Nutrition and Nutrient Management of the Oil Palm – New Thrust for the Future Perspective

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Introduction

The oil palm (*Elaeis guineensis* Jacq.) was first introduced from West Africa into Bogor on Java Island in 1848 but commercial exploitation did not take place till the end of that century in North Sumatra. From there it spread to the West Coast of Malaya in the early nineties, but phenomenal growth in oil palm plantations in South East Asia occurred only after World War II. Over a relatively short period of 40 years since 1960, palm oil has become a major vegetable oil, second only to soybean oil (**Table 1**). Malaysia, Indonesia, Thailand and Papua New Guinea together produced nearly 90% of world palm oil output in 2000. Other significant producers are Colombia, Ecuador, Ivory Coast and Nigeria.

The oil palm is predominantly cultivated on tropical soils that belong mainly to the soil orders Ultisol, Oxisol, and Inceptisol. These soils are highly acidic and have low buffering capacities. Consequently, fertilizers are essential for economic production as attested by ample field experiments and growth in fertilizer usage in the oil palm sector. For good yields to be sustained, fertilizer inputs are necessary and typically constitute 40-50% of total field upkeep cost.

With palm oil projected to grow to 35 million tonnes by 2020, the expansion in fertilizer requirements is assured and this makes pleasant news to people in the trade. However, both the expected increase in palm oil production and concomitant fertilizer usage have to take full cognizance of worldwide environmental concerns on two major counts.

The first focuses on depletion of “green lungs” which can be further aggravated by increased felling of tropical rainforests for new plantations, while the second concerns pollution of water and the air by agro-chemicals, including fertilizers. In the light of such public concerns, particularly in developed countries, it would be prudent to select the path of yield improvement, as opposed to land expansion, for the purpose of achieving the palm oil production envisaged for 2020. This productivity cum environment responsive approach will strongly hinge on more efficient nutrient management of the oil palm.

Table 1. World palm oil output (million t)

Year	*SBO*	*PO*	*Malaysia*	*Indonesia*	*Thailand*
1972	6015	2220	580	250	–
1982	13370	5726	3514	838	50
1990	16040	10942	6095	2412	226
2000	25207	21124	10840	6530	430
2020		35000			

Source: Oil World Annual 2001
SBO = Soybean oil
PO = Palm oil

Palm Oil Production and Productivity

While world production has increased about 10 fold from 1972 to 2001, productivity in terms of mean oil yields have stagnated over the past 15 years (**Table 2**). If this trend continues over the next 20 years, most certainly more forest lands will be needed in order to meet production targets. A better alternative should be found and it is contended here that there is considerable scope in re-orienting attitudes in nutrient management from one of using cheaper nutrient carriers to promote fruit bunch yield to one of optimizing multiple nutrient balance to achieve higher oil yields.

Table 2. Trends in palm oil yields (t ha^{-1})

Year	*World*	*Malaysia*	*Indonesia*
1986	3.24	3.84	3.71
1990	3.23	3.56	3.89
1995	3.24	3.61	3.72
2000	3.32	3.63	3.45

Nutrition of the Oil Palm – An Update

Symptoms Of Deficiency: The oil palm is a research-friendly plant and manifests most deficiencies with typical and visible diagnostic symptoms as well described by Turner and Gillbanks (1974). A wide spread of elements is found in oil palm tissues but not all that are deficient give rise to characteristic symptoms in foliage. Deficiency symptoms for P, S, Cl and Mn are indistinct while hunger signs for N, K, Mg, B, Cu and Zn are well defined. However, economically, the primary task is to determine nutrient requirements for optimal yields by oil palms grown on different soil and climatic conditions.

Table 3. Nutrient deficiency symptoms in leaflets

Elements	*Distinct Symptoms*
N	Chlorosis
K	Orange Spotting/Orange Blotch
Mg	Orange Frond
B	Hook Leaf/Crinkle Leaf
	White Stripe (associated with high N, low K)
Cu	Mid-Crown Chlorosis
Zn	Yellow, Shortened Narrow Pinnae

Methodology of Determining Nutrient Requirements

Pragmatic Choice: There is no question that well designed field experiments on representative soil types are crucial for the accurate assessment of the quantum needs for various nutrients. In view of the long-term (8-10 years) requirement of such trials, the basis for fixing treatment levels must be fundamentally sound. Unfortunately conventional techniques of crop-cutting for determining progressive nutrient uptake with age are not appropriate for the oil palm. Hence, a more pragmatic method had to be devised.

