October'98

AA RESEARCH NEWS

EDITORIAL

This is the final issue of our AA Research News for this year. We would like to take this opportunity to wish our Muslim readers Selamat Berpuasa and our Christian readers, Merry Christmas. 1999 is just around the corner. We hope it will be a better year for all of us.

The current economic crisis has given us much food for thought. Crisis in Chinese also means opportunity. We should therefore treat this crisis as an opportunity to improve ourselves and emerge stronger than before.

In this issue, we would like to share with you an article on "Optimising return from fertilizer for oil palms : an integrated agronomic approach" jointly authored by a team of AAR agronomists Teo C.B., Chew P.S., Goh K.J. and Kee K.K. - some food for thought ?

**SELAMAT BERPUASA,
MERRY CHRISTMAS
AND
HAPPY NEW YEAR**

Ooi, L.H.

OPTIMISING RETURN FROM FERTILIZER FOR OIL PALMS: AN INTEGRATED AGRONOMIC APPROACH

By Teo C.B., Chew P.S., Goh K.J. and Kee K.K.

(Paper presented at MOSTA Symposium at Lumut in Oct'98)

ABSTRACT

Fertilizers account for about 24% of total production costs in mature oil palm. The principal goal in optimizing fertilizer use is to produce sustained optimum yields and profits per unit area through balanced fertilization and minimal fertilizer rates from improved fertilizer efficiency.

Losses of the soluble nutrients eg. N, K, Mg and B appear mainly due to surface run-off and leaching or immobilization by weeds in young palms. Soil immobilization is usually minimal and losses may be reduced by correct choice and rate of fertilizers, method, timing and frequency of application. Less soluble fertilizers eg. rock phosphate and ground magnesium limestone are much less susceptible to leaching and run-off losses, and therefore timing may be less critical. Nutrient availability could be problematic in high pH soils. Additionally, high P fixation usually occurs in soils with high Fe and Al.

Fertilizer rates should meet the nutrient requirements for site yield potentials. This requires a site-specific approach to identify the agronomic and management factors operating in the area and to formulate agronomic measures to achieve our goals, which is maximising profit. Information to improve fertilizer efficiency and their analysis will be easier in future with availability of new technologies, enabling an integrated agronomic approach to be practised. The desired results can only be realised if the management plays its role in ensuring that all the recommended practices are implemented properly and on time.

1. Introduction

Today, in the midst of one of our country's worst economic crisis, the plantation sector, especially oil palm has emerged as a golden industry bringing home the much needed foreign exchange and providing good rewards to the investors and workers.

The growth of the oil palm industry in Malaysia has been phenomenal. With only 97,000 ha planted in 1965, it has increased to 2.8 million ha in 1997 (PORLA, 1998) and produced over 9.0 million tonnes of palm oil making her the largest exporting nation of oils and fats in the World (Oil World, No:16)

Fertilizer has played a major role in contributing to the advancement of sustainable oil palm yields in Malaysia (Chew, 1985). It was estimated that fertilizer constituted about 24% of the total cost of palm oil production in Malaysia (Tan, 1988). The current fertilizer consumption in Malaysia is about one million nutrient tonnes, and of these oil palm accounted for about 62.7% (MADI, 1997/98).

Good yield responses to fertilizers of up to 98% had been reported (Tarmizi et al. 1992, Goh et al. 1994). This is because the soil grown with oil palms are mainly Ultisols and Oxisols where fertility and nutrient supply are often limiting factors. High fertilizer inputs are therefore required to achieve and sustain high oil palm yields (Ng and Thong 1985, Von Uexkull and Fairhurst 1991).

However, with the economic slowdown, the Malaysian ringgit has depreciated sharply by almost 62% against the US dollar since early last year. This has inevitably raised the prices of imported fertilizers significantly and consequently caused the production costs to increase by as much as 13% (Ooi, 1997). Hence, proper fertilizer management is vital to attain efficient uptake, high sustainable yields and maximum benefits from the high expenditure on fertilizers. This will also avoid excessive application, which will reduce profitability and may have negative impact on the environment.

