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Performance of Oil Palm on Coral Soils

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ABSTRACT

The marked increase in oil palm hectarage in Sabah is largely due to the large tracts of land made available for oil palm planting. Out of the approximately one million hectares of land planted with oil palm, about 4246 ha are on coral soils located at FELDA Sahabat 23 and 24. These soils, derived from coral deposits have high soil pH and exchangeable Ca which can contribute to the imbalance of soil nutrients and affect nutrient availability to the palms. However, with proper agro-management inputs, the performance of oil palm on these soils can be as good as some of the mineral soils in the country. The highest yield obtained is about 24.05 t ha^{-1} yr^{-1} in the 11th year of harvesting. This paper provides some background information on the soils, the problems in their management and actual yield performance of palms based on 13 years of FELDA experience.

ABSTRAK

Kawasan tanah yang luas serta sesuai untuk tanaman sawit menyebabkan keluasan tanaman sawit di Sabah meningkat dengan pesat. Daripada sejumlah satu juta hektar anggaran keluasan tanaman sawit, terdapat lebih kurang 4246 ha sawit ditanam di atas tanah karang yang terletak di FELDA Sahabat 23 dan 24. Tanah jenis ini terbentuk hasil daripada mendakan batu karang, ketinggian kandungan pH dan kadar tukar ganti Ca dalam tanah menyumbang kepada ketidakseimbangan nutrien tanah dan menjejaskan pengambilan nutrien untuk sawit. Walau bagaimanapun, melalui amalan pengurusan agronomi yang baik, penghasilan sawit di atas tanah ini adalah setanding berbanding dengan beberapa tanah mineral yang terdapat dalam negara. Hasil tertinggi iaitu 24.05 t ha^{-1} thn^{-1} diperolehi dalam tahun penuaian ke 11. Rencana ini memberikan sedikit sebanyak latar belakang mengenai tanah ini, masalah pengurusannya dan prestasi sebenar hasil sawit berdasarkan kepada pengalaman sebanyak 13 tahun di FELDA Sahabat.

Keywords: Sabah, coral soils, soil pH, exchangeable Ca, nutrient imbalance.

INTRODUCTION

The total area planted with oil palm in Malaysia in 2001 was about 3.5 million hectares, out of which slightly more than one million hectares were in Sabah. Most of the oil palm (about 97% of the total area) is planted in the districts of Sandakan and Tawau, while the rest in Kudat, the interior and West Coast Divisions.

The oil palm sector had contributed significantly to Malaysia's economy during the 1997/98 regional financial crises. However, its future expansion is going to be limited due to several factors such as depletion of prime soils for planting, shortage of workers and rising costs of labour and material. In Sabah alone, the development has encroached on areas previously classified as marginal for agriculture including oil palm. As an example, there is a rapid increase in the oil palm hectarage in the Keningau–Sook plain which is located at an altitude of about 370 m above sea level, and situated in a rain-shadow area with a distinct dry season (Deratil *et al.*, 2001). Since the areas under prime soils have became less available, the subject of problem or marginal soils in the plantation industry has been thoroughly discussed. For example, Goh (1995) defined these soils as those which require special or specific attention, thought and method to successfully manage. The soils, as listed by Goh (1995), Tayeb (1999) and Chan (2000) include:

- deep peat;
- shallow acid sulphate soil;
- saline soils;
- shallow laterite;

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- podsols or spodosols;
- sandy (quartzipsamments);
- bris soil;
- high altitude (>300 m above sea level) soil; and
- steep land (>25°).

Chan (2000) also included calcareous soils in the list of marginal soils that are getting more prominence. These include soils from limestone, like Langkawi series, or from sea shell (coral) deposits, such as the Semporna family as found in Sabah. Most of the marginal soils mentioned above have been well reported by the same workers in terms of their management for oil palm cultivation. However, very little is known about the management of soils from coral deposits, such as the Semporna family. These soils have developed in Sabah over coralline limestone and have been mapped in the Sahabat and Semporna areas (Paramananthan, 1997).

Selvadurai and Aziz (1991) carried out detailed soil surveys in FELDA Sahabat and found that most of the profile characteristics are similar to those of the soils in Peninsular Malaysia except for some variation in the chemical content. Sinnasamy (1996a, b) did a general reporting of fresh fruit bunch (FFB) yield performance on coral soils in Sahabat and the physical and chemical properties of the soils. Paramananthan (1997), on the other hand, described the main characteristics, classification and correlation of these soils in the Malaysian system of soil classification.

The objective of this paper is to provide further information on the commercial performance of oil palm planted on coral soils in FELDA Sahabat, Sabah.

CHARACTERISTICS OF THE STUDY AREA

The study was conducted at FELDA Sahabat 23 and 24 Schemes, situated in the Dent Peninsula of Sabah (*Figure 1*). They lie approximately between latitudes 05° 14'N to 05° 21'N and longitudes 119° 12'E to 119° 15'E. The ages of palms were 12 to 13 years. The average annual rates of fertilizer applied from 1997 to 2000 were 4.01 kg palm^{-1} of sulphate of ammonia, 4.15 kg palm^{-1} of muriate of potash, 1.59 kg palm^{-1} of rock phosphate and 1.93 kg palm^{-1} kieserite. Aerial, manual and spreader methods of application were used to fertilize this area. The rest of the management inputs followed normal estate practice. The mean rainfall between 1996 to 2000 was 1787.53 mm. The rainfall exceeded the requirement from June to February, but a water deficit occurred from March to April (*Figure 2*). There was moderate variability in the sunshine hours between 1990 to 1995, ranging from 5.1 to 6.3 hr day^{-1} (Sinnasamy, 1996b). However, there was a gradual decrease in sunshine hours per day towards the end of the year.

