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Nutrition of coconuts – a review for formulating guidelines on fertiliser recommendations in Malaysia

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In Malaysia, the coconut is an important crop with 795 000 acres in 1975. However until recently, it appeared that the area under this crop would continue to grow very slowly at a rate of 1.3% for 1971–75 and 1.5% for 1976–80 (Third Malaysia Plan, 1976). On the other hand expansion of other crops increased and many areas especially on the coast were converted into oil palms.

The slow growth rate of this crop may be attributed to the relatively low profitability of this crop compared to oil palm and rubber as a result of the low yields obtained. Average yields in this country are only about 1 463 lb per acre for the estate sector and about 665 lb per acre for the smallholder sector. The chief reasons for the low yield are probably the old age of the palms and the lack of proper cultivation and upkeep in many of these areas.

The realisation in the 1950s that cocoa will grow well under coconuts on the coastal clay soil areas in Malaysia and the subsequent expansion of acreages of cocoa underplanted in the Bagan Datoh/Sabak Bernam areas in the 1960s and early 1970s probably helped preserve considerable acreages of the coconuts in estates. The enhanced value of the coconuts also caused more attention to be paid to the crop, albeit often indirectly as a result of cultivation practices in the cocoa areas.

Another factor which has caused renewed interest in coconuts has been the development and availability of new coconut hybrids particularly the Malayan Dwarf Yellow x West African Tall (MAWA). This hybrid has a potential of at least twice the potential yield of previous planting materials (Fremond & de Nuce 1972). The MAWA hybrids appear adaptable to Malaysian conditions (Vanialingam, Khoo & Chew 1975; Ng & Chan 1976).

The Government has embarked on a replanting scheme with the latter hybrids and interest in replantings with MAWA hybrids as a sole crop or in combination with cocoa has often been expressed.

Unfortunately, only limited work on nutrition of coconuts has been carried out in Malaysia. The few fertiliser trials laid down have been mainly in coastal areas and recent trials concerned adult bearing palms mainly.

It was therefore felt that this review on nutrition of coconuts would serve its purpose best if it dealt with:-

(a) the more basic consideration of nutrient requirements of the crop in the absence of data from actual fertiliser trials in this country.

(b) review of work on nutritional requirements of immature coconut areas in anticipation of replanting with hybrid materials.

(c) review of nutritional work done on coconuts elsewhere.

(d) review of work carried out on coconut nutrition in Malaysia with an account of its likely nutrient interactions with cocoa, a probable situation in many replants.

NUTRIENT REQUIREMENTS OF COCONUTS

As the varieties of coconuts grown may differ widely in their growth and yield development patterns, it is important as a first basis of estimation to assess the growth stages of the coconut to study its nutrient requirements more critically.

Growth

The present practice is to grow coconuts in polythene bags (15 in. x 20 in.) in the nursery for 8 months after germination of the nuts in the seed beds. These seedlings are then transplanted in the field.

The common planting materials currently readily available are the Malayan Tall and Malayan Dwarf varieties. In time, the MAWA hybrid materials should also be readily available.

Palm measurements in a trial comparing these materials on Selangor series which was planted in 1970 are given in *Table 1.*

TABLE 1. GROWTH MEASUREMENTS IN COCONUT VARIETAL TRIAL (VANIALINGAM *ET AL.*, 1975 AND UNPUBLISHED DATA)

Variety	Frond length (cm)						Stem height (cm)†		
	1971*	1972	1973	1974	1975	1976	1973	1974	1975
MAWA hybrid	111	202	246	348	370	375	201	277	348
Malayan Dwarfs	71	141	167	276	312	325	147	193	235
Malayan Talls	97	192	221	360	403	421	198	253	373

*Frond 9 measured. Rest were measured on Frond 14.

†To height of Frond 9

Frond length (and by inference, canopy size) appeared to be near its maximum in the fifth year for the Dwarf and hybrid varieties but growth in the 'Talls' continued in the sixth year. Trunk size was noted to be intermediate in the hybrids. Trunk height increment also increased in the 'Talls' in the fifth year. Until then, overall size of the hybrids appeared similar to the Talls. A probable reason for the reduction in growth rate could be the onset of bearing and partition of assimilates to the developing bunches in the hybrid and dwarf palms.

Dry matter distribution and nutrient uptake by the hybrid coconuts (the above ground parts of the tree) grown on Selangor Series were studied. The initial results for MAWA hybrid palms on dry matter growth at three different ages are given in *Table 2.*

TABLE 2. DRY MATTER DISTRIBUTION (KG) IN MAWA HYBRID SEEDLINGS AND A BEARING PALM (CHAN K.S. – UNPUBLISHED DATA)

Component	*7 months**	*26 months**	*72 months**
Rachis	.065	4.12	29.33
Pinnae	.051	3.25	32.16
Spears	nil	1.09	2.20
Stem	nil	1.32	37.90
Fruits + spikelets	nil	nil	49.19
Total dry weight	.116	9.78	150.78

*Age from germinated seed: 2 seedlings for 7 months and 26 months group and one for 72 month old palm dissected. The plants were visually representative of the populations involved.

Dry matter production in the MAWA palms therefore appears considerably less than in the oil palm where dry matter production per palm per year in years 2½ to 4½ in the field was between 138 to 155 kg/palm/year (Ng, 1972). The main increase in dry matter production probably occurred when palms started to bear fruits at the end of the fourth year in the field.

Nutrients immobilised in these seedlings at the various ages are given in *Table 3.*

Of the total nutrient uptake N is taken up in largest quantities at the nursery stage. After planting in the field, K uptake increased with increased accumulation in the fronds and later in the stem. With increase in age K was required in largest amounts. Mg appeared to be taken up in large quantities as well but the amount was less than nitrogen.