In this paper, we shall show that optimising fertilizer use to produce sustained maximum yields and profit per unit area involves correct fertilizer rates, balanced fertilizer programmes and improved fertilizer efficiency. The latter requires not only maximising uptake efficiency but also minimising potential nutrient losses. This paper is largely drawn from our earlier work presented in the "1998 International Oil Palm Conference: Commodity of the past, today and the future" in Bali, Indonesia (Teo et al., 1998) with minor modifications.

2. Getting accurate fertilizer rates

The first step to optimise profit from manuring is to obtain the correct fertilizer rates for each uniform area in the oil palm plantation. This is because over or under application of fertilizers can have disastrous effects such as poor crop productivity due to lack of fertilizer or imbalance; low profit due to excess fertilisation and in extreme cases; soil acidification, degradation and environmental pollution due to excessive leaching and run-off losses. A site-specific fertilizer recommendation system (INFERS) for mature oil palm (Kee et al., 1994) was therefore developed at AAR towards this objective. Interested readers may refer to the paper for further details.

Briefly, INFERS formulates fertilizer rates for oil palm based on the concept of nutrient balance. It takes into account all the important agronomic and management factors that influence nutrient demand and supply. These factor, *inter alia*, are climate, planting materials and pattern, palm vigour and canopy sizes, soil conditions, block history and management standard. A computer programme has been written to facilitate the use of INFERS, and can provide amongst others the targeted yield and the fertilizer rates to achieve it.

Evaluation and verification of the system indicated that it can predict yields fairly accurately and that nutrient requirement can be predicted to within 0.25 kg ammonium chloride and 0.25 kg Muriate of potash per palm per year for 59% and 96% of the cases tested (Table 1) respectively.

Table 1 : Frequency of absolute differences between predicted and actual fertilizer N and K rates applied

Soil type	Total no. of cases	Difference in kg AC		Difference in kg MOP	
		< 0.25	0.25 - 0.50	< 0.25	0.25 - 0.50
Akob	10	4	6	9	1
Briah	8	7	1	8	0
Lunas	8	8	0	8	0
Sogomana	8	7	1	8	0
Musang	9	4	5	9	0
Bernam	8	0	8	7	1
Total	51	30	21	49	2

*Difference (kg) = (Predicted - Actual fertilizer rate) expressed as Kg AC and MOP per palm. AC denotes ammonium chloride and MOP denotes Muriate of Potash. Source : Kee et al. (1994)

3. Balanced fertilisation

High fertilizer rates alone will not always provide optimum economic returns: a balanced fertilizer programe is equally essential. This can be illustrated by the various trials on nutrient interactions on both inland (Chan 1982, Foster 1985, Chan et al., 1993) and coastal soils (Teoh and Chew 1980, Gurmit 1990). A typical example is provided by Chan (1982) and reproduced in Table 2. Nitrogen increased yield by 49 % in the presence of high K rate while yields increased 25 % when K was supplied together with high nitrogen fertilizer. Both N and K had beneficial effect on the vegetative dry matter production also.

Table 2 : Effect of NK interaction on yield and growth of oil palm on Rengam series (Typic Paleudult) soil in Malaysia

Parameters	Nitrogen levels	Potassium levels			s.e.
		K0	K1	K2	
FFB Yield (kg palm^{-1} y^{-1})	N0	71.6	65.3	66.3	4.3
	N1	68.4	95.2	95.8	
	N2	79.1	95.8	98.6	
Vegetative growth (kg dry matter palm^{-1} y^{-1})	N0	88.9	84.0	89.2	4.0
	N1	96.6	117.4	119.4	
	N2	106.4	120.0	123.0	

Source : After Chan (1982)

Apart from this, Foster et al. (1988) showed that K decreased oil to bunch ratio (Table 3) in the absence of N fertilizer. However, with sufficient N level, K fertilizer generally increased the oil to bunch ratio to similar level compared to the control.