First, the holistic concept of a complete nutrient balance (**Figure 1**) of supply and demand had to be established, which was first mooted by Hew and Ng (1968) and further defined subsequently (Ng, 1977). In this balance a major component of demand was nutrient uptake by the palm and this would vary as the palm developed from a seedling to an adult palm. To estimate the annual nutrient uptake, 1 to 15 year old palms grown on a good soil under sound management were destructively sampled and representative tissues drawn for nutrient analysis over a period of one year in 1963.

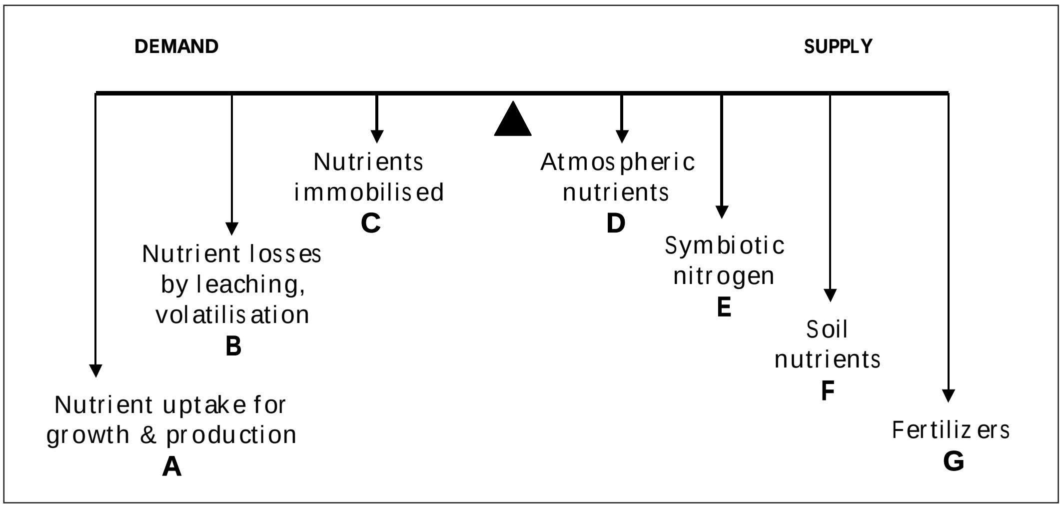

Figure 1. Components of Nutrient Balance

With nutrient composition data, it was possible to construct nutrient uptake curves for the first 10 years of the life span of the oil palm (Ng, 1979; Ng, 1977) as presented in **Figure 2**.

