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NUTRIENT DEMANDS OF *Tenera* OIL PALM PLANTED ON INLAND SOILS OF MALAYSIA

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ABSTRACT

Oil palm is unrivalled in its ability to convert solar energy into dry matter and vegetable (palm) oil. This process requires a large amount of nutrients, which must be supplied through soil or fertilizers. Good nutrient management, which includes a site-specific nutrient management plan, is important to achieve high yields of palm oil. Good knowledge of nutrient requirements at the various stages of growth and development of the oil palm is needed for the nutrient management plan and greater fertilizer-use efficiency. This paper highlights the nutrient requirements of oil palm based on the nutrient contents of tenera *palms from analysis of their nutrients in fresh fruit bunches (FFB), trunk and roots in a 3^2 NK x 2P factorial fertilizer trial on Bungor series soil. The results showed that more of N is actually removed than previously estimated but an annual application of 4.2 kg ammonium sulphate per palm meets the nutrient demands to produce 30 t FFB ha^{-1}, i.e., the N applied balances the N demand. However, the K applied was surplus (23% of the 3.5 kg potassium chloride per palm applied) to the actual requirement of the palms. The unaccounted P (surplus of 20%) could have been fixed by the soil, which suggests that more phosphate rock fertilizer, i.e. over 2 kg palm^{-1} yr^{-1}, is required to compensate for the P immobilized by the soil. The paper also proposes a comprehensive and sound nutrient management plan comprising various complementary components.*

Keywords: oil palm, tissues, nutrient balance.

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INTRODUCTION

The oil palm is a perennial plant which, under suitable climatic conditions, grows well and is highly productive. To support its growth and yield, it requires large amounts of nutrients such as nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg). Its regular planting and growth pattern and somewhat predictable yields make it easier to study its nutrient requirements. In recent years, there has been increased emphasis on site-specific nutrient management to improve its growth and productivity to match its potential to the site (Chew *et al.*, 1992; Kee *et al.*, 1994). Good knowledge of nutrient requirements at its various stages of growth and development will allow the development of nutrient management plans, from which better recommendations can be made for nutrient rates, sources, timing and application methods to achieve the grower's agronomic, economic and environmental objectives.

A high yield palm oil production system depends on good agronomic practices. The following are examples of good agronomic practices:

- good nutrient management plan;
- implementation of legume cover crop policy;
- nutrient recycling to build up soil organic matter;
- soil moisture conservation practices; and
- erosion control practices.

Protecting the organic matter in topsoil from erosion, providing organic soil amendments and soil moisture conservation will lead to efficient fertilizer use through inorganic fertilizer interactions with mulch (Chan *et al.*, 1993; Khalid, 1997; Hamdan *et al.*, 1998). In Malaysia, surface runoff is highest

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during the wet season (Kee and Chew, 1996). Growers must learn to manage their soils by conserving the valuable plant nutrients and minimizing losses in order to maximize yields.

Most nutrient management plans emphasize a balance between nutrient supply and removal by the crop. While a balance is ideal, it does not apply to some situations of high deficiency demand such as the high K requirement for oil palm growing on peat and P requirement on inland soils. Previous studies by Ng and Thamboo (1967) on nutrient contents of oil palm, which the results were used to estimate nutrient removal by oil palm, were on *dura* (DxD) palms. To verify and update these data for the current *tenera* (DxP) palms planted, their nutrient contents in fresh fruit bunches (FFB), trunk and root were studied in a factorial fertilizer trial (3^2NK x 2P) on Bungor soil series. This paper highlights oil palm nutrient requirements based on the nutrient contents of *tenera* palms.

MATERIALS AND METHODS

All the works to estimate the nutrient requirements of oil palm through analysis of the nutrients in FFB, trunk and roots of the palms were carried out in a 3^2NK x 2P factorial fertilizer trial on a Bungor series soil (*Typic Paleudult* derived from sandstone/shale) in Paloh, Johor. The trial was initiated on six-year-old DxP (*tenera*) palms. The rates of fertilizers applied (by even broadcasting in the weeded circle) were:

Fertilizer	**Level**		
	1	2	3
	kg palm^{-1}yr^{-1}		
Ammonium sulphate (AS)	0	4.2	8.4
Christmas Island Rock Phosphate (PR)	-	1.5	3.0
Potassium chloride (muriate of potash - MOP)	0	3.5	7.0

The plot size was 6 x 5 palms with the 12 central palms recorded for FFB yield (bunch weight and number), vegetative measurements, bunch analysis and tissue sampling/analysis.