Table 3 : Effect of NK interaction on oil to bunch ratio (%) in Malaysia

Soil series	Soil taxonomy	Potassium levels	Nitrogen levels			
			N0	N1	N2	LSD
Bungor	Typic	K0	27.1	23.4	24.0	3.0
	Paleudult	K1	25.0	24.8	24.2	
		K2	23.5	24.6	25.4	
Rengam	Typic	K0	26.9	25.6	24.8	3.0
	Paleudult	K1	23.7	24.6	21.3	
		K2	22.8	23.5	24.1	

Source : After Foster et al. (1988)

Positive interactions of K fertilizers with other agronomic practices such as mulching, frequency of application and frond placement which resulted in yield responses of 4% to 14% have been reported by Chan et al. (1993).

While capitalizing on synergistic effects will improve yield and fertilizer efficiency, avoidance of antagonistic effects is also necessary to maximise return from fertilizer use. For example, high K rates have been shown to depress Mg and B uptakes (Rajaratnam, 1973; Chan and Rajanatnam, 1977; Tan et al., 1982) which in turn might decrease yield.

4. Potential nutrient losses in the oil palm ecosystem.

The recommended fertilizers should be applied in a manner that they are absorbed by the palms at maximum efficiency. This is best done by minimising fertilizer losses in the plantation, which is even more essential now in view of the current economic woes. Nutrients may be lost by surface run-off, leaching through the soil profile, nutrients fixation, volatilisation and immobilisation by ground covers in young oil palm.

4.1 Surface run-off

Maene et al. (1979) estimated that on average 11% of N, 3% of P, 5% of K, 6% of Mg and 5% of Ca applied can be lost in surface run-off alone (Table 4). These results were obtained during a low rainfall year with only 1426 mm on a 9% slope. The most susceptible areas for run-off tended to occur in the harverster's path and along the oil palm rows where the soils are more compacted and the ground vegetation is generally sparse.

Table 4 : Mean nutrient losses through run-off water

	Nutrient lost as percent added.					
Position in field	N	P	K	Mg	Ca	B
Oil palm row	13.3	3.5	6.0	7.5	6.8	22.9
Harvest path	15.6	3.4	7.3	4.5	6.2	33.8
Pruned frond row	2.0	0.6	0.8	2.7	0.8	3.3
Pruned frond/harvest path	6.6	1.4	3.5	2.2	3.4	12.5
Average for the field	11.1	2.8	5.0	5.6	5.2	20.7
Nutrients applied (kg ha^{-1})	90.2	52.0	205.9	32.8	78.9	2.4

Source : Maene et al. (1979)

More recent data obtained by Kee and Chew (1996) also indicated that the mean run-off losses as percentage of the nutrient applied were within the following ranges: 5-8% N, 10-15% K, 4-6% Mg and less than 2 % for P (Table 5). These results showed that soluble nutrients, N, K and Mg are more susceptible to run-off losses. Kee and Chew (1996) further found that nutrient losses via surface run-off are highly dependent on the rainfall pattern at the time of fertilizer application, particularly the first few rains after application and the moisture status of the soil. Other equally important factors, which might affect run-off, are the canopy cover, rainfall intensity and quantity, soil characteristics and slope (Chew and Pusparajah, 1996).

Table 5 : Mean net nutrient losses in the oil palm ecosystem via surface run-off and eroded sediment on Rengam series (Typic paleudult) soil

Nutrient	Net annual losses (kg ha^{-1}y^{-1})			Net loss as % of applied fertilizer*
	in runoff	in eroded sediment	Total	
N	4.5 – 7.2	0.5 – 0.8	5 – 8	5 – 8
P	0.7 – 1.1	0.5 – 1.3	1.2 – 2.4	0.8 – 1.6
K	20.8 – 33.0	Trace	21 – 33	9.8 – 15.3
Mg	3.6 – 6.8	0.1	3.7 – 6.9	4.1 – 7.6

*Mean (1992-1994) fertilizer input was equivalent to: 101kg N, 145 kg P, 215 kg K and 90 kg Mg ha^{-1}y^{-1}. Source : Kee and Chew (1996)

4.2 Leaching losses

Foong (1993) showed that leaching losses during the first four years of oil palm growth (as % of total nutrient applied) were about 17% N, 10% K and 70% Mg. Losses were substantially reduced to about 3% N, 3% K and 12% Mg when the palms were fully matured (Table 6). The main reasons for the high leaching losses during the early stage of palm growth were poor palm canopy covers, less extensive root system and ground covers were generally not well established especially during the first year after planting.

