fertilizers (near a water supply). Herbicides must be clearly marked and kept separately from insecticides, fungicides, and foliar fertilizers to prevent contamination and incorrect handling.

Pre-Nursery: Materials, Preparation and Practice

Pre-nursery seedling beds, normally 10 m in length x 1.2 m in width, hold 1,000 seedlings (100 x 10) planted in 250 gauge, black UV stabilized, 15 cm x 23 cm polybags. Two rows of drainage holes are punched in the bags.

Using the best available hygienic soil, and after sieving it through a 5 mm metal screen and amending it with phosphorus (P) fertilizer, bags should be filled to within 2 cm of the rim. The fertilizer should be mixed thoroughly with the soil to provide optimum P availability to the seedling's root system. If quality topsoil is used, no further manuring is required in the pre-nursery. The filled polybags must be prepared four weeks before the seed arrives and should be watered daily until planting to ensure adequate P availability.

Rankine and Fairhurst (1998) suggest the following planting procedure:

1. Pre-germinated seeds received by the grower must be kept under shade and cool. Once seed bags are opened, maintain moist seeds by sprinkling them with distilled water.
2. The two-person planting team should work as follows: The 'seed handler' places the seed on the soil (which is about 2 cm below the top of the bag) with the root (radicle) pointing downwards. The 'planter' positions the seed correctly so that the shoot (plumule) is 1 cm beneath the surface after covering the seed with soil and gently tamps and levels the added soil with the palm of his hand.
3. Return the empty seed bags containing the rejected seeds to the recording staff so they can note seed quality.
4. Irrigate the seedlings immediately after planting.

Photo 2. Pre-nursery shade house with shade partly withdrawn. The 60-day-old plants are ready for transplanting in the main nursery. Sprinkler heads, installed 1.5 m above ground at 9 m intervals, supply irrigation water through a pressurized, underground tube system.

When ambient solar radiation levels and very high mid-day temperature prevail, shade is required for at least six weeks, after which the plants are exposed to increasing amounts of sunlight. Coconut or oil palm fronds are often used for shade. In Mexico, the National Institute for Research on Forestry, Plant and Animal Sciences (INIFAP) designed a shade house which provides 40 percent shade for 100,000 plants within a 1,800 m^2 area. The shade house, measuring 120 m x 15 m, is constructed of metal (PTR) uprights and steel lines to secure shade cloth. Columns at the centre of the shade house are 3 m high, and the two parallel steel lines are fixed 2 m above the floor (**Photo 2**).

Pre-nursery seedlings must be watered daily. Whenever rainfall is less than 10 mm per day, irrigation is required, and the system must be capable of uniformly applying 6.5 mm water per day. The irrigation systems most commonly used have overhead sprinklers at about a 2 m height (**Photo 2**), or flat sprinkler tubes with two rows of holes in the upper surface to spray a fine mist at opposite angles when the tube is pressurized. Hand watering systems may be adequate in small (less than 1 ha) nurseries. Monitoring during irrigation ensures complete soil wetting and avoids over-watering, which can cause soil loss from the pots and result in the roots of the seedlings being exposed.

Weed control, if required, must be done manually to avoid seedling damage. The normal rule is to not use herbicides in pre-nurseries.

Insect control is most effective when pests are detected early and treated promptly after clear identification. In Mexico and other places, the insecticide Carbofuran (75 percent, 1 g per polybag) is used to control leaf-cutting worms, and Metamidofos (49 percent, 3.75 ml per liter of irrigation water) is applied for control of leaf insects.

Disease control may be required in the pre-nursery, particularly when hot and humid conditions prevail. During the early stages of development, the best means for controlling leaf diseases is to reduce excessive shade and ensure adequate air movement. Preventive fungicide applications may start 25 days after emergence and continue at intervals of 15 days. (Benomil 50 percent, 2.5 g/l; Captan 50 percent, 5 g/l; or Clorotalonil 40 percent, 2 g/l water, are commonly used.)

Transplanting

Pre-nursery seedlings in the four-leaf stage of development (10 to 14 weeks after planting) are usually transplanted to the main nursery, after their gradual adjustment to full sunlight and rigid selection process. During culling, seedlings with abnormal characteristics such as "grassy", "crinkled", "twisted", or "rolled" leaves should be discarded. In case of doubt, the seedling should be removed.

Main Nursery

Pre-nursery seedlings are transplanted into main nursery polybags (i.e., 40 cm x 45 cm, 500 gauge, black UV stabilized) containing soil prepared in the same manner as for the pre-nursery. A 25 cm deep hole is made with a trowel or a cylindrical core cutter in each main nursery polybag. The seedling is transplanted after removing the pre-nursery polybag. Temporary shade (e.g., nipah palm leaflet) and watering should be applied immediately following transplanting to reduce transplanting shock.