Selvadurai and Aziz reported in 1991 that approximately 6% of the total area under coral soils in the Sahabat Scheme has been developed with the main areas in Sahabat 23 and 24. Coral soils are normally located about 4 km to 5 km away from the coast. The soil map produced by FELDA shows five soil mapping units of the Semporna Family subdivided into five series as follows:

- Semporna;
- Semporna Shallow;
- Semporna Medium;
- Dent; and
- Dent Shallow.

The main features of the soils are their depths and the depth of the coral rock from the soil surface (*Figures 3, 4, 5* and *6*). Details of the soil characteristics are shown in *Table 1.*

MATERIAL AND METHODS

A description of the study area is summarized in *Table 2.* Due to the variation in soil depth, samples were collected from five blocks in each estate. The monthly fresh fruit bunch (FFB) yields in each block from 1991 to 2000 were summarized to yearly figures. Leaf samples from palms three to 13 years of age and soil samples from the palm circle area and depth 0–15 cm were collected and analysed by FELDA Agriculture Services Sdn. Bhd. (FASSB) from 1990 to 1998. The MPOB team took two sets of soil and leaf samples, once during the dry season in July 1999 and once during the wet season in October 2000. Soils were sampled at three different locations, in the palm circle, palm avenue and frond pile areas. In each location, the samples were taken from three depths, 0–15 cm, 15–30 cm and 30–60 cm. Other relevant records such as rainfall, planting density and fertilizer programme were also compiled.

All the soil samples were analysed for soil pH (H_2O, 1:2.5), organic carbon (Walkley and Black, 1934), total nitrogen (macro – Kjeldahl), available phosphorus (Molybdenum Blue), exchangeable potassium, calcium and magnesium (shaking with 1 M ammonium acetate) and aluminium, hydrogen (direct titration with an alkali). Only the soil samples taken in October

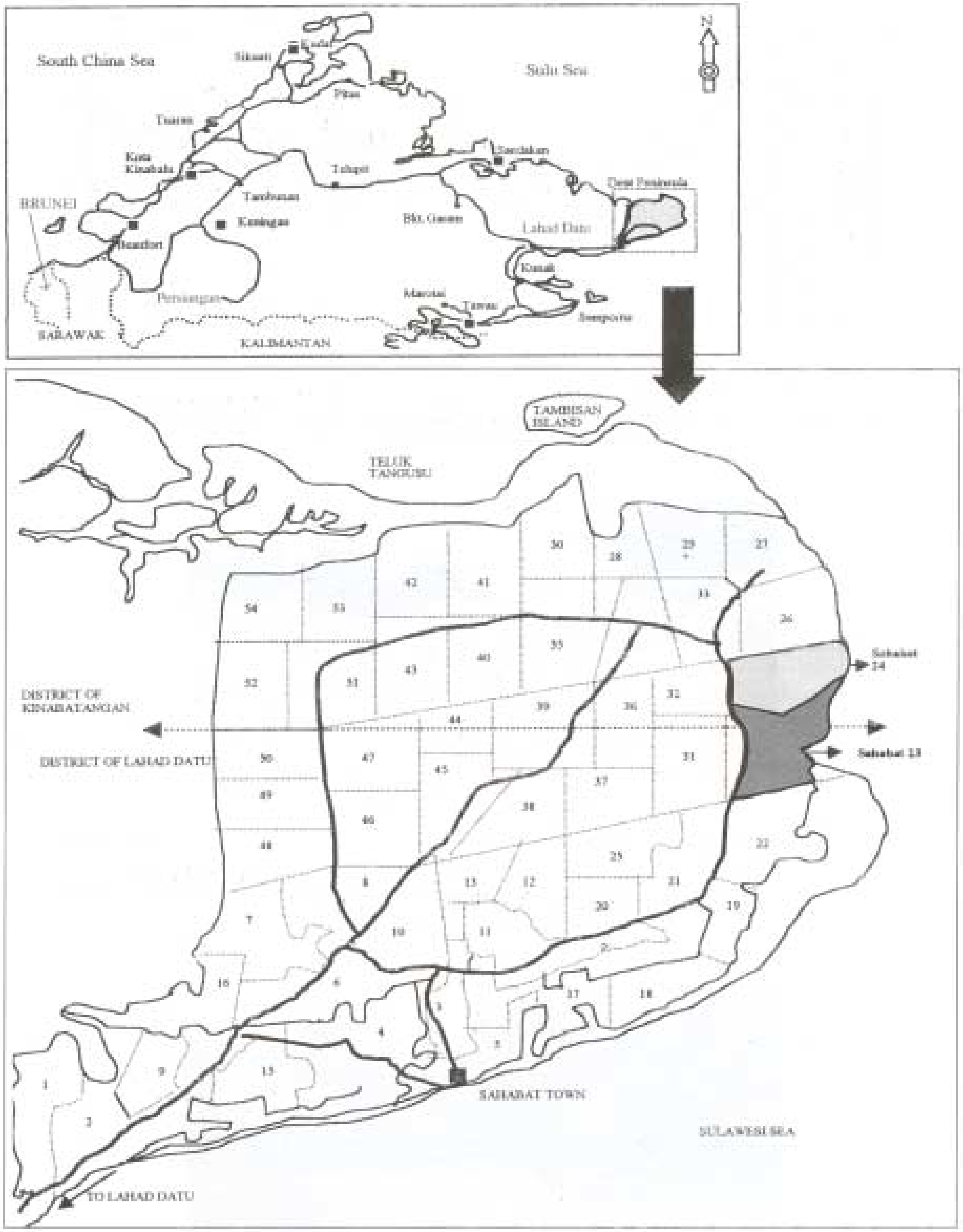


Figure 1. Location of FELDA Sahabat in Sabah.