Table 6 : Leaching losses of nutrients measured in an oil palm lysimeter study

Palm age (y)	Leaching losses as percentage of applied nutrients			
	N	P	K	Mg
1-4	16.6	1.8	9.7	69.8
5-8	1.2	1.6	2.5	11.5
9-14	3.0	1.5	2.9	15.5

Source:Foong (1993)

4.3 P Fixation

Losses due to fixation by the soil involve mainly phosphate fertilizers. The P fixing capacities of some of the common Malaysian soils are shown in Table 7. The amount of P 'fixed' ranged from 208 mg to 1172 mg per kg soil and is related to its clay mineralogy. Although soils with high P fixing capacity improve P dissolution of phosphate rock, they also decrease the soil solution P (intensity), which is required for plant uptake (Chien and Hammond 1989). The general approach is to use less reactive phosphate rock and concentrated application of fertilizer through high rate and banding (Zaharah, 1979, Goh and Chew, 1995).

Table 7:P sorption capacity and mineralogy of some common Malaysia soils

P Sorption	Soil	Orders	P fixed (mg kg^{-1})	Kaolinite (%)	Gibbsite (%)	Fe_2O_3 (%)
Low	Marang	Ultisol	208	n.d.	-	0.3
	Lanas	Ultisol	247	5.6	-	0.6
	Rengam	Ultisol	308	8.6	0.6	1.3
	Tebok	Ultisol	383	11.8	-	0.2
	Serdang	Ultisol	396	13.0	0.2	0.9
	Tok Yong	Ultisol	450	16.8	3.2	2.9

Source : after Tessens and Shamshuddin (1983)

cont. Table 7:P sorption capacity and mineralogy of some common Malaysia soils

P Sorption	Soil	Orders	P fixed (mg kg^{-1})	Kaolinite (%)	Gibbsite (%)	Fe_2O_3 (%)
Moderate	Harimau	Ultisol	568	16.0	1.0	3.3
	Jempol	Oxisol	571	4.2	-	1.3
	Bungor	Ultisol	663	9.0	-	2.1
	Lanchang	Ultisol	668	38.6	-	5.2
	Munchong	Oxisol	735	31.8	7.7	5.8
Strong	Sg. Mas	Oxisol	928	19.9	0.6	10.0
	Prang	Oxisol	985	40.2	4.0	4.8
	Segamat	Oxisol	1084	33.8	-	7.4
	Kuantan	Oxisol	1172	21.1	9.8	18.8

4.4 Volatilisation losses

Volatilisation losses are only significant when urea is surface applied, usually over the compacted weeded palm circles. High volatilisation losses in the oil palm field occurred at high rates of fertilisation and on light texture soils as shown in Table 8 (Chan and Chew, 1984).

Table 8 : Urea Volatilisation losses (%) on various soils under oil palm

N rates	Silty clay soils		Sandy clay soil		Sandy clay loam	
	at 3 days	at 7 days	at 3 days	at 7 days	at 3 days	at 7 days
250kg N/ ha.	29	29	27	38	35	42
500kg N/ ha.	38	42	35	45	38	48

Source : Chan and Chew (1984)

To increase the efficiency of urea, it should preferably be buried in the ground. However this practice is only suited to small-scale cultivation and unlikely to be practical and economical on a large plantation. Correct timing provides a more suitable means to improve the efficiency of applied urea. For example, Chew and Pusparajah (1988) advocated the application of urea when moderate rains are expected so that the fertilizer may be washed into the soil, which reduced volatilisation.

4.5 Immobilisation by ground cover in young oil palm

Weed growth is strongest in high light conditions in immature plantation. The young crops without extensive root systems are less able to compete for nutrients at this stage, which reduce nutrient uptake and growth in oil palms (Table 9).