TABLE 3. TOTAL NUTRIENT UPTAKE BY MAWA HYBRIDS
(CHAN K.S. – UNPUBLISHED DATA)

Component	*Nutrient(a) and age at sampling (months)*														
	N			*P_2O_5*			*K_2O*			*MgO*			*CaO*		
	**7 g*	*26 kg*	*72 kg*	**7 g*	*26 kg*	*72 kg*	**7 g*	*26 kg*	*72 kg*	**7 g*	*26 kg*	*72 kg*	**7 g*	*26 kg*	*72 kg*
Rachis		.011	.085		.011	.070		.060	.496		.018	.310		.018	.181
Pinnae	2.41	.059	.434	.35	.014	.081	1.76	.082	.383	.52	.017	.161	.37	.020	.090
Spears		.007	.030		.003	.008		.019	.067		.003	.011		.002	.005
Stem		.009	.176		.005	.055		.023	.797		.009	.247		.009	.118
Fruits + spikelets†	nil	nil	.263	nil	nil	.111	nil	nil	.615	nil	nil	.057	nil	nil	.028
Total	2.41	.086	.988	.35	.033	.325	1.76	.184	2.358	.52	.047	.786	.37	.049	.422

*For 7 month seedlings, the whole plant was analysed without separation into the components and nutrient weights are in grams.
†Nutrient content in fruit bunches is estimated from the dry weight of all fruits in 72 month old tree and multiplied by the nutrient concentration in ripe MDY x WAT coconuts analysed in a separate experiment.
(a)At 7th month in g per palm; thereafter in kg per palm.

Yield of the coconut

The yield increase of the coconut with age differed with the planting materials. The varieties probably have different yield potentials. This is illustrated in *Table 4.*

TABLE 4. YIELD PATTERNS OF COCONUTS (HRU UNPUBLISHED DATA)

Variety	Palms/ ha	Year from planting 5: nuts/ palm	5: Copra kg/ha	5: Copra nuts/kg	6: nuts/ palm	6: Copra kg/ha	6: Copra nuts/kg
MAWA hybrids	148	52	1 491	5.2	69	2 130	4.8
Mal. Dwarf Yellows	215	16	417	8.2	26	715	7.8
Mal. Dwarf Reds	215	11	388	6.2	30	998	6.5
Mal. Dwarf Greens	215	13	462	6.1	27	969	6.0
Malayan Talls	148	0.3	15	3.5	6	224	3.7

Although the Dwarf varieties came into flowering at about 30–36 months compared to 45–51 months in the hybrids (Vanialingam *et al.*, 1975), the total yields of the hybrids in the fifth and sixth years from planting were very much higher while yields from the Talls were negligible.

The hybrids reached peak yields in the Ivory Coast at the 9th to 10th year with yields of 6 200–6 300 kg copra/ha./year (42 pikuls copra per acre per year) (de Nuce & Rognon, 1975) while the highest recorded yields of the Malayan Dwarf Yellow was about 26 pikuls/ac. (Wardlaw & Mason, 1936). The yield potential of the Talls is probably of the same order as the Malayan Dwarf Yellow.

Nutrient uptake at different yield levels by the different varieties can therefore be expected to be different. An estimate of the nutrients in nuts from the MAWA hybrids and Malayan Dwarf Yellows in the varietal trial as well as nuts from Malayan Tall was made in 1975 (*Table 5*).

The results indicate that at the same yield level, the nutrients removed in MAWA hybrids are about the same order as in the Malayan Talls. The Malayan Dwarf Yellows appear to have higher requirement for K, N and Mg per unit yield . For K, Mg and Ca, the requirements of the hybrid appear intermediate between the Dwarf and Tall. Highest nutrient requirements for nut production are for K, N and P respectively. At the realised yield potential of the MAWA hybrids, nutrient requirements will be considerably higher than for coconuts in cultivation currently.

TABLE 5. ESTIMATES OF MAJOR NUTRIENTS REMOVED IN NUT YIELD BY DIFFERENT COCONUT VARIETIES

Nutrients	*Yields at 2 386 kg/ha*			*Yields at realised potentials*			*Previous estimates in Malaysia*	
	MDY	*MDY x WAT*	*MT*	*MDY**	*MDY x WAT†*	*MT**	*Ng + Thamboo≠ (1967)*	*Georgi + Gunn§ (1932)*
N kg	13.2	11.7	11.7	20.6	29.2	18.3	16.3	14.2
P_2O_5 kg	5.1	4.8	5.1	8.0	11.9	7.9	6.1	6.2
K_2O kg	39.7	31.3	29.4	62.0	78.5	40.5	48.1	36.3
MgO kg	4.6	3.6	2.6	7.1	9.0	4.1	4.7	2.6
CaO kg	1.7	1.5	1.4	2.6	3.7	2.2	2.0	1.1

* 3 727 kg/ha (25 pikuls/acre)

† say, 5 964 kg/ha (40 pikuls/acre)

≠ 2 386 kg/ha (16 pikuls/acre)

§ soil rich in nutrients (3 000 nuts – tall variety)

Nutrients removed by the MAWA hybrid at the potential yield level are comparable with that in 10 tons F.F.B. oil palms/acre reported by Ng & Thamboo (1967) *i.e.*, 29.4 kg N, 10.1 kg P_2O_5, 44.7 kg K_2O, 13.5 kg MgO and 10.8 kg CaO. Mg and Ca removal by MAWA may be lower but K removal is very much higher.

RESULTS ON RESPONSE TO FERTILISERS

Results from field trials carried out are probably the most reliable indicators of nutrient requirements although great care has to be taken when extrapolating the results in situations other than the trial areas. In the present case in Malaysia only few trials on coconuts have been carried out. Therefore results of fertiliser trials and investigations overseas are of interest particularly when they present information on the physiology and nutrition of the crop.

Nursery stage

The amount of nutrients supplied to the growing seedlings by the endosperm decreases from the fourth month after germination (Foale, 1968 cited by Nelliat 1974). Trials on the MAWA hybrid seedlings planted in polybags on the sandy soils in the Ivory Coast showed that all the major nutrients, N, P, K and Mg improved growth. A complete and balanced programme was required to obtain plantable seedlings at 6 months (Brunin, Coomans & Ouvrier 1975).

Immature coconuts

Early manuring trials carried out in Malaysia in the Bagan Datoh area did not give significant yield responses although palms which received N yielded more at the end of the seventh year recording period in one trial (Wilshaw, 1941 a).