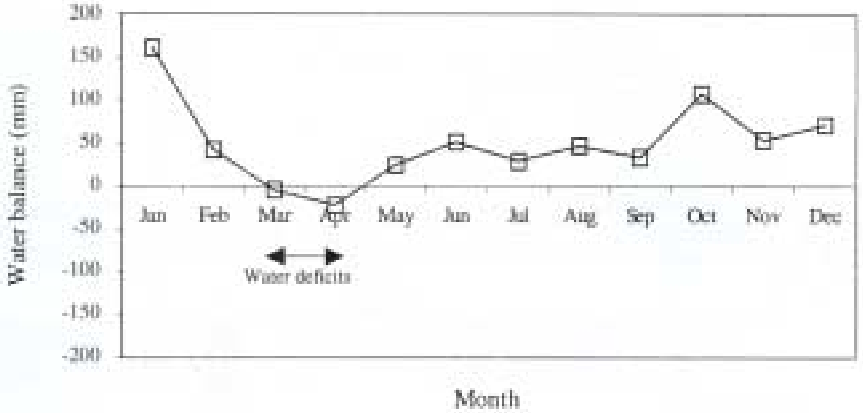


Figure 2. Water balance between availability and oil palm demand from 1996 to 2000 at Sahabat 23 and 24.

Figure 3. Oil palm planted on coral soil – observe the coral deposits throughout the profile of more than 9 m.

Figure 4. Soil profile – presence of coral rock all over the profile.

Figure 5. Close-up view of coral soils collected at depth 30–45 cm (effervescence with dilute hydrochloric acid).

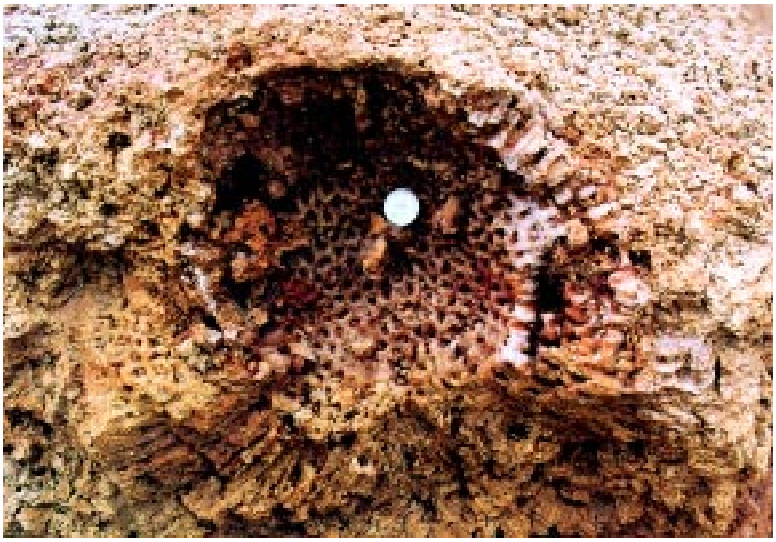


Figure 6. Bee nest structure of coral rocks – a close-up view.

2000 were analysed for textural composition using the pipette method. Soil mechanical and chemical analyses followed the *Manual of Soil and Plant Analysis* (Zulkefli and Masnon,1993a, b). Leaf samples from frond 17 were analysed for total nitrogen, phosphorus, potassium, calcium and magnesium.

RESULTS AND DISCUSSION

Yield Performance

Table 3 shows the FFB yield obtained over 10 years (1991-2000) in the estates. From the data, it can be seen that during the early years of production, the average FFB yields of oil palm on coral soil were very low (6-13 t ha^{-1}) compared to palms on inland, coastal and peat soils, and far behind the average yield of palms planted on common inland soils in Sabah. However, the FFB yield markedly increased after the palms became fully mature at about eight years after planting with yields between 20-24 t ha^{-1}. This could be due to the capability of the palms to adapt with time to the coral environment in spite of the several limitations prevailing. Sinnasamy (1996b) reported that the potential yield of oil palm on these soils ranges between 18-25 t ha^{-1} depending on the soil depth and depth of coral from the soil surface. *Figure 7* shows the actual yield pattern of oil palm on coral soils compared to other types of soils.