Table 9 : Dry matter production and nutrient immobilized by Ground Covers in young oil palms

Vegetation	Dry matter production (kg ha^{-1})	Nutrients immobilised (kg ha^{-1})				
		N	P	K	Mg	
Grasses	15098	109	19	156	29	Selangor series @ 20mths after planting
Grasses [1]	10437	90	16	128	22	Serdang series @ 12 mths after planting.
Mikania [1]	5986	76	15	120	11	Planted as cover Serdang series @ 12 mths.
Ischaemum muticum [2]	11390	73	6	188	9	5 year old palm.
Ischaemum muticum [2]	12240	84	-	-	-	1 year old palm.
Asytasia gangetica [3]	7300	181	-	-	-	120 days in open conditions.
Asystasia gangetica [3]	4300	142				120 days in shade.

Sources : 1. Han and Chew (1982) 2. Teo et al. (1990) 3. Quah (1977)

One point of interest is that the total N immobilised by the ground covers commonly exceeded run-off losses and immobilisation by young oil palms.

With respect to interrow vegetation management, Hew and Tam (1971) showed that spraying out of competitive weeds in the interrow vegetation at immaturity and maturity on Selangor series soil gave the highest oil palm yields after 4 and 6 ½ years respectively. On the other hand, over spraying could lead to bare ground conditions which might cause higher leaching losses, reduce soil moisture (Joseph 1991) and result in poorer soil structure (Soong and Yap 1975). This in turn may lower FFB yield.

5. Strategies to reduce fertilizer losses and improve fertilizer efficiency

With the potential large losses of fertilizers in the oil palm agroecosystem, it is only natural that we devise techniques to reduce them and improve fertilizer efficiency. These techniques call for an integration of agronomic practices as briefly described below.

5.1 Choice of fertilizer

Managing an oil palm plantation is a business proposition and as such the choice of fertilizer is largely an economic issue, not only in terms of fertilizer prices but also the likely returns from their applications in the fields. Therefore, the properties of the fertilizers and the agronomic conditions in the plantations such as climate, soils and terrain should also be considered.

i) N fertilizer

There are several sources of nitrogen and the more common ones for oil palms are ammonium sulphate (21% N), ammonium nitrate (34% N), ammonium chloride (25% N) and urea (46% N). Various trials showed little differences in fresh fruit bunch (FFB) yield responses to them except for urea (Sinnasamy et al., 1982, Lim et al., 1985, Tarmizi et al., 1993). The latter gave comparable results only under high rainfall conditions and on clayey soils.

ii) P fertilizer

An agronomic evaluation of different sources (rock phosphate versus soluble super phosphate) of P fertilizer is shown in Table 10. The results indicated that there was no difference between P sources, although P fertilizer improved palm growth.

Nevertheless, the choice of P fertilizer would depend on the cost of fertilizer and the availability of P to meet the demand by the palms. For example, water soluble P source is commonly provided to immature palms via compound fertilizers while phosphate rocks are probably more economical for mature palms.

Table 10 : Agronomic evaluation of phosphate fertilizer and method of application on Oil Palm seedlings at 14 months

Source	Method	P Rate (g bag^{-1})	Diameter (cm)	Height (cm)	Frond/ palm	Leaf area (m^2)	Length (cm)	Dry weight (g)	Frond produced in 4 months
Nil	-	0	6.8	127	15.9	0.7	81.5	32.3	4.5
CIRP	Mixed	0.2	8.2	167	16.9	0.9	101.4	45.9	5.1
CIRP	Mixed Surface	0.2 +0.3	8.3	159	17.6	1.0	100.3	47.5	5.3
CIRP	Surface	0.3	7.3	156	16.3	0.9	92.2	41.8	4.3
Super phosphate	Surface	0.3	7.7	164	16.3	0.9	97.7	43.6	5.3
Super phosphate	Surface	0.6	7.7	149	16.7	0.9	93.4	40.0	5.2
Mean			7.7	154	16.6	0.9	94.4	41.8	5.0
SE			0.3	26	0.5	0.8	5.5	4.0	0.4