Subsequent trials reported (Anon, 1957; Paterson, 1968) indicated favourable responses to fertiliser application on young palms on Selangor series in the same district as above. One non-replicated trial showed good yield responses to N and Mg (as magnesium limestone) during the first six years. A follow-up 2^3 NPK factorial trial split for Mg application showed early growth responses to N and confirmed the yield responses to N and Mg. (*Table 6*)

A marked positive interaction between N and Mg applications (as magnesium limestone) was evident. K application appeared to increase yield by about 11% in the presence of Mg but little response to P was noted.

TABLE 6. COPRA YIELDS (PIKULS/ACRE) IN TRIAL ON FERTILISER APPLICATION TO YOUNG PALMS. YIELDS OVER 1959–66 (PATERSON, 1968)

	MgO	*Mg1*	
N_0	77.3	105.3	91.3
N_1	89.4	136.1	112.8
$\bar{x}$	83.4	120.7	

The differences in results between the two sets of trials may probably be explained by the apparently higher rates of application in the later trials (4.8 lb ammonium sulphate per palm) and also may be due to inter-row covers in the old trials which had 'a heavy cover of *Centrosema* and grass' which may have satisfied the palms' requirements for nitrogen.

No trials on the less fertile inland soils of Malaysia appear to have been reported.

Several interesting trials on immature palms carried out in other countries have been reported. Fertiliser applications to young palms improved growth and leaf production (Fremond & Ouvrier 1972; Nelliat & Muliyar, 1971). The latter trial in India on a sandy loam soil compared fertiliser responses on several high yielding types of coconuts (*Table 7*).

TABLE 7. GROWTH MEASUREMENTS OF 3 YEAR OLD COCONUT PALMS WITH DIFFERENT FERTILISER TREATMENTS (NELLIAT & MULIYAR, 1971)

Variety	*Treatment*	*Measurements at 2 years after treatments commenced*					
		Height		*Girth*		*No. of leaves*	
		cm	*% increment*	*cm*	*% increment*	*cm*	*% increment*
Dwarf natural cross	M_0	111	76	23.8	159	16.2	225
	M_1	259	173	57.6	387	20.0	285
	M_2	275	185	59.4	388	20.6	292
Tall x Dwarf hybrid	M_0	100	80	18.9	143	15.2	261
	M_1	194	161	35.4	280	17.2	306
	M_2	205	168	37.7	296	17.8	312
Pre-potent Tall	M_0	82	69	21.9	169	15.1	245
	M_1	204	157	44.6	349	18.3	314
	M_2	232	171	54.1	430	18.8	326

The fertilisers were applied as mixtures of ammonium sulphate, superphosphate and muriate of potash at 3 rates. All the varieties showed good responses to the fertiliser applications. No interactions between levels of fertiliser and types of palms were detected.

In Jamaica, on a drought susceptible stony soil, nitrogen and magnesium applications increased leaf production in Malayan Dwarf palms. There was also a positive PK interaction on leaf production. The rate of leaf production in the early years was found to be closely related to the onset of bearing (Smith, 1971).

The age at bearing of young palms is therefore much speeded up by fertiliser application as shown in Ceylon (Nethsinghe, 1962), in Jamaica (Smith *loc. cit.*) and the Ivory Coast (Fremond & Ouvrier *loc. cit.*). In Ceylon, 90% of the palms planted from secondary jungle with complete NPK application were in bearing at the eighth year as compared to only 50% of the palms with no fertiliser applied. The results from Jamaica showed that NPK fertilised Dwarf palms were nearly a year ahead in flowering and in the Ivory Coast, 30% more K fertilised palms were flowering after seven years.

Results on the effects of withdrawal of fertiliser in immature years and subsequent correction at bearing are not as consistent. Fremond & Ouvrier (*loc. cit.*) showed that on the quarternary marine sands in the Ivory Coast (exchangeable K_2O levels .01 to .02 m.e.), application of K only after maturity affected yield in comparison to palms manured after 4 years. These practices could not improve yields to similar levels as palms fertilised throughout immaturity; the former yields remaining about 10–20% lower in later years. This indicated a permanent effect on the tree from the acute deficiency (leaf K levels of 0.2 to 0.25% K in frond 12 after 5 years) suffered by the palms earlier. However in the trial in Jamaica (available P at about 60 ppm and available K 133 ppm in the soil at beginning of trial) where the whole trial was fertilised at the sixth year for 2 years, the palms gave similar yields in all plots after seven years although differences in foliar N and soil residual values of P and K could still be detected. The earlier yield differences were however very marked and estimated to justify fertiliser applications at immaturity (Smith, *loc. cit.*).

In Ceylon, where fertiliser treatments continued in maturity, yields were nearly twice that of control at the thirteenth year.

Excess fertilisation with N may result in more leaf disease. In Ceylon, excess N when phosphate was deficient made the leaves of young palms highly susceptible to *Helminthosporium* (Nethsinghe, *loc. cit.*). Sumbak (1971) observed very serious damage by *Helminthosporium incurvatum* after applications of 5 rounds of 4 oz ammonium sulphate per palm at 10 months after transplanting in Papua New Guinea.

Sulphur is required at transplanting in acute sulphur deficient areas in Papua New Guinea (Sumbak, 1972) and on coraline islands with high pH soils, iron and manganese applications (by injections in the husk) are required to avoid deficiency (Pomier, 1967).

Mature coconuts

A series of cultivation and manuring trials was laid down pre-war on 7 estates, mainly on coastal clays in Malaysia. Mixtures of organic fertiliser (quano compound and steamed bone meal) and muriate of potash, lime alone and lime with the organic fertiliser mixture were applied to 10 to 20 year old palms on these sites. There were no significant differences after 4 years except in one estate with "sandy soil over white silt" (Belgrave & Lambourne, 1934).

Another trial with liming at ½ ton per acre was successful in raising yield and copra weight per nut. This was on an acid area (top soil pH 3.9, 3 feet depth pH 3.5) at Carey Island. P application appeared to increase the number of nuts produced (Wilshaw, 1941b).