TABLE 1. CHARACTERISTICS OF SOIL SERIES OF SEMPORNA FAMILY MAPPED BY FELDA

Series	Predominant colour and structure	Texture	Consistency	Drainage	Soil depth	Remarks
Semporna	Strong brown to yellowish red, strong medium and coarse subangular blocky structure.	Clay	Friable	Well - drained	100 cm+	Deep soil derived from mudstone parent material. Coral rocks appear below 1 to 2 m. Physically this soil is suitable for most crops.
Semporna Medium	Strong brown to yellowish red, strong medium and coarse subangular blocky structure.	Clay	Friable	Well - drained	50 to 100 cm	Coral rocks appear below 50 cm. Marginal to suitable for deep rooting crops.
Semporna Shallow	Strong brown to yellowish red, strong medium and coarse subangular blocky structure.	Clay	Friable	Well - drained	Less than 50 cm	Very shallow soils with coral rocks at 50 cm and less. Unsuitable for most tree crops.
Dent	Reddish yellow to reddish brown, strong medium to coarse angular blocky structure.	Clay to silty clay	Friable to slightly firm in subsoil	Moderately well - drained	50 cm+	This soil is derived from alluvial deposits on nearly level land. Coral rocks are scattered within the profile and rooting is not restricted. Suitable for most tree crops.
Dent Shallow	Reddish yellow to reddish brown, strong medium to coarse angular blocky structure.	Clay to silty clay	Friable to slightly firm in subsoil	Moderately well - drained	Less than 50 cm	Coral rocks are scattered from the surface down the profile. The rocks are not massive and compact. Suitable to marginal for tree crops.

TABLE 2. DETAILS OF THE STUDY AREA

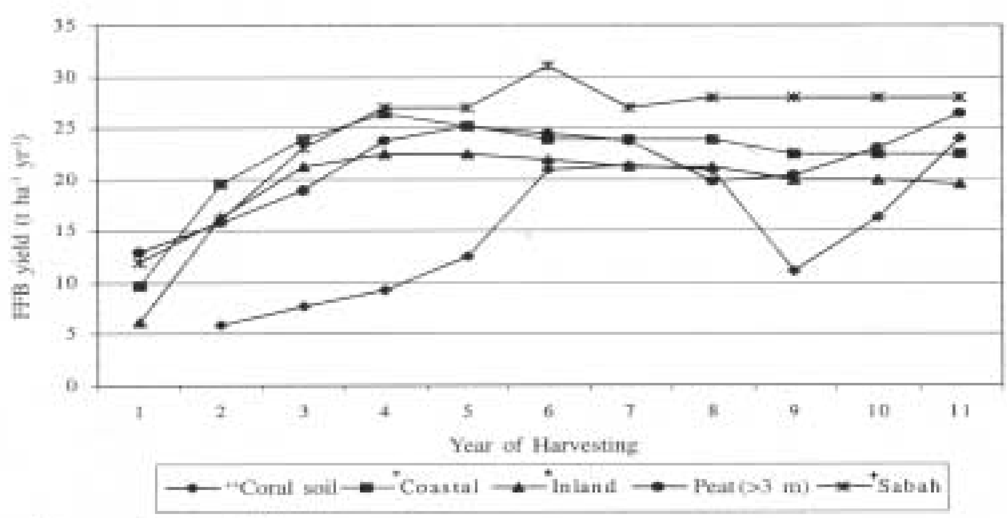
Location	Total area (ha)	No. of blocks sampled	Total block area sampled (ha)	Standing palm ha^{-1}	Planting date
Sahabat 23	2 210.73	5*	601.74	112 to 136	1987
Sahabat 24	2 034.51	5**	442.72	104 to 136	1987/88

Block*	Soil depth	Block**	Soil depth
1-4A	50+ cm	2-4A	100 cm+
2-9A	less than 50 cm	14-33A	50-100 cm
4-18A	50 - 100 cm	18-8B	less than 50 cm
5-21A	less than 50 cm	21-2C	50+ cm
7-28A	100 cm+	22-4C	less than 50 cm

TABLE 3. FRESH FRUIT BUNCH YIELD OF OIL PALM IN SAHABAT 23 AND 24 (t ha^{-1} yr^{-1})

Year	Year of harvesting	FFB yield (t ha^{-1} yr^{-1})		
		Sahabat 24	Sahabat 23	Mean
1991	2	3.79	7.88	5.84
1992	3	5.55	9.85	7.70
1993	4	8.14	10.46	9.30
1994	5	13.22	11.70	12.46
1995	6	19.08	22.70	20.89
1996	7	20.30	22.42	21.36
1997	8	18.37	23.39	20.88
1998	9	9.83	12.29	11.06
1999	10	15.43	17.18	16.31
2000	11	21.07	27.02	24.05

Note: first year data not available.



Note: **first year data not available.
Sources: *Jalani, B S (1993); +Goh *et al.* (1994).

Figure 7. Fresh fruit bunch yield comparison between coral and common soils in Malaysia.

The lower yields obtained between the ninth to 10th years of harvesting in 1998 and 1999 respectively, were probably due to the prolonged dry spell due to the *El Nino* phenomenon, which hit the country in the second half of 1997. Water deficit due to drought is considered as one of the factors that can significantly influence oil palm yield (Hartley, 1976). The yield can be decreased by up to 10%-40% below the normal production and, in the long-term, the effect may appear up to two years after the drought (Ochs and Liacopolus, 1983; Lubis *et al.*, 1993). In this case, the yield of oil palm in 1997, compared to 1998, dropped by 47.03% due to the drought (*Table 4*). It was relatively higher compared to the yield drop of palms grown on common inland soils in Sabah, which ranged between 14% to 32% during the same period.

The fluctuation in yield almost followed the annual rainfall distribution showing a marked response especially after the prolonged dry spell in 1997 (*Figure 8*). It took more than two years after the *El Nino* for the yield production to normalize.

Soil Textural Characteristics

Soil texture (particle size distribution) plays an important role in soil fertility such as its influence on the nutrient holding capacity and on the air and water availability to the plant. In the case of coral soils, the clay content in the topsoil (0-30 cm) is around 35% and this increases to over 40% at the 60 cm depth. The clay content ranges between 12.43% to 53.43%. The silt content slightly increases with depth and ranges between 3.80% to 20.70%. Meanwhile, the fine and coarse sand percentages decrease with depth with values ranging between 32.82% to 66.34% and 0.53% to 5.94% respectively. These soils can be classified as fine sandy clay. The details of the soil textural characteristics over depths are shown in *Table 5* and *Figure 9*.