Source : HRU Annual Report, 1973

iii) K fertilizer

In mature oil palm plantations, the choice of K fertilizer is usually limited to Muriate of potash. However, in view of the current economic situation and high fertilizer prices, other sources such as soil K if it is sufficient (more than 0.5 cmol kg^{-1}) can be used (Kee et al., 1993). This is based on a long term trial which showed that after 7 years of K fertilisation, there was a substantial build up of soil exchangeable K (from 0.2 cmol kg^{-1} in the control to 0.8 cmol kg^{-1}) particularly in the palm circle where the fertilisers were applied (Kee et al., 1993). Moreover, well-grown mature palms have a large reserve of K in the trunk, which can be utilised (Teoh and Chew, 1988). With careful monitoring of the soil K status, reduction in K fertilizer can be made without much adverse effect on the growth and yield of the oil palms in the short term. For example, withdrawal of K fertilizer up to 4 years before replanting did not affect yields on an inland soil (Nazeeb et al. 1995).

The oil palm plantation produces large quantities of by-products in processing the fresh fruit bunches (FFB) to palm oil. On average, every tonne of FFB produces about 220 kg empty fruit bunches (EFB). Gurmit et al. (1982) reported that 1 tonne of EFB contains an equivalent of 15.3 kg of ammonium sulphate, 2.5 kg of Christmas Island rock phosphate (CIRP), 18.8 kg of muriate of potash and 4.7 kg of kieserite. Therefore, for mature oil palms, 40 t ha^{-1} of EFB applied in the interrows can supply sufficient nutrients to meet palm requirement for a year. Supplementary fertilizer applications such as CIRP may be required to balance the nutrient requirements of oil palms.

iv) Mg fertilizer

The most common sources of Mg fertilizer in Malaysia are kieserite and ground magnesium limestone (GML). These two materials differ greatly in their solubilities and acid neutralising capacities. Kieserite is more water soluble compared to GML. However, GML is favoured as a major Mg source for mature oil palms due to its higher relative economic efficiency compared to kieserite (Table 11). For young palms or when quick availability of Mg is desired, then kieserite should be used.

The selected fertilizers must then be accurately timed and applied in the fields for best results. This involves correct timing of fertilizers, frequency of application and placement of fertilizers as discussed below.

5.2 Frequency of fertilizer application

Teoh and Chew (1985) and Foster and Tayeb (1986) showed that applying K fertilizer once a year was sufficient to sustain the growth and yield of oil palm (Table 12). Increasing the frequency of application up to 6 rounds a year did not improve the yield significantly (Chan et al., 1993). However, in most oil palm plantations, the actual frequency of fertilizer application depends on the crop requirement, palm age, ground conditions, types of fertilizers and rainfall. This is to minimise the risk of leaching and run-off losses and ensure that sufficient nutrients are available to meet the palm's need at all times. For example, higher frequency of application is provided to immature palm where palm growth is rapid but the root system is not fully developed. Similarly, only one round of phosphate rock is generally required for mature oil palms due to its good residual value.

Table 11 : The relative agronomic and economic effectiveness of GML and Kieserite using oil palm as a test crop

Parameters	Methods	Results
Relative yield (%)	$\frac{\text{FFB}_{\text{GML}}}{\text{FFB}_{\text{Ks}}}$ x 100 at the same fertilizer rate	97.8%
Relative yield Index (%)	$\frac{\text{FFB}_{\text{GML}} - \text{CONTROL}}{\text{FFB}_{\text{Ks}} - \text{CONTROL}}$ x 100 at the same fertilizer rate	83.3%
Substitution rate (SR)	$\frac{\text{RATE OF Ks}}{\text{RATE OF GML}}$ to produce the same yield	0.74
Price ratio (PR)	$\frac{\text{PRICE OF GML}}{\text{PRICE OF Ks}}$ per unit MgO	0.30
Rel. economic efficiency	$\frac{\text{SUBSTITUTION RATE (SR)}}{\text{PRICE RATIO (PR)}}$	2.47

Ks denotes Kieserite GML denotes Ground Magnesium Limestone

Source : Goh et al., (1998)