Also, a 2.5 cm deep layer of disease free mulch should be uniformly spread around the seedling soon after transplanting to prevent soil erosion, to regulate soil moisture and soil temperature, and to suppress weed growth in the polybag. Commonly used materials are oil palm kernel shells, shredded coconut fibre, rice husks, peanut shells, and coffee shells.

Manuring and Fertilizer Management

With the exception of P, plant nutrient deficiencies can be corrected through surface or foliar application of fertilizer to transplants in the

Table 1. N, P, K, and Mg fertilizer nutrient application schedule for the main nursery (g per seedling).

Weeks after transplanting	N	P_2O_5	K_2O	MgO
1	0.8	0.8	0.3	0.2
3	0.8	0.8	1.2	0.1
5	1.1	1.1	0.4	0.3
7	1.2	1.2	1.7	0.2
10	1.5	1.5	0.6	0.4
13	1.2	1.2	1.7	0.2
16	2.3	2.3	0.9	0.6
19	1.8	1.8	2.6	0.3
22	3.0	3.0	1.2	0.8
25	2.4	2.4	3.4	1.3
28	2.4	2.4	3.4	1.3
32	3.0	3.0	4.3	1.4
36	3.0	3.0	16.3	2.0
40	3.0	3.0	4.3	2.0
44	3.6	3.6	5.1	2.0
48	3.6	3.6	5.1	2.0
52	3.6	3.6	5.1	4.0
56	3.6	3.6	5.1	5.3
Total	41.9	41.9	62.7	24.4

main nursery. It is essential that the required amount of P (e.g., 300 g P_2O_5 per tonne of soil) be applied and mixed in the soil before bag filling. Granular compound fertilizers are often used as they provide all necessary nutrients in a single application. In Southeast Asia, the two most frequently used compound fertilizer formulas are 15-15-6-4 [nitrogen (N)-P_2O_5-K_2O-MgO)] and 12-12-17-2+micronutrients [N-P_2O_5-K_2O-MgO+boron (B), zinc (Zn), manganese (Mn) etc.]. The recommendation in Mexico is to apply 5 to 10 g 18-46 (N-P_2O_5) per seedling at weeks 3 and 6 after transplanting, followed by rates of 12 to 23 g 17-17-17 (N-P_2O_5-K_2O) per seedling in 3-weekly intervals until week 30.

Table 1 provides a generic, main nursery fertilizer schedule which can assist growers in calculating fertilizer rates based on the types and sources of materials available. Compacted 'slow release' fertilizer tablets are expensive in terms of nutrient unit cost, and the benefits do not justify general usage in the main nursery.

Photo 3. Manual fertilizer application in the main nursery.

Plastic spoons or measures must be calibrated in order to apply the correct amount of fertilizer. The fertilizer should be sprinkled in a circle around the seedling stem, ensuring that it is not in contact with the seedling. To reduce risk of planting shock, applications of fertilizer should cease one month prior to field planting (**Photo 3**). At the same date, polybags should be rotated 180º to sever all roots which may have penetrated the nursery subsoil.

Weed control

Weeds growing in the polybags must be carefully pulled out. Herbicides should not be used. If chemicals are needed, the products Gramoxone and Diuron 80 WP are preferred for ground weed control, but they should be applied with great care to avoid damage to seedlings (**Photo 4**).

Photo 4. Ground weed control in the main nursery using protecting devices to avoid herbicide spray contact with seedlings.

Pest control

Numerous insects (e.g., ants, armyworm, bagworm, aphids, thrips, mites, grasshoppers, mealybugs) and vertebrates (e.g., rats, squirrels, porcupine, wild boar, monkeys) are pests in oil palm nurseries and must be carefully identified before control measures are implemented. Product advice should be sought locally.

Disease control

Diseases afflicting seedlings and young plants are common in nurseries. The most prevalent among them are *Blomerella cingulata*, *Botryodiploidia spp.*, *Melanconium spp.*, blast, Curvularia blight, Corticum leaf spot, Helminthosporium, and spear or bud rot (*Fusarium spp.*). Begin prophylactic fungicide applications of Thiram 30 WP or similar fungicides when the seedling is in the sixth leaf growth stage. Curative sprays are applied once the disease symptoms appear and the disease is clearly identified. No known treatment cures plants suffering from foliar rot (Flecha-arguco), which is a disease that occurs in Mexico. Foliar rot begins with brownish lesions at the base of the leaf and progresses until it affects leaves in the crown of the plant. Since the casual agent is unknown, affected palms must be discarded and burned.