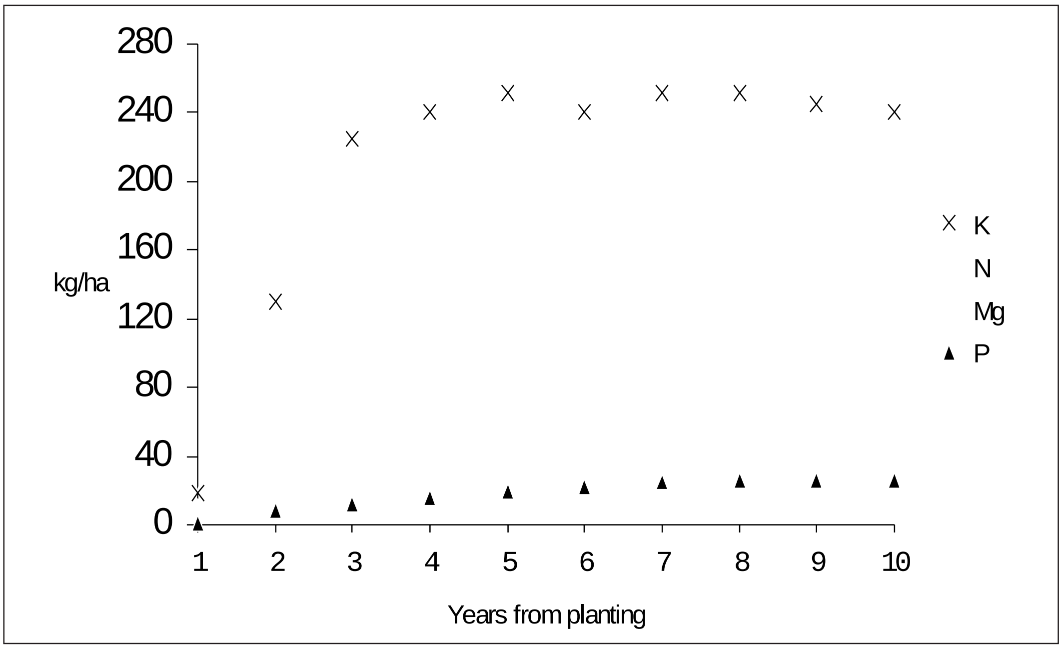

Figure 2. Nutrient uptake of oil palms up to 10 years from planting

Besides nutrient accumulation, biomass production data from the study also revealed two valuable pieces of information on oil palm growth physiology. The first showed that nutrient uptake during the first three to four years followed a more exponential form rather than a linear one as had been assumed hitherto. Thus, annual vegetative biomass production increased 8-10 fold in the second year of field planting and nutrient uptake followed in tandem (**Table 4**).

Table 4. Estimated annual biomass production and nutrient uptake by the oil palm in Malaysia (kg palm^{-1})

Year of Planting	*Biomass Production*	*N*	*K*	*P*	*Mg*
1st	6.85	0.068	0.095	0.006	0.017
2nd	57.3	0.509	0.965	0.059	0.140
3rd	70.4	0.586	1.383	0.067	0.139

Source: Ng (1979)

The result clearly indicated that the linear increment assumption adopted in both field experiments and manurial programmes up to the early sixties was entirely out of sync with physiological realities. The second and perhaps more original finding showed that assimilates were *a priori* assigned to vegetative biomass production and the residual surplus only then relegated to fruit bunch production, as can be clearly inferred from comparative data shown in **Table 5**. This finding implied that a basic quantum of nutrient inputs was essential and lack of this fundamental knowledge had resulted in unrealistic rates of fertilizers used in earlier experiments. The concept of LISA (Low Input Sustainable Agriculture) could find limited scope in the manuring of oil palms.

Table 5. Growth data for mature palms (t ha^{-1} yr^{-1}) of Malaysia and Nigeria

Country	*Total Biomass Production*	*Vegetative Biomass*	*Bunch Biomass*
Malaysia	29.8	16.5	13.3
Nigeria	18.3	14.3	4.0

Source: Ng (1970)

Verification of New Nutrient Uptake Data

A two pronged approach was undertaken to verify the validity of the newly acquired nutrient uptake data. This entailed:-

(a) Conduct of new comprehensive factorial experiments to determine optimal combinations of N, P, K, Mg and/or B for palms grown from immaturity on all major soil types in a region. This programme for Malaysia commenced from the mid-sixties and engaged major soils within the soil Orders of Ultisols, Oxisols and Inceptisols of low inherent fertility.

(b) Parallel testing of "simulated" optimal nutrient combinations of N, P, K, Mg, B for yield maximization of new large scale commercial plantings of oil palms, over different major soils and agro-climatic regimes.

This system was given the acronym MEGYP (Maximum Exploitation of Genetic Yield Potentials) as shown in **Figure 3**. The campaign started in the early seventies and was first reported by Ng (1983).

It is pertinent to present an update on this two pronged approach.

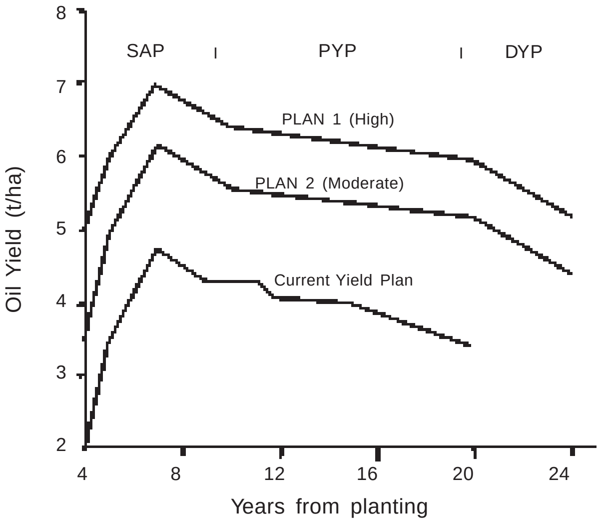

Figure 3. Maximum Exploitation of Genetic Yield Potentials (MEGYP)