Chemical Properties and Soil Nutrient Status

Table 6 shows the data of soil analyses carried out by FASSB from the oil palm weeded-circle area at depth 0-15 cm. The data show that most of the soil chemical parameters are very high compared to the absolute nutrients required by the palms (*Table 7*). The results of soil samples analysed by MPOB taken in 1999 and 2000 are shown in *Table 8.* The results show that soil available P, exchangeable K and Mg are higher in the weeded-circle compared to other locations. Soil pH ranges from medium to slightly acidic, and is much lower in the weeded-circle area compared to the other locations. The generally high soil pH is mainly due to the coral rock in the soil profile, which comprises limestone.

As shown in *Table 8,* most of the soil nutrients decrease with increase in soil depths, especially for mobile nutrients such as nitrogen, potassium and magnesium. The concentration of available P is much higher in the topsoil (0-15 cm) because P is relatively immobile. However, the concentration of exchangeable Ca does not change much at different depths. This could be due to the widespread presence of the coral rock scattered throughout the profile.

As summarized in *Table 6*, the very high levels of exchangeable Ca and Mg in the soil will definitely affect K uptake or even Mg uptake due to the dominance of Ca ion in the soil. Soil clay and organic matter hold the exchangeable Ca where it is usually the most dominant cation in the soil. Even at low pH, it normally occupies 70% or more of the sites on the soil cation exchange complex (International Soil Fertility Manual, 1995). Under this situation, the uptake of Ca is much higher compared to K and Mg, resulting in an imbalance of nutrients. As a comparison, *Table 9* shows the individual bases in the soil expressed as percentages of the total exchangeable bases at three different locations and depths. The percentage of soil Ca is over 70% of the total soil exchangeable cations. Compared with other soil groups from different regions, exchangeable Ca and Mg of coral soils are relatively much higher, especially exchangeable Ca (*Table 10*).

Leaf Nutrient Status of Palms on Coral Soil

One of the major problems of coral soils is its *nutrient imbalance*. Information on leaf nutrient status and soil data will provide important information on nutrient availability and the requirements for palms on these soils. Leaf analysis results indicate that the concentrations of leaf nutrients decrease with an increase in palm age (*Figure 10).*

The leaf analysis results from year 1990 to 2000 are summarized in *Table 11*. In this paper, only the leaf nutrient status of mature palms (more than six years old) are discussed. It is shown that the concentrations of nitrogen and phosphorus are adequate for palms and K is below the optimum range for oil palm. On the other hand, Ca is very high while Mg is very low

TABLE 4. EFFECT OF DROUGHT ON FRESH FRUIT BUNCHES YIELD AT DIFFERENT LOCATIONS IN SABAH

Agency	Location	FFB yield (t ha^{-1} yr^{-1})		
		1997	1998	Difference (%)
SKB	Sandakan	24.70	21.20	14.17
SKB	Lahad Datu	25.00	20.80	16.80
SKB	Tawau	24.90	18.50	25.70
SKB	Beaufort	18.60	14.50	22.00
SKB	Kudat	18.80	12.70	32.40
FELDA	Coral soils (Sahabat 23 and 24)	20.88	11.06	47.03

Note: after Zulkifli (2000).

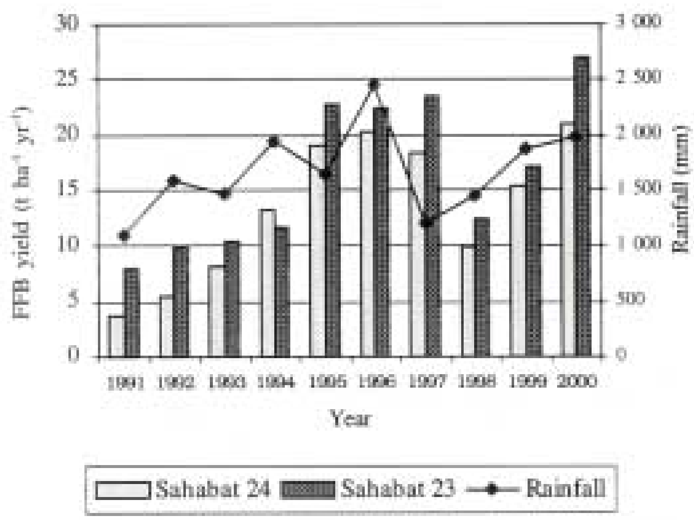


Figure 8. Fresh fruit bunches yield and means of annual rainfall at Sahabat 23 and 24.