Other Disorders

After 8 months in the nursery, normal healthy plants should be 0.8-1 m in height and display 5 to 8 functional leaves, with the middle leaves forming a 45º angle with the plant's axis and leaflets spreading at an angle greater than 60º to the leaf rachis (**Photo 5**). At this time, a rigorous selection process should be started (Hartley, 1983).

Photo 5. A main nursery in Mexico with healthy, well-developed seedlings.

Abnormal seedlings will not produce an economic yield and must never be dispatched from the nursery for field planting. The most common disorders requiring seedling culling are:

- Fronds set at narrow angles to the main stem.
- Flat top appearance.
- Undivided pinnae.
- Pinnae that are narrow and rolled.
- Pinnae with respectively narrow and wide internodes.

These plants must be culled after a period of close observation.

A final culling should be undertaken when seedlings are dispatched to the field. This prevents the planting of abnormal seedlings that escaped previous cullings. Culling rates are usually between 15 and 30 percent. If culling rates exceed 35 percent, the grower should consider purchasing seed from a new supplier. BCI

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The World of Palm Oil

Asia accounts for nearly 79 percent of the world's oil palm fresh fruit bunch (FFB) yield, Malaysia and Indonesia being the two leading producers, with about 95 percent of total Asia production. Oil palm continues to be Southeast Asia's most rapidly expanding crop. Africa and Latin America also harvest significant areas of oil palm.

In 1998, total world FFB production was more than 95 million tonnes, 75 million by Asian growers in eight countries. Twenty-two countries in Africa produced 14 million tonnes, 8 million of that coming from Nigeria. Thirteen Latin American countries produced slightly more than 6 million tonnes of FFB. Highest national average FFB yield produced in 1998 was 26.5 t/ha in Nicaragua. Ten countries produced yields averaging above 15 t/ha. The world average was 10.8 t/ha. **BCI**

Sources: FAO Database, 1999; PPI-PPIC, 1999.

Oil Palm Clones: Productivity Enhancement for the Future

By E. Mutert and T.H. Fairhurst

Mass reproduction of high yielding palms is a major objective of oil palm tissue culturists. Developing plantlets from tissue of selected *tenera* palms is seen as the most promising technique towards more uniformity and higher efficiency in oil palm plantations.

Clonal oil palm offers the potential for greater productivity because it is possible to establish uniform tree stands comprising identical copies (clones) of a limited number of highly productive oil palms (**Figure 1**). In addition, improved standards of field agronomy have a greater effect on productivity.

Cloning is a process in which identical or true-to-type 'photocopies' of a selected palm (ortet) are reproduced by developing plantlets from the leaf tissue of *tenera* oil palms with desirable characteristics (e.g., large yields...t palm products/ha...precocity, disease resistance, drought tolerance, and small height increment). Unfortunately, tissue culture sometimes accentuates the expression of defects in oil palm, particularly when embryogenesis is induced in a particular callus for prolonged periods. However, when suitable cloning protocols are used, the incidence of abnormalities (mantle fruitlets) is small whilst other defective traits that occur in DxP *tenera* palms (e.g., androgyny, hermaphroditism, parthenocarpy, sterility, chimera, collar snap, genetic orange spotting, etc.) are eliminated. In order to overcome problems related to genetic conformity, genetic identification (DNA finger printing) and the registration of proven clones have been proposed as preliminary steps towards controlled mass clone production (Khaw et al., 1999).

The greatest potential for increased productivity of oil palm is with properly prepared clones grown with balanced fertilization.

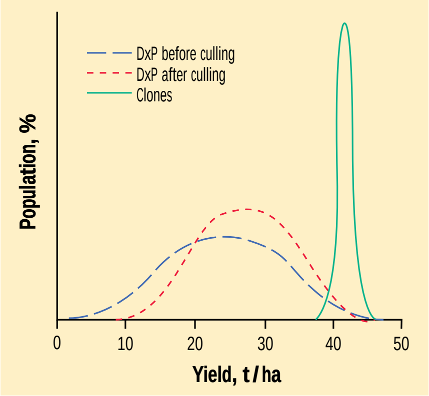


Figure 1. Diagram representing the distribution of palms in unselected DxP, culled DxP and clonal oil palm populations.

The cloning process involves the following steps:

- Selection of palms (ortets) with desirable characteristics.
- Removal of physiologically young leaf tissues (explants) from close to the growing point of the selected ortets.
- Development of callus on explants raised on a nutrient medium in culture tubes.
- Initiation of embryoids on callus (embryogenesis).
- Removal of embryoids from the callus and development of plantlets with functioning roots and shoots.
- Transplanting of plantlets and preliminary "hardening off".
- Transfer of plantlets to the field nursery for adaptation to ambient climatic conditions.
- Conventional nursery phase. Planting takes place after 12 to 15 months.

The whole process from initial tissue culture to the development of mature, field-tested clones takes about 10 years.