Bunch Sampling and Separation into its Components for Analysis

After eight years of treatment, two ripe bunches were sampled from each of the 19 plots in the trial including the absolute control plot (no fertilizer). Each bunch was weighed in the field and immediately taken to the laboratory. In the laboratory, it was stripped and divided into the major components of fruits, stalk and spikelets with trash and weighed. Sub-samples were obtained as follows: A quarter of the fruits were taken for a sub-sample of 60-70 fruits. They were cleaned and separated, firstly, into pericarp and nut (depericarping). The pericarp was diced, gently ground up in a porcelain mortar and dried overnight at 70°C. The nut was dried similarly and then cracked with a hammer to extract the kernel. After separation, the shell was placed in a canvas bag and crushed with a hammer before grinding in a mill. The kernel was pounded up in a porcelain mortar. The spikelet/trash was diced, dried overnight in an oven and ground in a hammer mill. The ground material was then quartered for a sub-sample of about 250 g. The stalk was cleaned and treated in the same way as the spikelet/trash.

Trunk and Root Sampling/Preparation for Analysis

The nutrients immobilized in the trunk were estimated based on its annual height increment averaged over four years and nutrient contents of its tissue sampled from six palms a plot. After removing the old frond butts, the trunk was sampled at the bottom, middle and upper sections using a specially designed mechanical drill (two points per section to 20 cm depth). The tissues were oven dried at 70°C for 24 hr before analysis.

Root samples were taken using a root auger of known volume from the same six palms in the 18 plots. They were taken from three equidistant points, 1 m, 2 m and 3 m from the palm base and at horizons of 0-30 cm, 30-60 cm and 60-90 cm. The roots were thoroughly washed (cleaned), diced and dried in the oven at 70°C. They were subsequently ground in a hammer mill before being quartered for a sub-sample of about 250 g. The annual root increment was estimated following Corley *et al.* (1971).

Tissue Analysis

All the tissue samples (mesocarp, shell, kernel, trash/spikelet, stalk, trunk and root) were analysed for N, P, K, Ca and Mg according to the standard procedures of the *PORIM Plant Analysis Manual* (Zulkifli and Masnon, 1993).

RESULTS AND DISCUSSION

Nutrient Demand

A large amount of nutrients is needed for good oil palm growth and yield. As the oil palm is a perennial crop, the amount of nutrients immobilized in the growing trunk and roots have to be estimated along with the nutrients removed with the harvested

FFB. In this paper, the nutrients in the fronds, male flowers and dead roots were not quantified as they were assumed to be recycled as the standard plantation practice leaves the pruned fronds and male flowers in the field.

Nutrients in FFB. The bunch component ratios, dry matter and nutrient contents for the *tenera* palms from this study were compared to those for *dura* palms from Ng and Thamboo (1967) in *Tables 1* to *3*.

The N and K contents in *tenera* bunches were higher than those in *dura* bunches by 5% and 6% respectively (*Table 4*). However, the P and Mg contents in *tenera* bunches were noticeably lower than those in *dura* bunches by 16%.

TABLE 1. BUNCH COMPONENT RATIOS AND DRY MATTER (DM) - *Tenera vs. Dura*

	Bunch ratio		%DM		kg DM/kg FFB	
	Dura	***Tenera***	***Dura***	***Tenera***	***Dura***	***Tenera***
Mesocarp	0.417	0.451	**65.4**	73.3	0.273	0.330
s.d.	-	0.055	-	8.5	-	0.056
Shell	0.182	0.045	84.7	80.1	0.154	0.036
s.d.	-	0.010	-	2.3	-	0.008
Kernel	**0.058**	0.077	**80.9**	**69.1**	**0.047**	**0.053**
s.d.	-	0.016	-	8.0	-	0.012
Trash/spikelet	0.218	0.238	33.0	33.8	0.072	0.080
s.d.	-	0.020	-	7.7	-	0.018
Stalk	**0.093**	0.103	17.0	14.3	0.016	0.015
s.d.	-	0.019	-	3.00	-	0.003

Notes:
Tenera planted on inland soil of Bungor series (26 t FFB ha^{-1} yr^{-1}); Means of 36 bunches (2 bunches per plot for 18 plots);
Dura planted on inland soil of Jerangau series (24 t FFB ha^{-1} yr^{-1})(Ng and Thamboo, 1967).