TABLE 5. MECHANICAL ANALYSIS OF CORAL SOILS

Soil texture (%)	Soil depth (cm)					
	0 - 15		15 - 30		30-60	
	Mean	Range	Mean	Range	Mean	Range
Clay	29.98	23.94 - 37.34	35.51	12.43- 46.53	43.45	27.33- 53.43
Silt /	8.97	5.31 - 13.11	11.36	6.28- 20.70	8.44	3.80- 12.01
Fine sand	57.92	51.61 - 66.34	50.55	40.36- 64.74	45.49	32.82- 63.25
Coarse sand	3.13	0.53 -5,94	2.58	0.57- 4.39	2.62	0.54- 3.58

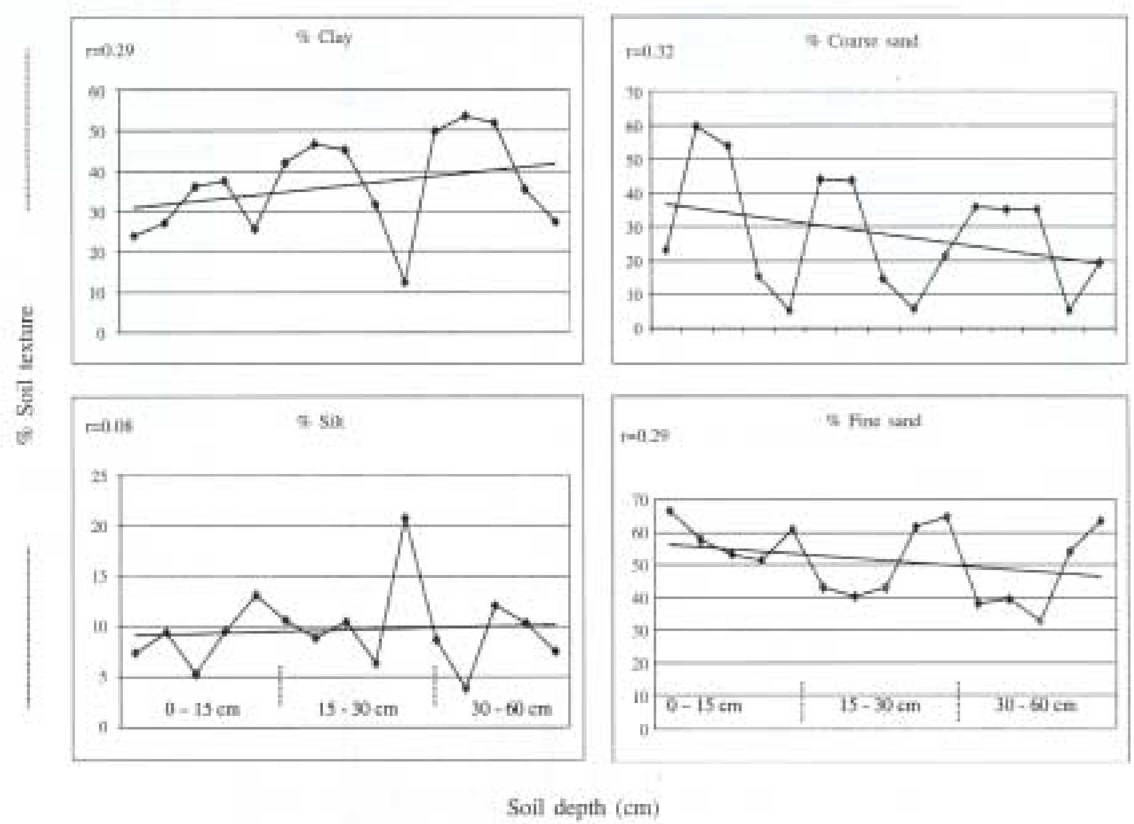


Figure 9. Soil textural changes with depth.

TABLE 6. SOIL CHEMICAL ANALYSIS (0-15 cm)

Year	Total N (%)	Soil nutrient concentration					
		Avail. P mg kg-1	Ex. K cmol kg-1	Ex.Ca cmol kg-1	Ex. Mg cmol kg-1	TEB cmol kg-1	pH
1990	0.14	88	0.75	16.20	0.86	17.80	6.49
1991	0.12	83	0.68	14.25	1.34	16.27	6.12
1992	0.12	86	2.13	22.06	1.81	26.00	6.78
1993	0.15	111	1.39	18.19	1.83	21.40	6.63
1994	0.16	269	2.16	21.87	1.93	25.96	6.73
1995	0.17	52	1.34	14.89	1.96	18.18	6.35
1999	0.13	81	0.42	8.15	3.54	12.11	5.53
2000	0.13	127	1.00	12.32	4.80	18.12	6.21
Mean	0.14	112	1.23	15.99	2.26	19.48	6.36
S.D	0.02	66	0.32	4.71	1.15	4.72	0.41

Note: S.D-standard deviation.

TABLE 7. SOIL FERTILITY CLASSIFICATION FOR OIL PALM

Property	V. low	Low	Mod.	High	V. high
pH	<3.5	4	4.2	5.5	>5.5
Org.C, %	<0.8	1.2	1.5	2.5	>2.5
Total N, %	<0.08	0.12	0.15	0.25	>0.25
Total. P, mg kg^{-1}	<120	200	250	400	>400
Avail. P, mg kg^{-1}	<8	15	20	25	>25
Ex. K, cmol kg^{-1}	<0.08	0.2	0.25	0.3	>0.30
Ex. Mg, cmol kg^{-1}	<0.08	0.2	0.25	0.3	>0.30
ECEC, cmol kg^{-1}	<6	12	15	18	>18
Deficiency	Likely	Possible	-	-	Induced
Hidden hunger	-	-	Likely	-	Possible
Fertilizer response	Definite	Likely	Possible	-	Possible

Source: Goh (1997).