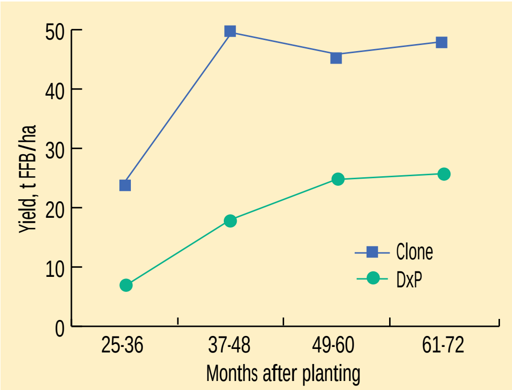
Only 30 to 40 percent of ortets are developed into viable clones. Therefore, a clone production facility requires a large resource base of elite palms...more than 10,000 per year...from which ortets are selected. A variable, but generally small number of plantlets (100 to 10,000) can be produced from a single ortet, and each ortet can only be harvested for leaf explants once in 3 to 5 years.

After the enthusiasm for clonal oil palm generated in the 1970s and the setbacks incurred in the 1980s, several thousand hectares have been planted successfully in Southeast Asia with clonal oil palms. A Malaysian group with nearly 100,000 mature clones in the field has met the most stringent criteria of success. This has been achieved by maintaining a near 100 percent level of key fruit and bunch trait replication and a very small incidence of abnormalities (less than 1 percent). Yield was 30 percent higher in the clones compared with DxP material grown in commercial size polyclonal test plots.

Greater amounts of fertilizer nutrient inputs are required to sustain higher yields in clonal oil palm, but clonal oil palms also use fertilizer nutrients more efficiently than DxP seedlings, **Table 1** (Woo et al., 1994). Clones yielded 9 to 11 t oil/ha from the third year of production onwards (**Figure 2**), and a world record fruit yield of 50 t fresh fruit

Table 1. Efficiency of K fertilizer use by clonal and DxP oil palm seedlings in Malaysia (Woo et al., 1994).

Planting material	Cumulative (6 years) Oil yield t/ha	K_2O requirement kg/ha	Efficiency kg oil/kg K_2O	%
Clones	31.3	1,865	16.8	146
DxP	19.4	1,687	11.5	100



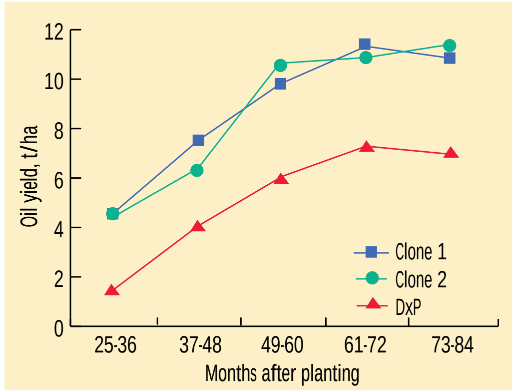


Figure 2. (At left) Fresh fruit bunch (FFB) yield of oil palm clone AGK19 and DxP seedlings during years 2 to 6 after planting on soils (Bukit Lunchu series) in Sarawak, Malaysia (Khaw et al., 1999).

Figure 3. (At right) Oil yields of oil palm clones and DxP seedlings during years 2 to 7 after planting on coastal soils (Carey series) of Malaysia (after Agrocom, 1998).

bunches (FFB)/ha was recorded in the second year after the start of harvest (**Figure 3**). Therefore, in spite of the greater cost of clones compared with DxP material and their greater fertilizer requirements, clones offer a large economic advantage over DxP material. **BCI**

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Oil Palm in Southeast Asia, 1998

Oil palm continues to be Southeast Asia's most rapidly expanding crop.
These data for 1998 summarize production and nutrient use for four countries.

Country		Indonesia	Malaysia	Philippines	Thailand
Area harvested	thousand ha	1,980	2,320	19	143
Immature area	"	800	650	10	45
Total	"	2,700	2,970	29	188
Likely expansion	"	4,500	1,000	30	100
Production FFB	thousand tonnes	29,510	43,700	273	2,300
Prod. crude palm oil (CPO)	"	5,900	8,370	40	380
Prod. palm kernels (PK)	"	1,300	1,650	8	90
N, P, K, Mg fertilizer nutrient use	kg/ha/year				
Average N application	"	60	95	50	55
Average P_2O_5 application	"	25	45	25	35
Average K_2O application	"	10	170	70	120
Average MgO application	"	5	30	1	3

PPI-PPIC ESEAP, 1999

Interpretation and Management of Oil Palm Leaf Analysis Data

By T.H. Fairhurst and E. Mutert

Fertilizer recommendations are effective when planters combine the interpretation of leaf analysis with field knowledge and common sense.