A more recent liming trial on Selangor Series soil has shown no effect on yield or nutrient status from the liming carried out after 3 years (United Plantations Annual Report 1974/75).

An observation trial in 1959 with 29 year old Tall coconut palms on Selangor series appeared to show good responses in yield to N and magnesium limestone application (Paterson, *loc. cit.*).

More recently, some trials on coconuts were laid down in the coastal clay areas at Lower Perak/Sabak Bernam. Responses in nut yield were seen to N applications on previously unfertilised 18 year old Malayan Dwarf Red palms grown on Kangkong series within 1 to 2 years of application. Frond size and production rate were also increased (Chew & Lee, 1972). N significantly increased the number of female flowers per bunch at 15 months after commencement of treatment on Kangkong series (UPRD Annual Report, 1973/74). Leaf area also appeared to be markedly increased (Khoo, Chew & Chew 1976). P and K applications appeared to improve frond size but to a lesser extent than N.

Continued applications of N decreased the size of nut and copra content per nut while K application increased copra per nut. Cumulative results of selected treatments since commencement of the trial are given in *Table 8*.

Malayan Tall palms also responded quickly to nitrogen application on Kangkong series soil (Khoo *et al., loc. cit.*). Palms planted in 1950/51 increased their yields significantly over a 2 year period after commencement of treatment (*Table 9*).

TABLE 8. YIELD RESULTS (JULY 1969 – DEC. 1975) OF 2^3 NPK FERTILISER TRIAL ON KANGKONG SERIES (KHOO *ET AL.*, 1976)

	Nuts/palm	*Copra/nut (kg)*	*Copra/palm (kg)*
Control	363	.151	55.0
N_1	487	.144	69.9
P_1	411	.156	64.0
K_1	398	.163	64.9
$N_1P_1K_1$	459	.155	71.2

TABLE 9. YIELD (APR. 1974 TO JUNE 1976) OF MALAYAN TALL PALMS ON KANGKONG SERIES SOIL (KHOO *ET AL.*, 1976)

Treatment	*Nuts/palm*	*Copra/nut (kg)*	*Copra/palm (kg)*
Control	137	.223	30.6
N_1K_0	173	.205	35.5
N_1K_1	183	.200	37.0
N_2K_1	205	.209	42.8

A recent 3^3 NPK trial on 1938 planted Tall coconuts on Kangkong series soil has not shown yield responses (Shepherd Gilbert & Cowling 1976), possibly due to fertiliser application to the underplanted cocoa in the area which were fertilised.

On Selangor series soil, a 3^2 x 2 NKCa trial on Dwarf coconuts gave poor response to fertiliser application. Only nitrogen affected yields slightly. No effect was seen to potassium or calcium application (United Plantations Annual Report 1974/75).

Results of only one trial in inland soils of the country appear available. Good responses in nut yield were apparent in a trial on smallholders' land in Trengganu (*Table 10*).

TABLE 10. RESULTS (NUTS/PALM) OF COCONUT MANURIAL TRIAL IN TRENGGANU (ANON, 1957)

Treatment	*Pretreatment*	*Post-treatment*		
	1953/54	*1954/55*	*1955/56*	*1956/57*
Control (no fertiliser)	16	7	8	16
7 lb NPK fertiliser/palm/year	11.5	7.5	9.5	21.5
14 lb NPK fertiliser/palm/year	13	9	15	37.5

A later report noted that 7 lb NPK fertiliser continued to increase yield of nuts but no significant increase resulted from 14 lb NPK applications (Anon, 1959).

Of other countries, Sri Lanka appears to have the most number of long term fertiliser trials on coconuts. Nethsinghe (1966) cited examples of increases in yield due to fertiliser applications in different parts of the country and this is listed in *Table 11.*

TABLE 11. EXAMPLES OF FERTILISER RESPONSES OBTAINED IN SRI LANKA TO FERTILISER APPLICATION (NETHSINGHE, 1966)

	Yields (nuts/acre)		
District/Area	*Fertilised*	*Unfertilised*	*Remarks*
Chilaw district	5 000 nuts/acre	2 500–3 000 nuts/acre	One of the best coconut areas in Sri Lanka.
Madampe	4 200 nuts/acre to 5 700 nuts/acre	2 400 nuts/acre	4½ lb NPK 9 lb NPK. From young palms to 15th year without fertiliser. Mixture equal weights of amm. sulphate, m. potash and saphos phosphate.
Nattandiya	4 200 nuts/acre	2 500 nuts/acre	4 lb NPK. Underplanted young palms.
Bandirippawa	5 000 nuts/acre	2 500 nuts/acre	
Bingiriya	5 500 nuts/acre	4 000 nuts/acre	5 lb NPK. Comparatively better soil conditions.
Veyangoda and Ahangama	2 500 nuts/acre	600–800 nuts/acre	3½ lb NPK. Poorer coconut growing districts of the wet zone.
Colombo	3 500 nuts/acre	600–800 nuts/acre	3½ lb NPK + Mg. Wet zone.

Deficiencies of N, P and K therefore appear common in the country and in the wet zone areas, Mg was also deficient.

K appeared to be the most common nutrient limiting yield. In one of the earliest coconut fertiliser trials at Bandirippawa, a 3^3 NPK factorial trial on a sandy loam overlying lateritic gravel, responses in copra yield were found to K applications only. P had no significant effect on number of nuts or copra produced and this exceptional result in Sri Lanka was attributed to residual effects of heavy bone meal applications prior to the trial. N increased the number of nuts produced but not the copra yield. Only a small NK interaction was noted after 26 years (Eden, Gower & Salgado 1963). The K applications appeared to maintain yields while the no-potassium plots deteriorated in yields.

Responses to fertilisers in Sri Lanka varied with the soil (Nethsinghe, 1960).

Results of some more recent trials (Balakrishnamurti, 1973) are listed below. The 1972 results are also provided.

(a) 4 x 4 x 4 NPK experiment on adult palms in Bandirippawa Estate.

Trial commenced in 1960. Highly significant responses to P and K applications were obtained. N also appeared to increase yield.