TABLE 2. NUTRIENT CONTENTS IN MESOCARP, SHELL AND KERNEL - *Tenera vs. Dura*

Mesocarp	**%N**	**%P**	**%K**	**%Mg**	**%Ca**
*Tenera**	0.468	0.048	0.401	0.138	0.106
s.d.	0.105	0.005	0.108	0.023	0.036
*Dura***	0.384	0.049	0.399	0.113	0.148
s.d.	0.048	0.012	0.079	0.017	0.024

Shell	**%N**	**%P**	**%K**	**%Mg**	**%Ca**
*Tenera**	0.492	0.021	0.223	0.047	0.034
s.d.	0.072	0.007	0.027	0.011	0.019
Dura **	0.313	0.006	0.095	0.014	0.019
s.d.	0.034	0.002	0.014	0.003	0.004

Kernel	**%N**	**%P**	**%K**	**%Mg**	**%Ca**
*Tenera**	1.432	0.312	0.378	0.151	0.124
s.d.	0.195	0.022	0.033	0.013	0.018
*Dura***	1.301	0.331	0.465	0.155	0.102
s.d.	0.100	0.012	0.046	0.010	0.010

Notes: * Bungor series (26 t FFB ha^{-1} yr^{-1}); Mean of 36 bunches (2 bunches per plot for 18 plots).
** Jerangau series (24 t FFB ha^{-1} yr^{-1}) (Ng and Thamboo, 1967).

TABLE 3. NUTRIENT CONTENTS IN TRASH/SPIKELET AND STALK - *Tenera vs. Dura*

Trash/spikelet	**%N**	**%P**	**%K**	**%Mg**	**%Ca**
*Tenera**	0.843	0.091	1.986	0.163	0.193
s.d.	0.081	0.015	0.161	0.037	0.052
*Dura***	0.895	0.126	2.326	0.275	0.467
s.d.	0.147	0.024	0.281	0.067	0.164

Stalk	**%N**	**%P**	**%K**	**%Mg**	**%Ca**
*Tenera**	0.914	0.100	5.158	0.091	0.285
s.d.	0.093	0.018	0.563	0.041	0.063
*Dura***	0.923	0.111	6.617	0.172	0.435
s.d.	0.171	0.057	0.780	0.062	0.107

Notes: * Bungor series (26 t FFB ha^{-1} yr^{-1}); Mean of 36 bunches (2 bunches per plot for 18 plots).
** Jerangau series (24 t FFB ha^{-1} yr^{-1}) (Ng and Thamboo, 1967).

TABLE 4. NUTRIENT CONTENTS IN *Tenera* AND *Dura* FRESH FRUIT BUNCHES (FFB) (kg t^{-1})

	N	**P**	**K**	**Mg**
Dura (Ng and Thamboo, 1967)	2.94	0.44	3.71	0.81
Tenera (current study)	3.10	0.37	3.92	0.68
Tenera above/below *dura* (%)	5	-16	6	-16

The mean FFB yield and amounts of nutrients over four years computed from all the fertilized plots in the trial are shown in *Table 5*.