Five zones have been identified in terms of the relationship between leaf nutrient content and yield response (**Figure 1**), although it has been suggested that luxury uptake (Zone D) does not occur in oil palm.

Differences in leaf nutrient concentration may be due to a wide range of factors (**Figure 2**), which underlines the importance of strict adherence to proper procedures for leaf sampling. They also result in difficulties involved in the interpretation of the results of leaf analysis. Critical leaf nutrient concentrations, considered to have wide applicability, are given in **Table 1**. However, these values should only be used with the greatest caution. 'Optimum', or 'critical', values for individual nutrients can vary over a considerable range, depending on such factors as the age of palms, soil moisture regime, ratio to other nutrient concentrations, type of planting material, spacing, and inter-palm competition. These factors do not act in isolation, but should be considered in sum (**Figure 2**). It is therefore advisable to refer to optimal 'ranges' rather than to critical or optimal 'values'. Suggested nutrient ranges associated with optimum, deficient, and excessive nutrition are given in **Tables 2** and **3** for young and mature palms, respectively.

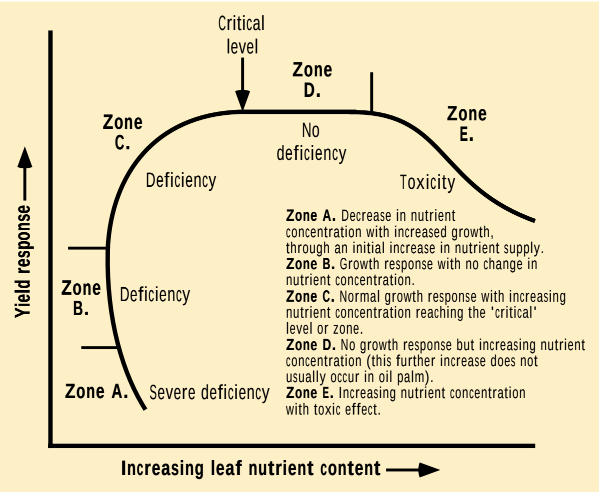

Figure 1. Diagram of deficiency and toxicity in relation to leaf nutrient concentration, growth, and yield (after Hartley, 1988).

Because of the synergism between nitrogen (N) and phosphorus (P) uptake, leaf P concentration must be assessed in relation to leaf N concentration (Ollagnier and Ochs, 1981). This is due to the constant ratio between N and P in protein compounds found in plant tissue. A

Table 1. Critical nutrient levels for oil palm leaves 9 and 17 (Ochs and Olvin, 1977).

Leaf #	N	P	K	Mg	Ca	Cl	S
17	2.50	0.15	1.00	0.24	0.60	0.55	0.22
9	2.75	0.16	1.25	0.24	0.60	–	–

'critical curve' has been developed where:

Critical Leaf P Concentration = 0.0487 x Leaf N Concentration + 0.039.

In the end, critical leaf nutrient concentrations must be determined for each agroecological environment, taking into account local soil and climate conditions, and this can only be achieved by means of factorial fertilizer experiments. Some workers have suggested larger critical nutrient concentrations where the number of effective sunshine hours is very high.

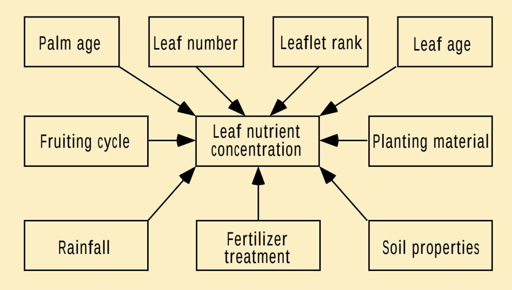

Figure 2. A large number of factors affect leaf nutrient concentration.

A different approach to determine whether potassium (K) and magnesium (Mg) are deficient involves taking into account the relative concentrations of leaf cations...K, Mg and calcium (Ca). First, the total amount of bases in the leaf (TLB) is calculated (see formula below) and K and Mg assessed as a percentage of TLB (Foster, 1999).

TLB (cmol/kg) = (Percent leaf K/39.1 + Percent leaf Mg/12.14 + Percent leaf Ca/20.04) x 1000

Very approximately, K and Mg deficiency can then be individually assessed, based on their percentage of TLB, as follows:

(X/TLB) x 100	Deficiency rating
<25	Deficient
25-30	Low
>30	Sufficient

Note:
X = partial TLB
of K, Mg and Ca

For example, if K = 0.91, Mg = 0.23, and Ca = 0.56, TLB = 70.16 and X = 23.27 for leaf K and 18.94 for leaf Mg, then X/TLB = 33 percent for leaf K and 27 percent for leaf Mg. With this method we would conclude that K is sufficient and Mg moderately deficient.