Best yield responses were obtained to P at 0.68 kg P_2O_5 (P_3)(P_o = 100, P_3 = 130) and K at 0.45 kgm K_2O (K_2) and 0.68 kgm K_2O (K_3) (K_0 = 100, K_2/K_3 = 152) per palm per year.

The NK interaction was highly significant with best results at N_2K_3 or N_1K_2; N_1 = 0.23 kg N and N_2 = 0.45 kg N/palm/year. (N_0K_0 = 100, N_2K_3 = 145, N_1K_2 = 135)

(b) 5 x 5 x 5 x 5 NPK Mg experiment on adult palms at Monrovia Estate, Rathgama.

The trial commenced in 1967 on a lateritic soil in wet zone, typical of Southern Province. Highly significant responses to N and K applications were obtained. Best yields were from nitrogen at level four (N_0 = 100, N_4 = 300) at 2.0 lb N/palm/year and K (K_0 = 100, K_4 = 162) at 2.4 lb K_2o (K4) per palm per year. There were also signs of responses to P (P_1 at 0.5 lb P_2O_5/palm/year) and Mg (Mg_1 at 0.36 lb MgO/palm/year).

In the wet zone areas of Sri Lanka, correction of Mg (0.06% Mg in first and sixth leaves) in deficient palms resulted in a yield increase after 3 years (*Table 12*) (Nethsinghe, 1961).

It appears better to avoid Mg deficiency in the above instance.

In a trial on middle aged palms on a sandy loam soil in the West Coast of India, responses in nut yield were seen to N application in the second year, P applications consistently after nine years and K applications after 4 years. P did not affect nut characters but N significantly depressed copra per nut and K had the reverse effect. There was a significant PK interaction which increased yields. No increase in yield was seen in palms which yielded 50 nuts or more during the pre-treatment period (Muliyar & Nelliat 1971).

TABLE 12. RESPONSE TO CORRECTION FOR MAGNESIUM IN COCONUTS (NETHSINGHE, 1961)

		1960/61
Palms with Mg deficiency symptoms	NPK	35 nuts/palm
	NPK + Mg	50 nuts/palm
Palms with no Mg deficiency symptoms	NPK	70 nuts/palm

In the Philippines, good responses in yield to muriate of potash applications on 8 and 17 year old palms were obtained on Tugbuk clay, a reddish brown residual soil formed from igneous rocks, predominently andesite at Davao (Von Uexkull 1972; Magat *et al.,* 1975). Marked responses in yield to high rates of muriate of potash application were obtained within 2 years of application in both trials. N application increased number of nuts produced but reduced nut size in the absence of muriate of potash so that no yield increases were recorded while P appeared to have no effect (Von Uexkull 1972). In both these trials, levels of leaf K were high and not increased by muriate of potash application. Only leaf chloride content was correlated with yield. In view of the latter and the very low chloride leaf levels (.036% in 8 year old palms and .074% in 17 year old palms) in the control plots, it was postulated that the yield increases were due to correction of chlorine deficiency by the application of muriate of potash.

DIAGNOSIS OF NUTRIENT REQUIREMENTS

The basic information on nutrients required for growth and yield of coconuts and results from fertiliser trials will need to be supplemented by other suitable diagnostic techniques to assess fertiliser requirements of the crop more precisely for specific areas.

Visual deficiency symptoms

Descriptions of major nutrient deficiency symptoms in coconuts were reported by Fremond, Ziller & de Nuce de Lamothe 1966 and Child, 1974. Sulphur deficiency was illustrated by Southern (1967) and iron and manganese deficiencies by Pomier 1967; Southern & Dick 1969.

Nitrogen deficiency symptoms are commonly seen in coastal estates, particularly where drainage conditions are poor while nitrogen, potassium and magnesium deficiency symptoms may be seen in smallholdings and on the 'bris' soils on the east coast.

Soil analysis

Few attempts have been made to relate soil nutrient levels to responses observed in coconuts and many published trial results *e.g.,* Eden *et al.,* 1963 do not provide soil analytical data. This apparently is in line with the view that 'soil analysis is of very limited value in forecasting manurial requirement and in the present state of knowledge, it is only possible to correlate the mechanical and chemical composition of soils to a very slight degree with the yield of coconuts grown on them or with their responses to fertilisers' (Child, 1974).

In Sri Lanka, Nethsinghe (1961) was unsuccessful in finding differences in exchangeable Mg in areas of apparently healthy palms and affected palms in the same plantations. Salgado (1951) found that there were no responses to potash on soils with 0.2 me exchangeable K. Where responses were obtained, soil levels were 0.02 me exchangeable K.

Analysis for soil P, K and pH were carried out in trials in Jamaica but correlations with yield or yield components appeared low and largely non-significant. Correlations with leaf nutrient levels have been recorded, and pH was correlated to rate of leaf production in one trial and bunch production in another (Smith, 1971).

Interpretation of data from different trials may be complicated by the analytical methods used *e.g.,* Child (1974) cited two trials in Sri Lanka which showed different responses to P application but had similar amounts of available P as extracted by the Troug citric acid method. The Olsen's method using sodium bicarbonate solution as extractant however gave values reflecting the relative P responses.

However, it has been recognised that there are differences in responses to fertilisers on different soils in Sri Lanka (Nethsinghe, 1960) and recommendations on fertiliser applications are based on soil types (Nathanael, 1967).

Leaf analysis

Leaf analysis is now an established diagnostic technique in coconuts largely as a result of the work carried out by the IRHO (Child, 1974).

Studies have been carried out on variation in the nutrient contents in different leaves on a palm (Prevot & Bachy, 1962 cited by Fremond *et al.,* 1966) to arrive at the choice of a suitable leaf age for sampling. Frond 14 was chosen for diagnosis as it appeared to be at full physiological maturity and had not yet started to be senescent (Fremond *et al.*, 1966) and is now accepted as the standard frond for analysis in adult palms.

P and K values were noted to fall with age while Ca and Mg levels increased with age of leaves. N values rose to a maximum at about frond 6 and then declined after that. Analysis carried out in Malaysia on 2 year old hybrid seedlings and one 6 year old MAWA hybrid show the same trend of results for N and K (Chan K.S., unpublished data). However in the MAWA palm tested, the values of P and Ca were more or less the same in all fronds except in the last few fronds 25 to 31 in which P declined.