Results of New Fertilizer Experiments

New fertilizer experiments based on the derived nutrient uptake data were established since 1964, and early yield responses were readily demonstrated for nitrogen, phosphorus, potassium, magnesium (Hew *et al.*, 1973; Tan, 1973, 1977; Forster *et al.*, 1988), and for copper on peat soil (Ng *et al.*, 1979). For boron, Rajaratnam (1973) showed that severe boron deficiency symptoms were related to significantly lower yields. The principal conclusion from these trials is that, for palms grown on predominant Ultisol, Oxisols, as well as medium textured Inceptisols, nitrogen, phosphorus, potassium, magnesium and boron are very important for high early yield performance. Copper is crucial only for peat soils both in Malaysia and Indonesia (Wanasuria and Gales, 1990).

Maximum Yield (MEGYP) Campaigns

These campaigns are large-scale commercial plantings designed to maximize early yields with an optimal plan of balanced nutrition (**Table 6**), provided by efficient nutrient management for each consistent soil composite, delineated within a 30-40 ha field. These campaigns commenced in the mid-seventies, followed by campaigns in the eighties and nineties over tens of thousands of hectares throughout Malaysia. Results in the seventies and early eighties have been reported (Ng and Thong, 1985; Ng *et al.*, 1990). For completeness, representative yield profiles of MEGYP plantings covering a span of 20 years are presented in **Figure 4**.

Yields over the 6th to 10th year from planting did not fluctuate widely ranging from 5.70 to 6.39 (tonnes oil ha^{-1}). These levels all exceeded 5.0 (tonnes oil ha^{-1}), the benchmark for good commercial management.

Table 6: Nutrient inputs used in MEGYP campaigns (kg $palm^{-1} yr^{-1}$)

Soil Group	*N*	*P_2O_5*	*K_2O*	*MgO*	*B_2O_3*	*CuO*
Ultisols	0.8-1.0	0.55-0.70	2.10-2.50	0.20-0.30	0.05-0.07	–
Oxisols	0.8-1.0	0.75-1.00	1.80-2.20	0.15-0.20	0.05-0.07	–
Inceptisols	0.70-1.2	0.40-0.70	1.20-2.0	0.0-0.15	0.07-0.10	–
Entisols (Sandy)	0.8-1.2	0.50-0.70	2.40-3.00	0.25-0.40	0.70-0.10	0.40
Histosols	0.60-0.80	0.40-0.60	3.00-3.60	–	0.70-0.10	0.60