Table 12 : Effect of frequency of fertlizer application on oil palm yield in Malaysia

Soil series	Soil taxonomy	Unmanured	Frequency of application(t ha^{-1}y^{-1})				
			F1	F2	F3	F4	F5
a. Munchong	Tropeptic Haplorthox	13.5	18.7	19.6	18.4	-	-
b. Rengam	Typic Paleudult	-	-	23.9	-	24.5	-
c. Seremban	Orthoxic Tropudult	26.6	-	-	-	27.3	27.6

Source : a) After Teoh and Chew (1985) b) After Foster and Tayeb (1986)
c) After Chan et al. (1993)

Note: F1 - once in 2 years F2 - once in a year F3 - Twice a year
F4 - 3 times a year F5 - 6 times a year

5.3 Placement of fertilizers

Fertilizers should be applied in areas with maximum feeder root distribution to ensure good nutrient uptake, and this varies according to palm age. In the young palms, N fertilizers should be spread evenly over the weeded palm circle close to the palm base and gradually extended to the palm interrows and frond heaps when the canopy has overlapped and good root development is found there.

Trial results showed that apart from the harvester's path, the site to apply N and K fertilizers was not critical for mature oil palms above 10 years old due to their extensive and efficient root systems (Teoh and Chew, 1985; Foster and Tayeb, 1986; Foster et al., 1985). Therefore, it is advantageous to broadcast N and K fertilizers in the interrows and over the frond heaps to avoid concentration of nutrients in the palm circles which can lead to higher leaching losses and acidification (Kee et al., 1993). Nevertheless, interrow should be free from dense ground vegetation to avoid serious competition for nutrients and water as discussed earlier.

Broadcasting of phosphate rock is generally practised for older mature palms as this will increase the likelihood of root contact with rock phosphate particles resulting in better fertilizer efficiency (Goh et al., 1995).

In hilly terraced areas with mature palms, fertilizers should be broadcast in the terrace itself and between the palms. In areas with platform, the fertilizers should logically be placed around the palms.

5.4 Timing of fertilizers

For most of the soluble fertilizers, proper timing of fertilizers holds the most promise for improving efficiency. There is evidence in Malaysia to show that run-off losses of K in mature oil palm are markedly reduced if applied in dry months or months after low rainfalls. (Kee and Chew, 1996).

On the other hand, timing of rock phosphate application is usually less critical because of its low solubility and therefore, lower run-off losses.

The general guideline (AAR unpublished) is to avoid fertilizer applications during:

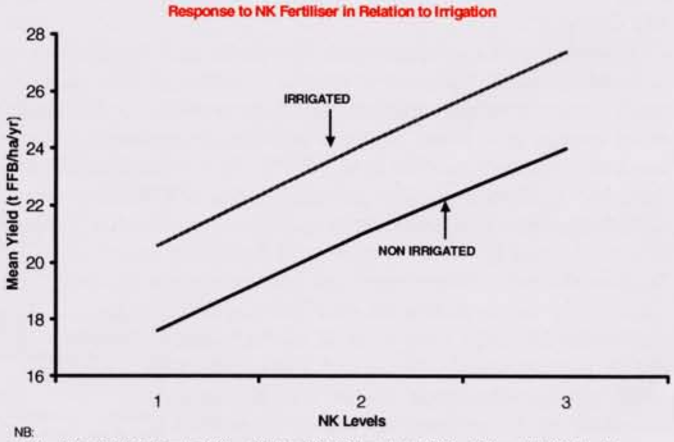
a) period with high rainfalls of more than 250 mm month^{-1} and low rainfalls of less than 25 mm month^{-1},
b) months with high rain days of more than 15 days month^{-1},
c) months with high rainfall intensity of more than 25 mm day^{-1}, and
d) periods when the soil is saturated after continuous rains.

Fertilizer applications should also be timed to follow circle-weeding rounds to minimise competition from ground vegetation particularly during the immaturity stage.