The influence of seasonal effects on leaf nutrient levels has also been studied. N and P values were found to vary little but K levels fluctuated considerably in relation to rainfall, being lowest in the dry season (Fremond *et al.*, 1966). Coomans (1974) studied the fluctuations in nutrient content in 4 countries and found that the increases and decreases in nutrient contents generally appeared at the same time of year irrespective of the yield level and the fertiliser applications. The curve of the graphs of nutrient contents was also the same every year for at least the 3 years studied. The maxima and the minima were more or less accentuated but the general aspect of the seasonal variations remained the same. The variations were dependent upon climatic conditions, amongst which rainfall seemed to play a predominant part.

Of the major nutrients, N and K were most sensitive to the effect of water supply. The variations in N were mainly affected by rainfall or surface irrigation, water from the water-table had no effect.

The K contents were strongly influenced by the yield, whose rhythm and amount depended directly on the water regime. Irrigation affected the levels but had only slight effect on the general pattern of variation.

Leaf analysis results from a 2^3 NPK trial on Kangkong series showed marked differences in leaf N levels over 6 years but differences between treated and untreated palms were fairly consistent in each year. Annual fluctuations were not as marked for leaf K levels and again differences between treatments were consistent each year (HRU unpublished data).

Varietal differences between planting materials were also studied by Coomans (*loc. cit.*). The Cameroon Red Dwarf appeared to show different nutrient levels from the Ghana Yellow Dwarf or the West African Tall. Extent of general variations in a year seemed about the same but variability within a year was more pronounced in the Yellow Dwarf compared to the West African Tall.

Kanapathy (1972) sampled palms of 3 varieties, tall, semi-tall and dwarfs in Malaysia to examine their leaf nutrient contents. There appeared to be little relationship between yield of nuts per palm and leaf nutrient levels within each variety. There however appeared to be differences in leaf nutrient levels between varieties within the same yield groups for most of the nutrients. Differences were also evident in leaf nutrient levels between progenies of each variety.

The critical levels proposed by the IRHO workers after comparing the leaf nutrient levels and yields in different ecological conditions and studying the mutual action of nutrient elements on each other (Fremond *et al.*, 1966) are given in *Table 13.*

TABLE 13. CRITICAL NUTRIENT ELEMENT LEVELS IN COCONUT LEAVES (IRHO) % ON DRY MATTER

N	*P*	*K*	*Ca*	*Mg*	*Na*	*Fe*	*Mn*
1.8–2.0	0.120	0.80–1.00	0.50	0.30	uncertain	50 ppm	60 ppm

Ollagnier & Ochs (1971) proposed that levels of chlorine in the leaves should be 0.5 to 0.6% to obtain maximum yields, mainly on the basis of evidence in oil palm trials in Columbia. The evidence for coconuts presented were from the Ivory Coast where Cl levels were high in the region of 0.5% and 0.8%. The experiments by Magat *et al.*, (1975) and Von Uexkull (1972) however indicate that responses to Cl applications in muriate of potash are possible in coconuts with very low Cl levels.

Southern (1969) obtained spectacular and very quick results from treatment of sulphur deficient plants with sulphur applications, ammonium sulphate and potassium sulphate. He suggested that the easily reducible sulphur fraction (probably all sulphate) in coconut leaves and coconut water is a much better index of sulphur status than the total sulphur content. Tentative results for sulphur for the trials carried out indicate a critical level of 150 ppm sulphate S in frond 14.

In Papua New Guinea, Southern & Dick (1969) suggested that the critical level for Fe should be 40 ppm and that 20 ppm is probably the level where symptoms are likely to occur. They also suggested that the critical level of Mn should be 30 ppm with symptoms likely to occur below 20 ppm Mn. The critical level of boron has been suggested at 10 ppm by Fremond (cited by Southern & Dick, 1969).

Application of a nutrient will affect levels of that nutrient and levels of other nutrients as well *e.g.*, in the Ivory Coast, application of potash improved leaf K and P levels. It also affects N levels which tended to be lower in younger palms but higher as the palms got older and depressed Mg levels (Fremond & Ouvrier 1972). In Malaysia, on the heavy clay Kangkong series soil, N applications increased leaf N but decreased leaf P and Mg levels. P leaf level was increased by P applications. K application increased K level but decreased Mg level (Chew & Lee, 1972).

Experience in trials and in commercial areas on coastal soils in Malaysia so far indicate that the IRHO critical levels for N and P levels are probably correct but poor responses to potassium have been recorded at low leaf K levels at about 0.6% to 0.7% K (Chew & Lee, 1972; Khoo *et al.*, 1976). It is known that on the coastal clay soils in Malaysia, the critical leaf level of K in oil palm is lower at about 0.8% compared to over 1.0% on the inland soils and this relationship may also hold for coconuts. Another feature of the leaf nutrient levels in Malaysia is the lower leaf Ca levels seen in all coastal areas.

In one trial on an organic clay soil with subsoil pH of 3.8 and with low leaf Ca levels, calcium limestone application which commenced in 1972 appeared to increase copra content per nut, especially in the Dwarf palms among the coconut population (*Table 14*).

On Selangor series, good responses to magnesium limestone were reported and leaf levels in Frond 15 at 10 years after commencement of the trial (Paterson, 1968) are shown in *Table 15*.

TABLE 14. EFFECTS ON COPRA CONTENT PER NUT BY Ca AND K APPLICATIONS (HRU UNPUBLISHED DATA)

Treatment	*Copra (gm/nut)* 1973		1974		1975		1976		1976 frond 14	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*%Ca*	*% K*
Ca_0	131	114	124	108	122	104	115	94.7	.10	1.07
Ca_1	114	127	143	130	140	127	113	97.8	.20	.96
Var. ratio	NS	NS	NS	*	*	*	NS	*	**	NS
K_0	122	117	126	118	124	113	114	95.4	.15	.91
K_1	123	123	142	120	138	119	114	96.8	.15	1.12
Var. ratio	NS	NS	NS	NS	*	NS	NS	NS	NS	*
Ca x K Var. ratio	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

a = hybrid palms * significant at 5% level NS = not significant
b = dwarf palms **significant at 1% level

TABLE 15. NUTRIENT LEVELS IN FROND 15 (PATERSON, 1968)

Treatment	*% on dry matter* K	*Mg*	*Ca*
Control	1.17	0.26	0.31
Mag. limestone	1.16	0.25	0.35

It appears that Ca levels in the leaves are difficult to raise to high levels on the coastal soils in Malaysia or the palms have a low requirement for the nutrient in this country.