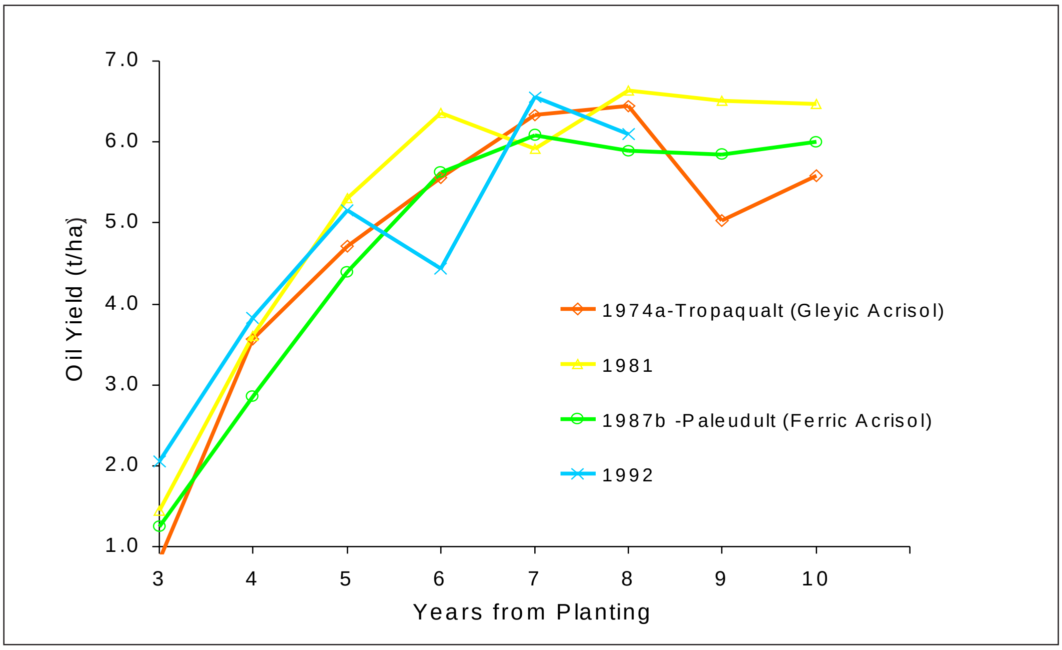

Figure 4. MEGYP Yield Profiles for Large Plantings over 20 years

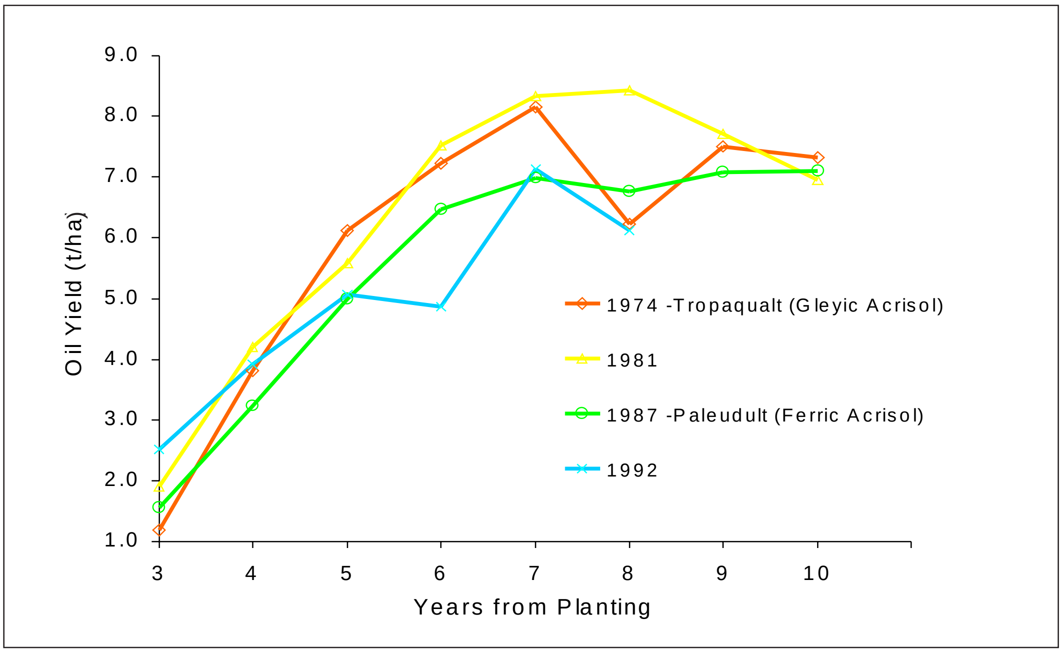

Figure 5. Yields of Highest Yielding Fields

Of greater importance are the data for the highest yielding field within each large block. Yields from these fields were 15-22% higher than means of large blocks for the 6th to 10th year from field planting (**Figure 5**). Variations in genetic traits, soil properties and water relationship probably account for most of the yield differences between individual fields. As soil and moisture characteristics determine availability of nutrients, refining nutrient management for achieving best multiple nutrient balance should be the most attractive step forward.

Future Thrusts of Maximum Yield Research

Oil Productivity, the Key: For far too long, the oil palm industry has focused on yields mainly in terms of fresh fruit bunches (FFB), relegating the critical parameters of bunch oil extraction rate (OER) and kernel extraction rate (KER). However, it is oil and kernel yields in terms of tonnes oil per ha and tonnes kernel per ha that are more finite for defining efficiency of production and profitability. Thus, while FFB yields may show an upward bias, declining OER could give a negative trend finally.

Ng *et al.* (1998) have asserted that a specific nutrient recipe giving a higher FFB yield per se need not guarantee a higher profit as an alternative combination favouring a higher OER is more lucrative (**Table 7**). The components of FFB and OER are impacted upon differently by the same nutrient, particularly potassium (Forster *et al.*, 1988), but other nutrients may have interactions. Unlike the case of oilseeds, scanty research has been done on the relationships between palm nutrition and oil synthesis or productivity and the continuing gap in knowledge spells danger for palm oil as a competitive commodity. It is our considered view that techniques that can achieve optimal balance of all nutrient elements is essential for best exploitation of yield potentials of new genetic materials.