Leaf analysis may be used to determine whether differences in nutrient status explain the abnormal appearance of a particular selection of palms (e.g., where some palms exhibit particular deficiency symptoms, but the cause is not clear). A bulk sample based on 20 to 30 sampled palms should be prepared in the normal way for both affected and unaffected palms. Leaves should be analysed for micronutrient content if symptoms are not obviously related to one of the macro-nutrients. Affected palms should also be photographed to assist with leaf analysis interpretation at a later date.

The estate profits from properly implemented leaf sampling and analysis only when the results are correctly interpreted and transformed into a fertilizer program. Leaf analysis data begin to provide more useful information when a series of data has accumulated over a number of years. Formerly, data storage and retrieval were difficult tasks and required the use of clip card systems of the kind developed by PT London Sumatra in the 1960s. However, personal computers equipped with database software now provide powerful tools allowing much more thorough and detailed analysis of leaf data.

A suitable system, 'Oil Palm Monitoring Program (OMP7)', is available from PPI/PPIC. Provided the necessary background information has been collected and entered, a suitable monitoring program can be used to run queries on sets of data. Examples are given below:

- Show all fields where leaf N and K concentration is below critical levels.
- Calculate mean leaf P concentration in all Ultisol fields.
- Select blocks with above critical leaf N concentration and show yield.
- Calculate mean leaf N concentration in fields affected by caterpillars.
- Calculate mean N concentration in similarly aged palms (averaged over several planting years).
- Calculate mean leaf K level in a particular planting material.

After two to three years, booklets may be printed for each block showing yield, leaf analysis, and past fertilizer applications for each year. When such information is available, a discussion in the field between different levels of staff is based on actual data rather than guesswork and memory.

Table 2. Nutrient concentration in leaf 17 associated with deficiency, optimum and excess in young palms, less than 6 years from planting (von Uexküll and Fairhurst, 1991).

Nutrient	Units	Deficiency	Optimum		Excess
N	% DM	<2.50	2.60	2.90	>3.10
P	% DM	<0.15	0.16	0.19	>0.25
K	% DM	<1.00	1.10	1.30	>1.80
Mg	% DM	<0.20	0.30	0.45	>0.70
Ca	% DM	<0.30	0.50	0.70	>0.70
S	% DM	<0.20	0.25	0.40	>0.60
Cl	% DM	<0.25	0.50	0.70	>1.00
B	mg/kg	<8	15	25	>35
Cu	mg/kg	<3	5	7	>15
Zn	mg/kg	<10	15	20	>50

Table 3. Nutrient concentration in leaf 17 associated with deficiency, optimum and excess in mature palms, more than 6 years from planting (von Uexküll and Fairhurst, 1991).

Nutrient	Units	Deficiency	Optimum		Excess
N	% DM	<2.3	2.40	2.80	>3.00
P	% DM	<0.14	0.15	0.18	>0.25
K	% DM	<0.75	0.90	1.20	>1.60
Mg	% DM	<0.20	0.25	0.40	>0.70
Ca	% DM	<0.25	0.50	0.75	>1.00
S	% DM	<0.20	0.25	0.35	>0.60
Cl	% DM	<0.25	0.50	0.70	>1.00
B	mg/kg	<8	15	25	>40
Cu	mg/kg	<3	5	8	>15
Zn	mg/kg	<10	12	18	>80

Conclusions

Because of the importance of fertilizer in the production and maintenance of large and sustainable yields of fruit bunches, considerable efforts have been made to develop methods providing a scientific basis for estimating fertilizer requirements of oil palm. However, while soil and leaf analysis may provide the basis for decisions on fertilizer use, the final crop is the result of the interaction of so many different factors, some of which cannot be controlled or predicted. Hence, exact 'prescriptions' are not possible. Effective fertilizer recommendations are usually the result of combining the results of leaf analysis with field knowledge and common sense. Fertilizer recommendations should not rely on prescriptions based on leaf analysis data, determined in an analytical laboratory without recourse to field inspections. For example, applying large amounts of N fertilizer based on low leaf N status will be ineffective where the underlying constraint to palm productivity is over-pruning and poor drainage. However, under good management, the oil palm is so responsive to fertilizer that it almost always pays to use rates that are close to the agronomic maximum, which in turn will depend on the prevailing soil and climate conditions.

The underlying cause of small leaf nutrient concentrations and observed deficiency symptoms may be careless and incorrect application rather than insufficient amounts of fertilizer. Indeed, attention to application technique (e.g., spreading, use of calibrated measures) may often eliminate the need to increase application rates. Field inspections are thus an integral part of leaf analysis data interpretation, and professional consultants will always insist on walking all the fields for which they provide recommendations. BCI

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PPI/PPIC Nutrient Management Services for Oil Palm

By T.H. Fairhurst, Armin Gfroerer-Kerstan and Ian Rankine

The Institute works closely with oil palm growers and scientists around the world. Responding to growing demands for sound information, it has developed three services to assist growers to improve field agronomy, productivity, and staff development.