Nut water analysis

Initial work in Sri Lanka indicated that this technique would be promising for diagnosis of the potash requirement of the coconut palms. However subsequent work (Salgado and Abeywardena 1964) indicated a complex situation where the K_2O content may be affected by high levels of N and P in the soil. The K_2O content of nut water was found to be low for high yielding palms, high for a larger volume of water per nut and unaffected by the copra content per nut. P_2O_5 contents of nut water were investigated and it was found that high N or K also depressed P_2O_5 content in nut water.

Work in the Ivory Coast showed similarities in interpretation of results of foliar diagnosis and those suggested by composition of the nut water. There were however certain discrepancies in the comparison which required to be verified (Fremond *et al.*, 1966).

It appears that much more work is required on this technique before it can be used satisfactorily or be more acceptable than leaf analysis.

Other agronomic factors

Growing conditions and agronomic practices in the coconut areas will have to be taken into account for assessment of fertiliser requirements.

The importance of the coconut root system in utilisation and uptake of nutrients has been stressed (Fremond *et al.*, 1966; Von Uexkull, 1972). Soil conditions should allow for good root growth, particularly aeration and avoidance of compaction and water-logging.

Grasses compete for nitrogen and permanent leguminous covers will improve yields (Fremond *et al.*, 1966).

Cultivation and upkeep methods employed will also affect coconut nutrition. Mechanical upkeep methods reduced nitrogen nutrition. Herbicide spraying was the best upkeep method. Disc harrowing in conjunction with spraying was unnecessary and when carried out alone was detrimental (Hew, 1972).

Cocoa underplanting – competition for nutrients with coconuts

In view of their extensive root system, coconut roots absorb nutrients applied on all parts of the inter-rows and adjoining palms compete and poach nutrients applied around other palms. As much as 30% of applied 32P may be taken up by other palms (IAEA, 1975).

When cocoa is planted in the inter-rows, it may be expected that it will compete with the coconuts for nutrients. In the absence of or as a result of inadequate applications of fertiliser to the cocoa, this may result in reduction of yields of the coconuts (Tam, 1968).

Results of comparisons of adjoining observation plots of Malayan Dwarf Reds with fertilised underplanted cocoa yielding about 500–600 lb/acre with palms in a fertiliser trial on Kangkong series showed that yields are only comparable to that of unfertilised palms and less than that of fertilised (N) palms (*Table 16*).

Rates of fertiliser to the cocoa were not high in view of the high shade and low yield potential in the area and it appears that the fertiliser applied to the cocoa has not resulted in yield increase of the coconuts. Slightly better N nutrition of the coconuts was indicated in the leaf analysis results.

The other implications of underplanting cocoa are beyond the scope of this paper but it appears that the nutrient requirements and applications to both crops will have to be considered carefully particularly with respect to calcium (Ng, 1968). Application of fertiliser around the cocoa bushes can be satisfactorily taken up by the cocoa. If it is wished to fertilise the coconuts, this should preferably be a separate operation around the palm base where work in Sri Lanka have shown highest root activity and preferably after checking the nutrient status of the trees by foliar analysis.

TABLE 16. COMPARISON OF YIELDS AND LEAF ANALYSIS RESULTS OF UNDERPLANTED AND NON-UNDERPLANTED MALAYAN DWARF RED COCONUTS (HRU UNPUBLISHED DATA)

Treatment		*Copra (kg/palm)*				
Cocoa	*Coconuts*	*1972*	*1973*	*1974*	*1975*	*1976*
No cocoa	No fertiliser	9.8	5.73	10.5	9.5	8.5
	N	14.4	7.36	13.1	11.1	11.4
Underplanted & fertilised	No fertiliser	11.6	5.14	9.9	9.1	9.2
		Leaf N in frond 14				
No cocoa	No fertiliser	–	1.63	1.81	1.63	1.71
	N	–	1.74	1.88	1.76	1.74
Underplanted & fertilised	No fertiliser	–	1.67	1.85	1.65	1.72

AREAS OF APPLICATION OF FERTILISER

Studies with 32P were carried out in coconuts in the Philippines and Sri Lanka (IAEA, 1975).

In the Philippines, 15 and 60 year old coconut trees showed similar patterns of root activity. Highest activity was noted at 2 m. distance and 15 cm depth and highest zone of root activity was at 1 to 2 m. distance and 15 cm depth. Wet season activity was very much higher than in the dry season. In one other site, root activity was more widespread at 4 m distance and 30–60 cm depth as determined by 32P uptake after 30 days after application.

In Sri Lanka, root activity in wet seasons was highest at 1 m. distance and 10 cm depth with high activity also at 0.5m. distance and 10 cm depth. Root activity at all depths at 2 and 3 m. distances and below 10 cm depth at the 0.5 to 1 m. distance was significantly lower. In the dry season, root activity was highest at the 0.5 m. distance at 10 cm depth with the 1 m. distance and 10 cm depth a close second. Root activity was very much lower in the dry season than in wet weather.

In a lateritic soil, root activity at 2 m. distance was not very much lower than that at the 0.5 and 1 m. distances during the wet weather. During the dry season, highest root activity was at 0.5 m. distance at 12–24 cm depth.

An experiment on fertiliser placement showed that fertiliser application near the tree 0.5 m. radius or in a band near the palms was more efficient than placement mid-way. Ring application on larger surface 0.8 $m.^2$ was more efficient than in a band 0.4 $m.^2$

DISCUSSION

There is considerable work on nutrition of coconuts now which indicates the need for fertilisers to promote growth and increase precocity of the coconut palms at immaturity and to increase yield during maturity. The need for balanced nutrition is indicated at immaturity (Fremond & Ouvrier, 1972) and at maturity (Balakrishnamurti, 1973).