Table 7. Impact of nutrient balance on profitability

	*Nutrient Combination**	
Parameter	*I*	*II*
FFB (t ha^{-1})	30.0	27.0
OER (%)	20.0	22.2
Total Expenditure (US$ ha^{-1})	605	544

**I = High KCl, K not in balance with Mg; B and Cl not in balance with S*
II = K, Mg, B, S and Cl in balance

Multiple Nutrient Equilibria

Results of MEGYP have clearly demonstrated the potential of doubling existing average palm oil yields in S.E. Asia, even with seedling materials. One of the principal ways is to fine-tune nutrient management on an individually defined soil environment entity basis, so that multiple nutrient equilibria (MNE) both within the palm system and the soil medium is attained for maximum oil productivity. The MNE system calls for more research on the interactive roles of nutrients which are present in significant amounts in palm tissue but whose roles have not been identified in oil synthesis. Such nutrients are calcium, chlorine and silica besides the better known secondary nutrients of magnesium, boron and sulphur. In addition, micronutrients such as copper, zinc and manganese may also play important roles in catalyzing the activity of enzymes involved in oil biosynthesis. A similar approach for annual crops has been advocated by Beaton *et al.* (1990).

Figure 6 depicts the challenge to optimize equilibria amongst all the nutrients taken up by the palm. It is self-evident that new fertilizer experiments, which focus on oil productivity, are urgently required if accurate parameters of MNE are to be established.

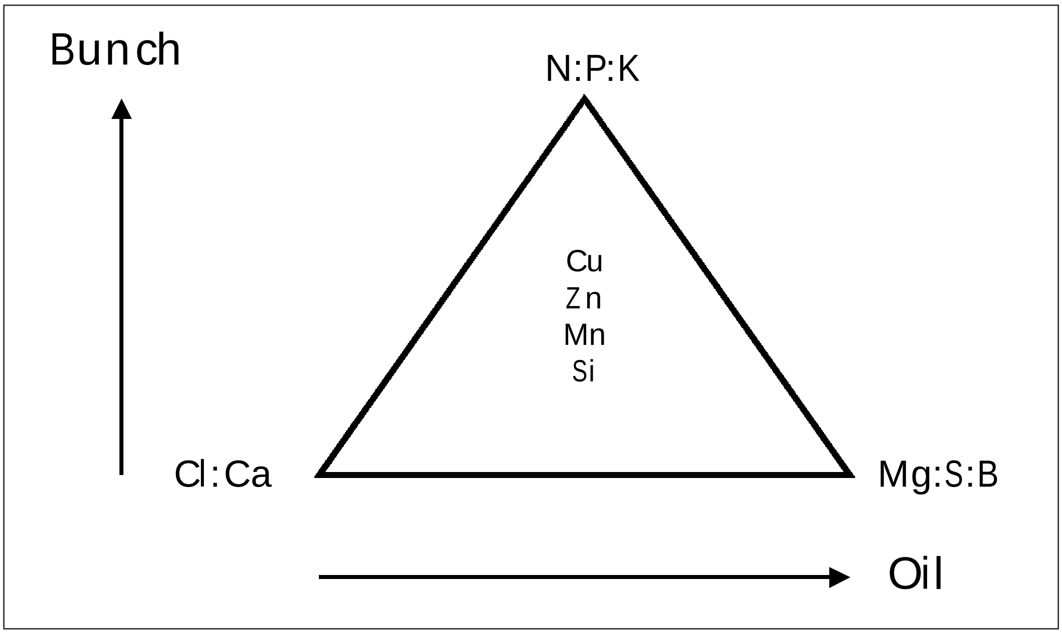

Figure 6. Effects of Nutrients on Bunch and Oil Production

The Future Quantum Leap in Oil Yields

When sufficient knowledge in MNE management is attained within the next decade, the oil palm industry will be timely poised to harness the most out of the new generation of elite clonal palms propagated vegetatively by tissue culture involving somatic embryogenesis. Clonal palms have long been touted to have the potential to out yield seedling materials by 30% and recent trials over the past 10 years in Malaysia have confirmed this superiority (Khaw and Ng, 1998; Khaw *et al.*, 2000; Simon *et al.*, 2001).