TABLE 5. NUTRIENTS (kg ha^{-1} yr^{-1}) REMOVED IN FRESH FRUIT BUNCHES (FFB)

Average of 4 years	FFB (t ha^{-1} yr^{-1})	N	P	K	Mg	Ca
		(kg ha^{-1} yr^{-1})				
Mean of 18 plots	25.9	80.7	9.6	101.5	17.7	15.7
Standard deviation	3.41	14.76	1.70	15.46	4.02	4.95
Minimum	18.8	48.6	6.5	69.9	9.7	9.0
Maximum	32.3	100.3	12.2	124.6	23.9	31.4

Nutrients immobilized in trunk and root. Annually, a mature oil palm grows 60 to 90 cm in height which is more dry matter and nutrients added. In this fertilizer trial on Bungor series soil initiated on 6-year-old palms, the immobilization of nutrients in the trunk was computed from palm age 9 to 12 years. The nutrients immobilized in the trunk were estimated based on the annual height increment averaged over four years and nutrient analysis of sampled tissue from six palms in each of the 19 plots, including the non-fertilized plot. The estimated amounts of nutrients immobilized are given in *Table 6*. The roots were also sampled and analysed for their nutrient contents for all the plots but the annual root increment was estimated from Corley *et al.* (1971).

TABLE 6. ESTIMATION OF ANNUAL IMMOBILIZATION OF NUTRIENTS IN OIL PALM TRUNK AND ROOTS*

Palm trunk	Height increment (cm yr^{-1})	Dry wt. (kg palm^{-1} yr^{-1})	N	P	K	Mg
			(kg ha^{-1} yr^{-1})			
Mean of 18 plots (4 years average)	80.4	41.5	22.0	2.3	43.5	5.5
S.D.	10.1	6.8	6.7	0.5	22.4	2.8
Nutrients for zero plot (non-fertilized palms)	60.4	20.9	9.7	0.9	8.0	4.26
Palm roots (estimated)		4.2**	15.59	1.07	2.80	0.42

Notes: *Current study.
** From Corley *et al.* (1971).

Estimation of Nutrient Requirements

In this exercise, the annual nutrient requirements of oil palm were calculated based on the amounts of nutrients removed by the FFB, immobilized in the trunk and roots and lost through erosion, runoff and leaching. The nutrients in the fronds, male flowers and dead roots were not considered as they were assumed to be recycled in the system as the standard plantation practice leaves the pruned fronds and male flowers in the field. As all the whole FFB was exported from the field, recycling of the EFB was not considered in the following equation:

Nutrient requirement (kg ha^{-1} yr^{-1}) = nutrients removed in FFB + nutrients stored in trunk and roots + potential nutrient losses

All the palm data were derived from this study, but the nutrient losses from leaching, surface runoff and soil erosion adapted from Foong (1993) and Kee and Chew (1996). The equation is adjustable according to various soil types and field conditions with different potential in nutrient losses.

Table 7 shows a nutrient balance sheet based on the actual yields of the plots applied with 4.2 kg ammonia sulphate (AS), 3 kg phosphate rock (PR) and 3.5 kg potassium chloride (MOP) palm^{-1} yr^{-1} for four years. The annual nutrient demand by the palms was calculated based on measurements from the plots over four years.

The results on Bungor series soil suggest that application of 4.2 kg AS palm^{-1} yr^{-1} meets the nutrient demands of the palms to produce 30 t FFB ha^{-1}, *i.e.* the N applied balances with the N demand.

However, the surplus K (23% of 3.5 kg MOP palm^{-1} yr^{-1}) suggests that the K applied was slightly higher than the actual requirement of the palms.

It is difficult to predict the response to applied P based on the P content in the soil. The phosphate requirement would depend on the soil P buffering, or P fixing capacity. It is associated with the Al and Ca complex in the soil that influences phosphate recovery by the palms. Hence, the unaccounted for P (surplus of 20%) could have been fixed by the soil, which was estimated to be around 570 mg kg^{-1} for Bungor series soil (Tessens and Shamsuddin, 1983). Aminuddin (1985) showed that ammonium acetate lactate (AAL extractable P to assess the P availability from the soil) could only extract 30% of 300 kg PR ha^{-1} applied on Bungor series soil. Therefore, application of 3 kg PR palm^{-1} yr^{-1}, *i.e.*, 408 kg ha^{-1} of PR with 8% citric soluble P_2O_5 (16.1 kg of P ha^{-1} yr^{-1}), is required to compensate for immobilization of the applied P by the soil.