Information Services

There is a large and growing demand for science-based nutrient management information in a form useful to the fertilizer industry, planters, agricultural and environmental leaders, scientists, and policy makers. The Institute has set a goal to become the source of choice for nutrient management information. To this end, the PPI/PPIC East and Southeast Asia Programs office has established searchable databases containing over 1,000 scientific papers, books, and other articles about oil palm and more than 800 slides illustrating oil palm field agronomy from seed preparation to fresh fruit bunch (FFB) processing. In particular, the program maintains a comprehensive literature collection on issues relating to phosphorus (P) and potassium (K) use in oil palm. It is now able to provide growers and scientists with sources of information, as well as illustrations for use in company staff training programs and preparing company brochures and publications.

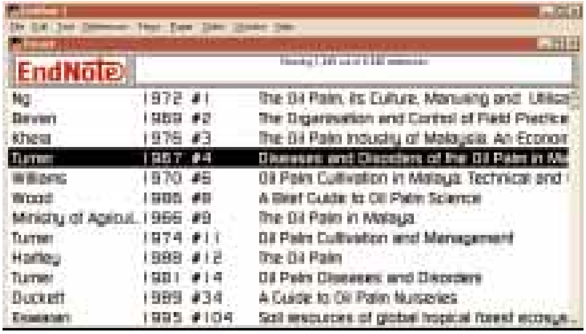

Figure 1. The PPI/PPIC Southeast Asia Programs literature database includes a large collection on P and K use in oil palm.

This service will be extended with the preparation of a CD-ROM containing a searchable database of oil palm references and photographs depicting all aspects of oil palm crop production.

Oil Palm Monitoring Program (OMP7)

All plantations accumulate large amounts of valuable data on yield, fertilizer use, leaf analysis, pest and disease incidence, tree census, etc. Unfortunately, this information is usually stored in a rather haphazard way, such that the routine analysis of trends is impossible.

How many plantations can answer the following questions using quantitative data analysis?

- *Which planting material in the estate is most susceptible to crown disease?*

- *What were the changes to soil chemical fertility over the past 10 years?*
- *What were the long-term changes in leaf nutrient levels?*
- *Are plantation soils being mined of nutrients?*
- *Does the installation of soil conservation techniques result in increased productivity?*

The implementation of a customised database system in each estate can significantly contribute to the estate's ability to answer these questions for itself, based on an analysis of its own data. Armed with such information, the estate will then be better able to exploit the services provided by visiting consultants and demand answers to important questions made evident from a full analysis of agronomic data. In collaboration with Agrisoft Systems, the PPI/PPIC staff have developed customised agronomy database software to store, process and analyse all agronomic aspects of the oil palm production process.

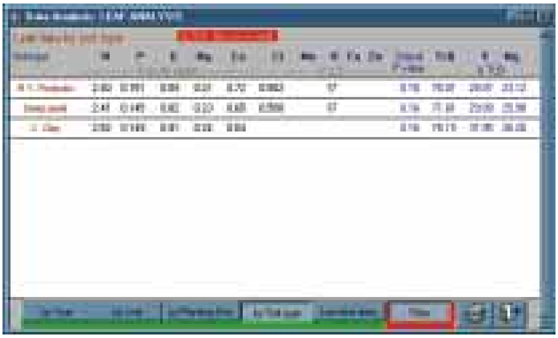

Figure 2. The OMP7 is programmed to provide the user with summarised information. Here, mean leaf levels are presented for each soil type for all blocks in production.

Handbooks in Cooperation with 4T Consultants

A series of oil palm booklets has been developed from the ground up, with practical input from recognized managers and supervisors in the industry. The series is made up of three modules: Nursery, Immature, and Mature. Each module consists of a field handbook and a pocket guide. The field handbooks are more detailed and provide the information required by estate managers. The pocket guides are summaries of the field handbooks and provide a field reference for line managers, supervisors, and team leaders. The pocket guides contain essential "need-to-know" information and are specifically designed for use in the field.

High yields depend on management which requires a team of trained workers, supervisors, and managers.

These guides detail each key task in a separate section, and each section is described as follows:

Objective **O** A statement of the final outcome(s) of the job. Managers understand why a job is being done.

Standard **S** Explains the required outcome of the task or action. Managers understand the quality of work that is required.

Equipment **E** Lists the equipment required to complete the task. A checklist of what equipment is required.

Materials **M** Lists the consumables and materials necessary for the job. A checklist of what materials are required.