Yield data for the first 4-6 years of commercial clonal plantings in the state of Sabah, Malaysia are given in **Table 8**.

Table 8. Oil productivity of clones (AGK) planted commercially in Malaysia

Location	*Year*	*Ha*	*Years Recorded*	*tonnes oil per ha*	
				Mean	*Highest*
(a) Peninsular Malaysia	1990	3.4	8	6.8	8.3
	1992	5.2	6	7.6	10.8
	1994	24.7	4	5.5	7.0
(b) Sabah*	1992	3.4	7	5.9	8.1
	1993	8.8	5	4.7	6.5
	1994	40.1	4	5.1	9.8
(c) Sarawak**	1994	19.0	4	5.4	7.3
	1995	28	3	5.0	8.5
	Seedling Benchmark		4	3.5	5.9

**Source: Simon et al. (2001)*
Based on mill OER (Oil Extraction Rate)
***Koh Hong Lian (Personal Comm.)*

Ceiling for Palm Oil Productivity

If plant biotechnology is the backbone for the next agricultural revolution, then this will surely apply to *Elaeis guineensis*, a la clone. Already, performance of an 8-year-old monoclonal plot of 56 palms planted on homogeneous soil in Sarawak (**Table 9**) has exceeded the theoretical ceiling computed on utilization of solar energy (Corley, 1985). Both the single lysimeter palm and clonal palms were planted in the field, the former subjected to irrigation, and their oil productivity levels are proximate enough to the theoretical estimate. As a matter of fact, in all probability, the theoretical ceiling might well be in the higher plane of 20 t/ha, since clones superior to the one tested are in the laboratory pipeline.

These very high yield potential of clonal oil palms provide an underlying assurance for the long-term economic survival of the oil palm industry. In commercial plantings, realizable yields of clones may be in the region of 10-12 (tonnes oil ha^{-1}), which is almost double that of seedling materials in well management plantations. To achieve and sustain these superior yield levels, the practice of MNE in nutrient management will become crucial.

Table 9. Estimates of ceiling oil yields (t ha^{-1})

	Laboratory	*Mill*
(a) Theoretical	17.0	14.4
(b) Best Seed Family	11.2	9.5
(c) Single Lysimeter Palm	15.3	13.0
(d) 0.42 ha Monoclone Plot	19.2	16.3

Environmental Issues of Clones

One of the major environmental perceptions of planting clonal oil palms is that more fertilizers and agro-chemicals will have to be used and pollution from processing may also be increased. This may be true on a per palm basis, but if input requirements are expressed in relation to unit of product achieved, then the scenario for clones vs. conventional seedlings will indicate that the quantum of nutrient required for unit weight of palm oil produced will be at least 30% lower. (Ng *et al.*, 1995). The amounts of agro-chemicals used will be reduced by the same margin on unit product basis. The mill effluent discharge will be 15-20% less per tonne of oil produced.

The other distinctive advantage of using clones for future palm oil production is that less tropical rainforests need to be cleared for new developments. This would apply particularly to Central Africa, South America and parts of Indonesia. Thus, for an additional 20 million tonnes of palm oil, land resource requirement will be reduced from 5.0 million hectares to 3.6 million hectares

Conclusion

Innovative endeavours on maximizing oil productivity of the oil palm through the practice of sound and balanced nutrition has demonstrated the scope of raising plantation yields from current levels of 4-5 (tonnes oil ha^{-1}) to 5-6 (tonnes oil ha^{-1}). With the increasing role of tissue cultured oil palm clones within the next two decades, oil productivity will enjoy a potential quantum leap to the 10 (tonnes oil ha^{-1}) level. With continuing growth of palm oil production envisaged over the next twenty years, the need for more fertilizers is assured. However, in the context of global economic competition and the need to address genuine environmental concerns, the challenge for both the oil palm plantation companies and fertilizer producers, is to work in closer rapport so as to develop a more cost effective and environment friendly system of nutrient management such as the Multiple Nutrient Equilibria or MNE proposed. The world will need more palm oil, especially in large developing economies like China and India and with biotechnology entering into the oil palm domain, the golden opportunity for mutual benefits to palm oil producers, fertilizer manufactures/producers and green interest groups should be grasped in all earnest.

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