The amount of nutrients needed to attain the maximum site yield potential would vary according to the palm growth, size and nutrition, yield level, site soil properties and characteristics (Foster *et al.*, 1986). The latter will affect the nutrient recovery and

TABLE 7. NUTRIENT BALANCE OF OIL PALM (9- to 12-year-old)

Fertilizer requirements based on nutrients removed, immobilized and lost (kg ha^{-1} yr^{-1})

Palm demand	N	P	K	Mg
a. Nutrient contents in 30 t FFB ha^{-1} yr^{-1}	97.6	10.0	105.4	18.2
b. Nutrient immobilised in trunk and roots	18.5	2.4	61.9	3.8
Total	116.2	12.4	167.3	22.0
Fertilizer application* for 136 palms ha^{-1}	120.0	16.1	285.6	0
Environmental demand				
Erosion losses and surface runoff losses (Kee and Chew, 1996) (%)	8.0	1.6	15.3	7.6
Leaching losses (Foong, 1993) (%)	3.0	1.5	2.9	15.5
Expected losses (%)	11.0	3.1	18.2	23.1
Expected losses (kg ha^{-1} yr^{-1})	13.2	0.5	52.0	0
Accounted for palm and environmental demand	129.4	12.9	219.3	22.0
Unaccounted (immobilized/lost *etc.*)	-	3.19	66.3	-
Surplus/over-application (%)	-	20	23	-

Notes: * 4.2 kg AS palm^{-1} yr^{-1}, 3 kg PR palm^{-1} yr^{-1} and 3.5 kg MOP palm^{-1} yr^{-1} [3 kg PR = 0.24 kg citric soluble phosphate (P_2O_5) = 0.119 kg P].

nutrient losses. A steep slope accompanied by high annual rainfall may be expected to reduce the efficiency of nutrient uptake. As such, the responses per unit fertilizer applied would decline with the slope, which results in more runoff losses. Likewise, the yield potential without fertilizer will increase appreciably with higher organic matter content and extractable K level due to greater K availability, and the N and K fertilizer requirements will be reduced proportionately. In some cases, such as in peat and sandy soil, K deficiency is common and usually the largest single nutritional factor that determines FFB yield.

The nutrient uptake by the palm will be higher if nutrient losses are minimized through better soil conservation measures (Kee and Chew, 1996*)* and improved soil fertility through organic matter amendment and nutrient recycling (Chan *et al.*, 1993; Khalid, 1997). In summary, the nutrient requirements besides this nutrient balance exercise are subject to, inter alia, the following site properties:

- steep slope - the major site factor affecting the efficiency of N and K uptake, which could cause considerable nutrient losses by runoff and erosion;
- soil drainage - poor drainage depresses the yield response to N fertilizer. In anaerobic condition from poor drainage, denitrification losses and interference with the root metabolic processes will result in less N uptake. In sandy soil, excessive drainage can cause considerable N loss through leaching; and
- other factors, besides runoff and leaching, are the ground cover, mulching, root impedance and methods of fertilizer application, which have to be considered when assessing the crop yield response to fertilizers.

CONCLUSION

With the current high crude palm oil prices and stiff global competition, growers and plantation managers must continue to give strong emphasis to high yields in order to maximize profit. Balanced fertilization with N, P and K according to nutrient removal, leaf analysis and soil tests are necessary for sustained and profitable palm oil production. Site-specific nutrient management plans incorporating nutrient balances are proposed to help identify situations where surplus fertilizer applications may result in high production cost or undue losses to the environment. This is especially pertinent with the current high costs of fertilizers in the market.

Nutrient management planning should be comprehensive and involve components that also complement each other. The components of a sound nutrient management plan of MPOB include:

- accurate yield level and goal (to predict yield using yield response equations based on previous trial data);
- estimate of nutrients applied and removed by crops (as discussed in this paper);
- determination of the most limiting nutrient (by foliar and soil analyses, and past fertilizer application records);
- consideration of all nutrient sources including commercial fertilizers, organic amendments and realistic estimates of availability of different nutrient sources;
- maintenance of soil fertility by replacing the nutrients removed and planning nutrient recycling for reducing of nutrient application;
- adequate soil conservation measures/ indicators of erosion and runoff transport; and
- timing of nutrient applications to minimize risk of weather-related losses.

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