6. Maintaining good growing conditions for oil palms

Liebig in 1855 proposed the "law of the minimum" which stated that with increasing additions of an input (eg. Fertilizer), the crop yield may be represented as a straight line sloping upward from the control yield to a higher yield at which another factor became limiting (Black, 1992). At this point, the linear increase ceased, and with further additions of the input, the yield remained substantially constant. Therefore, to obtain optimum benefits from fertilizer inputs the agronomic practices and factors that might limit yields should be preferably identified first and subsequently be alleviated or minimised. Some of site-limiting factors usually observed in the estates are poor drainage, overcrowding, pests and disease and poor soils. An example of the impact of identifying and alleviating a yield limiting site factor on FFB responses to N fertilizer is provided in Figure 1.

Figure 1 shows the mean (1986 to 1990) FFB yield response to NK fertilizers for irrigated and non-irrigated treatments (Kee and Chew, 1993). There was no interaction between irrigation and fertilizer treatments. Of interest is the fact that in the absence of irrigation, substantially higher fertilizer input is required to achieve the same FFB yield as irrigated treatment. For example, the fertilizer rate had to be doubled (N_2K_2 - 1.5 kg N and 4.2 kg K_20 per palm per year) to achieved a similar yield of 24 tonnes FFB per hectare without irrigation. In other words, by alleviating the yield constraint of water, there was a better efficiency in fertilizer use and therefore, returns in terms of FFB yield.



NB:
N1K1 = 0 N and 0 K_2O kg/palm/yr; N2K2 = 0.75 N and 2.1 K2O kg/palm/yr; N3K3 = 1.5 N and 4.2 K2O kg/palm/yr

7. New technologies

Good accurate maps are a basic management tool in the estates. They are essential to all of us in the plantation industry as we move towards site specific agronomic and management inputs for maximum and sustainable yields and profits.

With the advent of sophisticated computer technology today, not only can accurate maps be produced quickly for use but data from many sources can be captured, managed and manipulated, analysed and displayed graphically and spatially for problem solving and decision making. (Star and Estes, 1990). This technology is known as Geographic Information System (GIS) and is now one of the major applications in computer-based information systems for management purpose.

It is obvious that the integrated agronomic approach to optimise returns from fertilizers for oil palms as discuss above involves a massive assembly and analysis of agronomic and management information. This is perhaps best done using a decision support system which is primarily an interactive, flexible and adaptable computer-based system that captures the data and with a combination of tools, transforms these data into useful information to assist in site specific decision making. The system can also produce results in graphical spatial format and "what if" economic terms where the decision makers will be able to appreciate the problems better (Chew 1997).

We also need more precise fertilizer application and to ensure that every palm receives its quota of fertilizers. The only way is to use machine and control system that automatically calibrates and applies the fertilizer as it moves at a constant speed regardless of terrain and conditions (e.g. forward crawler gear) through the fields. This is still a research topic that could be explored.

8. Roles of Management in Oil Palm Nutrition

One of the most pressing issues in estate management is the shortage of field workers. Nevertheless, the estate managers should view this as today's challenges and strive to overcome them. With resourcefulness and entreprenal spirit, the planters can adapt new technologies and ideas to improve production efficiency and profitability in the plantations.

The performance of a plantation should be mainly in the hands of the manager through the consequences of his daily actions and decisions. The management roles in oil palm nutrition are many but the primary one is to implement the manuring recommendations made by the Agronomist diligently. This involves organising such as ordering the correct types of fertilizers, planning, such as ensuring that fertilizers are applied according to the schedule and supervision to ensure that fertilizers are applied correctly and each palm receives the desired quota of fertilizers. Wherever possible, the estate management should utilise existing technologies such as use of fertilizer spreader to achieve the best results.

9. Summary

Optimising returns from fertilizer use in oil palm plantations involve correct fertilizer rates, balanced fertilizer programmes and improved fertilizer efficiency. To achieve this, we need to minimise potential nutrient losses and create good growing conditions for the palms to ensure optimum nutrient uptake by their roots. This requires a site-specific approach to identify the agronomic and management factors operating in the area and to formulate agronomic measures to achieve our goals, which is maximising profit. The desired results can only be realised if the management plays its role in ensuring that all the recommended practices are implemented properly and on time.

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