TABLE 8. SOIL CHEMICAL ANALYSIS AT THREE DIFFERENT SOIL DEPTHS AND LOCATIONS (1999 to 2000)

Property	Depth (cm)	Weeded-circle	Avenue	Frond-pile	Mean from three locations	S.D
Total N, %	0 - 15	0.13	0.13	0.17	0.14	0.07
	15 - 30	0.10	0.09	0.09	0.09	0.05
	30 - 60	0.08	0.08	0.09	0.08	0.04
Avail. P, mg kg^{-1}	0 - 15	104	10	10	42	84
	15 - 30	24	6	4	11	18
	30 - 60	22	4	6	10	28
Ex. K, cmol kg^{-1}	0 - 15	0.71	0.26	0.29	0.42	0.37
	15 - 30	0.54	0.16	0.22	0.31	0.29
	30 - 60	0.34	0.17	0.22	0.24	0.22
Ex. Ca, cmol kg^{-1}	0 - 15	10.24	12.56	13.26	12.02	6.80
	15 - 30	10.93	13.02	11.83	11.93	7.60
	30 - 60	12.16	14.28	13.17	13.20	8.28
Ex. Mg, cmol kg^{-1}	0 - 15	3.92	2.58	2.56	3.02	1.93
	15 - 30	3.37	2.08	2.19	2.55	1.44
	30 - 60	2.77	2.06	1.87	2.23	1.20
Org.C, %	0 - 15	1.35	1.02	1.21	1.19	0.62
	15 - 30	0.89	0.77	0.93	0.86	0.48
	30 - 60	0.63	0.61	0.68	0.64	0.34
pH	0 - 15	5.87	6.15	6.25	6.09	0.86
	15 - 30	5.74	6.12	6.20	6.02	1.20
	30 - 60	5.67	5.86	6.11	5.88	1.09
TEB, cmol kg^{-1}	0 - 15	14.87	15.40	16.11	15.46	8.15
	15 - 30	14.84	15.26	14.24	14.78	8.57
	30 - 60	15.27	16.51	13.26	15.68	8.89
Al, cmol kg^{-1}	0 - 15	0.93	1.02	0.80	0.92	0.33
	15 - 30	1.17	0.89	0.81	0.96	0.43
	30 - 60	1.45	1.10	0.99	1.18	0.64
H, cmol kg^{-1}	0 - 15	0.48	0.41	0.46	0.45	0.17
	15 - 30	0.47	0.47	0.44	0.46	0.14
	30 - 60	0.52	0.53	0.41	0.49	0.21
TEC, cmol kg^{-1}	0 - 15	16.28	16.83	17.37	16.83	9.31
	15 - 30	16.48	16.62	15.49	16.20	10.48
	30 - 60	17.24	18.14	16.66	17.35	11.02

Note: S.D - standard deviation.

TABLE 9. PERCENTAGE OF INDIVIDUAL CATIONS TO TOTAL BASES FROM THREE LOCATIONS AND DEPTHS

Soil depth (cm)	Ca (%)	Mg (%)	**K (%)**
0 - 15	77.75	19.53	2.72
15 - 30	80.72	17.25	2.09
30 - 60	84.18	14.22	1.53