Procedures Details the actions to be taken in order to com-

In all plantations, in-field training is required to introduce and standardise production technology.

plete the task to the required standard. Outlines how the task is to be done.

Frequency How often a task is to be repeated. Outlines how often the task is to be done.

Timing What time of the year the task is to be completed. Indicates when the task is to be completed.

Task Provides a productivity 'benchmark' for work output. Allows a quantitative measurement of resources and productivity.

Records States the records that must be kept for the activity. Ensures that consistent records are maintained.

Notes Allows users to make notes on each section.

The booklets contain essential information in an easy to read format. Photographs, diagrams and examples support the text where applicable. The language used is clear and to the point, so that managers do not waste time trying to understand the point being made. The layout of each field guide is consistent so managers can locate essential information quickly. The books are printed on water resistant, thick paper to withstand daily field use. They set standards and describe procedures that are consistent with best management practices and form part of PPI/PPIC's range of training and reference materials. BCI

High yields are produced from well selected and carefully planted seedlings.

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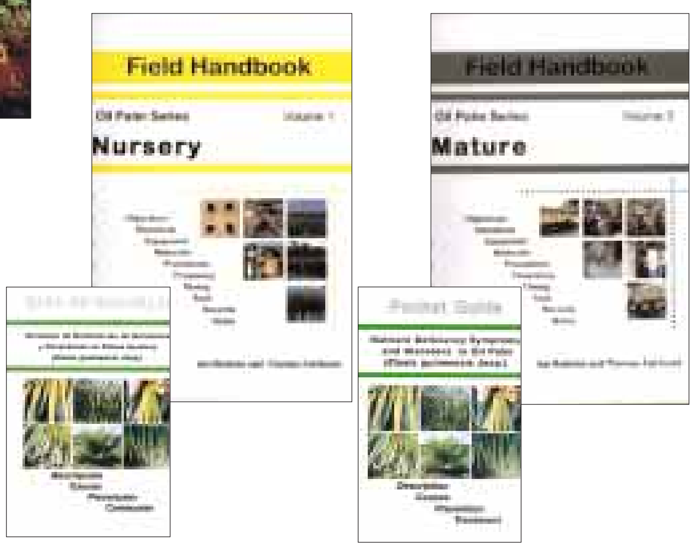

Order Form

Item #	Title	Quantity	Unit Price		Discount	Total Price
			US$	S$	%	S$
	Field Handbooks:					
OP 98 1	Nursery		25.00	40.00		
OP 99 2	Immature		25.00	40.00		
OP 98 3	Mature		25.00	40.00		
	Pocket Guides:					
OP 99 4	Nursery		10.00	16.00		
OP 99 5	Immature		10.00	16.00		
OP 99 6	Mature		10.00	16.00		
	Field Booklets:					
OP 97 7	Deficiency & Disorders		5.00	8.00		
OP Full set	3 FHB, 3 PG, 1 FB		105.00	170.00		
50-7000	Int'l Soil Fertility Manual		20.00	32.00		
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			Add: Postage (airparcel) and Handling Fee:			
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Sustainable Development... Agriculture in the Forest

To me, sustainable development means doing those things that nurture mankind's aspirations and provide society's needs while ensuring a safe and viable environment – the resource base we all live on...and in.

Progressive agriculture is basic to sustainable development. The aim of this issue of *Better Crops International* is to explain the oil palm cropping system that safeguards major areas of land throughout the tropics, by securing the soil, water, and air resources we all depend on and making them productive for its inhabitants.

Oil palm planters and other agroforesters around the world (growing rubber, citrus, coffee, cacao, etc.) continue to develop efficient tree-based agricultural production systems to provide food, fibre and wood to meet the escalating needs of our growing world population. These endeavors contribute tremendously to agricultural development and the needs of mankind. What about the environment's needs? Efficient agroforestry cleans up the air by fixing large amounts of carbon dioxide (CO_2), improves hydrological cycles through the 'rainforest effect', stabilises soil through protective and robust rooting systems, an ample supply of leaf litter, and a closed canopy, and becomes a bio-diverse habitat for many plant and animal species.

The advanced oil palm system is a sustainable one. It produces biomass at a rate comparable to tropical rainforests and, due to natural groundcover and the application of integrated pest management practices, allows much more bio-diversity than might be expected from a mono-cropping system.

Sustainable development doesn't just happen. It's planned, implemented and managed. Agroforesters and planters know that the best systems require inputs...improved genetics, appropriate soil fertility, and crop protection...all based on good science and documented evidence. In return for this, the world's environment...and its people...benefit greatly.

Our Institute thanks the farmers, planters and agroforesters of the world – stewards of our Earth's resources – for their significant and appreciated contribution to a safe and viable environment.

Dr. Mark D. Stauffer
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and President, PPIC

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