Fertiliser applications will have to be geared to the varieties grown and an understanding of the growth stage and yield patterns of the different coconut varieties will probably be useful. The dry matter production in the MAWA hybrids which is much less to that of young oil palms of similar age should be borne in mind in assessing fertiliser requirements.

In Malaysia, responses to N on the more poorly drained coastal clays *e.g.,* Kangkong and Briah Series are expected. Responses on the better structured Selangor Series will probably depend on local drainage in the areas. With the high K requirement by the MAWA hybrids, some applications of K are probably advisable. The benefits of magnesium limestone application have still to be confirmed in soils with average pH levels. Application is not suggested for the time being. Where soil pH is below pH 4.0 at the soil surface and pH 3.8 at subsoil, magnesium or calcium limestone application should be considered.

On inland soils, based on the work in Sri Lanka and elsewhere, good responses can be expected from applications of N, P and K. Responses to Mg application could possibly arise, particularly on the sandier soils and it will probably be useful to check residual values of soil P prior to deciding on rates to be applied.

The rates to be applied will have to be estimated from the nutrient uptake data available, soil nutrient content and experience with other crops on the particular soils until more information and experience on manuring of the crop is available, particularly from fertiliser trials. However, in view of the trial results obtained elsewhere, it appears advisable to ensure that good nutrition and growing conditions during immaturity are maintained.

It is not likely that chlorine and sulphur deficiency will be problems in this country as the oil palm shows adequate levels of these two elements in this country (Ollagnier, pers. comm.). Problems with the trace elements iron and manganese are also not expected. Boron deficiency has been seen in the Ivory Coast. Young MAWA hybrid palms, especially from Malayan Dwarf Red mother palms have shown boron deficiency symptoms in the first 18 months in the Bagan Datoh area (Ng, S.K., pers. comm.). It is probably advisable therefore to check the level of boron in young palms and regularly thereafter particularly in sandy areas and sedimentary soil areas on the East Coast which appear to show high incidence of boron deficiency when planted with oil palms.

In view of the relative inexperience with fertiliser application to coconuts, the nutrition of the trees should be regularly checked by leaf analysis. This technique appears adequate and the critical levels laid down by Fremond *et al.*, (1966) applicable apart possibly for the K levels on the coast and Ca levels. For the time being, it is suggested that on coastal clay soils, K applications should be considered only when K leaf levels are below 0.60% to 0.70% at leaf N levels between 1.8 to 2.0% N. Ca applications should be considered when leaf levels of 0.15% Ca and below are observed particularly if soil pH is about 4.0 only. Leaf analysis should however be carried out annually at about the same period each year to ascertain nutrient level range for individual areas.

While it may be true that good correlations between soil composition and performance of coconuts have not been found, it is probably premature to presume soil analytical data has limited application. The chemistry of the soil is complex and studies on the subject in coconuts have been limited and apparently restricted to determination of simple correlations with soil nutrient contents. New approaches in soil science and recent techniques of soil analysis *e.g.*, those that measure 'intensity' rather than 'quantity' have not been tested.

It is probable that soil analytical data will be found to be a useful adjunct to leaf analysis which applied alone may not be reliable as found for oil palms (Ng & Thamboo, 1966). Periodic checks on soil nutrient contents may be useful.

It is probable that pedological studies of potential coconut growing soils in Malaysia will also be rewarding. This is already applied in Sri Lanka (Nathanael, 1967) and the success and experience in *Hevea* in this country by workers of the Rubber Research Institute (*e.g.*, Chan & Pushparajah, 1972; Chan, Pushparajah, Yew & Zainol, 1975) indicate the potential value of such studies.

It was noted in the long term trial in Sri Lanka (Eden *et al.*, 1963) that the yield increases appeared to result from deterioration of the non-fertilised plots. Muliyar & Nelliat (1971) found that the yield response obtained decreased with increase in initial bearing capacity of the palms and no benefit was seen from fertiliser applications to palms yielding 50 nuts or more per year during pre-treatment. The latter was found to be not so in Jamaica (Smith, 1971). However, in view of the findings of Fremond & Ouvrier, 1972 that deficiency during immaturity can lead to permanent damage of the palms, it is possibly best to ensure that nutrition and growing conditions during immaturity are maintained at optimum conditions to obtain high early yields.

Information on the competition for nutrients by cocoa and coconuts planted together is limited. Fertilisers applied to the coconuts should take the competition factor into account and the fertiliser should be applied separately to the cocoa and coconuts if it is desired to fertilise both crops. Although the hybrid coconuts planted as shade may only be at low stands per acre, yield compensation from reduction in competition between palms for light and nutrients may increase yields per tree very greatly and yields per acre will still be relatively high *e.g.*, an area of dwarf and hybrid coconuts underplanted with cocoa thinned systematically to 36 palms per acre yielded 46% of the yield from 90 palms per acre in the first year after thinning. Nutrient requirement of coconuts for high yields in such situations will still be high. Adequate fertilisers should therefore be applied to meet the nutrient requirements of both crops to reduce the competition effect.

The best approach to fertilisation of coconuts in such situations therefore appears to be to monitor the nutrition through leaf analysis and possibly periodic soil analysis and to evaluate the yield against expected potential for the area. Fertiliser applications should be increased if yields are below potential and nutrition indicated to be deficient.

Fertiliser application in the herbicide sprayed palm circle of 1 to 2 m radius appears to be best.

CONCLUSIONS

Fertiliser applications are necessary to achieve potential yields of coconuts in this country. Responses to nitrogen are expected on the coastal soils. In view of the large removal of potassium, periodic applications may be beneficial. Applications of all major nutrients will probably be required in the inland soils. Fertiliser trials will be required on inland soils to determine the nutrient requirement of coconuts more precisely. The combined requirements of cocoa and coconuts for nutrients are also probably worthwhile investigating. In the interim, annual leaf analysis should provide useful guidelines on fertiliser requirement of coconuts.

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