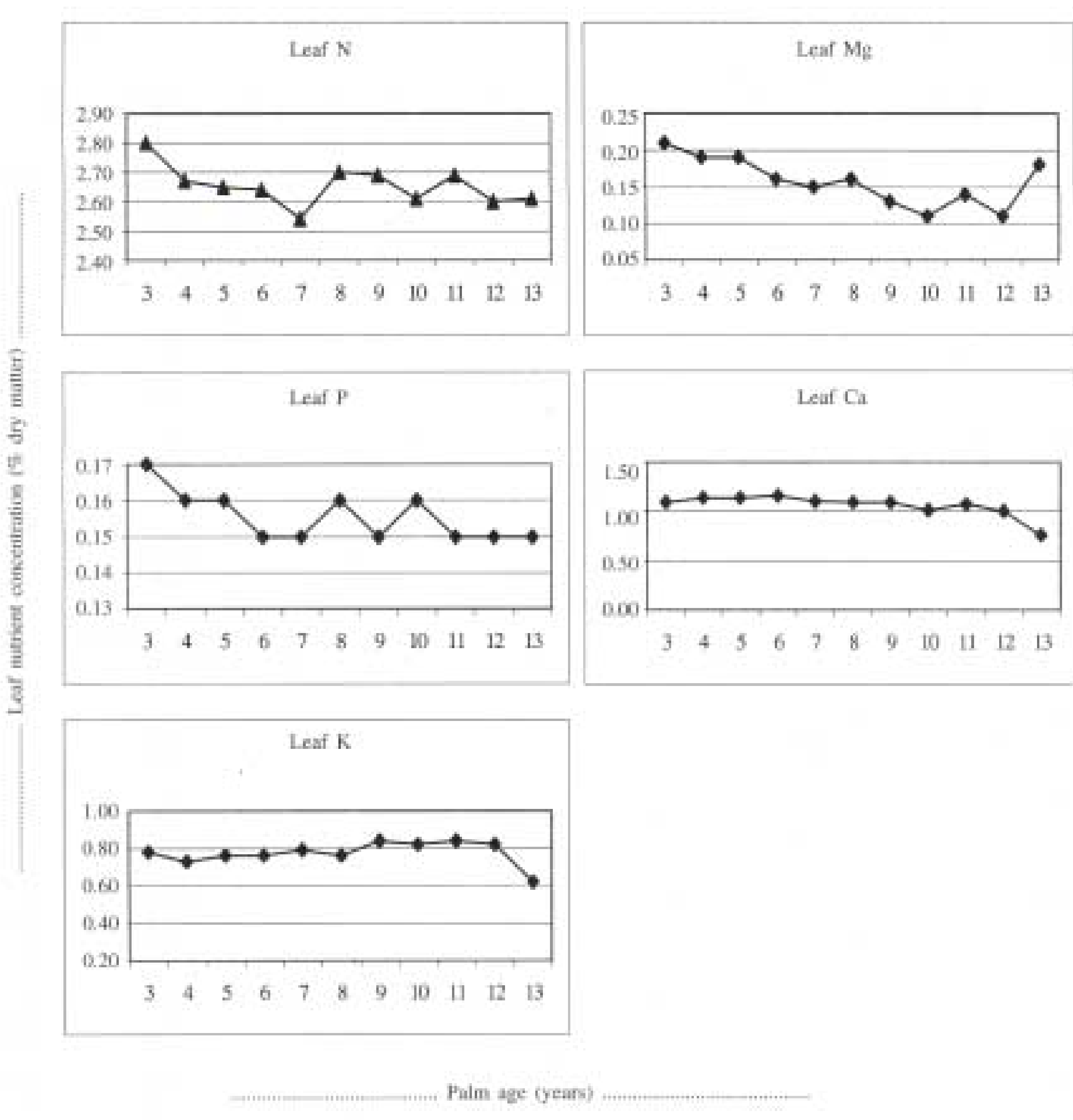


Figure 10. Variation of leaf nutrient concentration with palm age on coral soils.

TABLE 10. SOIL EXCHANGEABLE CATIONS FROM DIFFERENT SOIL REGIONS

Soil region	Exchangeable bases (cmol kg^{-1})		
	Ca	Mg	K
Inland soil (Malaysia)	0.88	0.43	0.33
Coastal (Malaysia)	2.04	2.73	1.83
Volcanic (Sumatra)	0.98	0.72	0.42
Volcanic (PNG)	8.10	1.55	0.24
Coral (Sabah, Malaysia)	Mean (range)	Mean (range)	Mean (range)
Soil depth: 0 – 15 cm	12.02 (0.38 – 27.42)	3.02 (0.13 – 10.72)	0.42 (0.02 – 1.69)
15 – 30 cm	11.93 (0.38 – 32.24)	2.55 (0.11 – 6.17)	0.31 (0.03 – 1.39)
30 – 60 cm	13.20 (0.50 – 44.03)	2.23 (0.12 – 4.87)	0.24 (0.03 – 1.05)

Note: after Foster (2000).

compared to the optimal values for nutrients in frond 17 as shown in *Table 12* (Fairhust and Mutert, 1999). This further explains the domineering effect of exchangeable Ca in the soil on the uptake of K and Mg by the palms.

Evaluation of leaf N and P by the *critical curve* method developed by Ollagnier and Ochs (1981) showed that critical leaf P concentrations in the optimum range for oil palm between 0.162% to 0.175% throughout 1990 to 2000. It shows that the constant ratios between N and P in the palm tissue are acceptable. Meanwhile, Foster (2000) reported a close correlation between the optimum values of leaf N, K, Mg and the amount of total leaf bases (TLB) in cmol kg^{-1}, where:

TLB = (percent leaf K/39.1 + percent leaf Mg/12.14 + percent leaf Ca/20.04) x 1000

Leaf K and Mg deficiency can be individually assessed based on their percentages to TLB as follows:

X/TLB x 100	Deficiency rating
< 25	Deficient
25 – 30	Low
> 30	Sufficient

where X = partial TLB of K, Mg and Ca.

Total leaf bases decrease with an increase in palm age (*Figure 11*). This concurs with that reported by Foster (2000) who pointed out that most of the variation in optimum leaf levels with differences in both the environment and palm age is, in fact, due to the effect of these factors on TLB.

Table 13 shows the percentage values of K and Mg to TLB. It can be seen that the leaf K/TLB values are in the range of low to deficient throughout the years. Leaf Mg/TLB are in the deficient range for most of the years. As shown earlier in *Tables 6* and *8*, soil exchangeable Mg is very high in these coral soils. However, the uptake of Mg is very low compared to that available in the soil resulting in Mg deficiency. The symptom is manifested in the field by chlorosis on the section of pinnae shaded from direct sunlight and is commonly seen especially during the dry season. Excessive amounts of exchangeable Ca on these soils have suppressed the uptake of Mg and K by the palms.

Magnesium deficiency normally occurs when the amount of soil exchangeable Mg is less than 0.3 cmol kg^{-1} or when there is an imbalance between Mg and other cations such as K and NH_4^+. Imbalance of nutrients is likely to occur if the Ca/Mg ratio exceeds 5 or the Mg/K ratio exceeds 1.2 (Ian and Fairhust, 1999). In the case of coral soils, the soil exchangeable Mg is very high but significantly low in uptake by the palms. To check on this imbalance, the ratios of soil exchangeable cations are calculated.

Table 14 shows the soil exchangeable bases over the years and their nutrient ratios. While most of the Mg/K ratios are below 1.2 indicating no imbalance between these two cations, the Ca/Mg ratios show contrasting results. All the values exceeded five showing strong imbalance between the two cations with Ca having a domineering effect on Mg. It is for this reason that in spite of the high soil exchangeable Mg, the uptake of this element by the oil palm is low.

TABLE 11. LEAF NUTRIENT CONCENTRATIONS

Year	Palm age	Nutrient level (% dry matter)										TLB (cmol kg^{-1})
		N		P		K		Ca		Mg		
		Mean (range)	S.D	Mean (range)	S.D	Mean (range)	S.D	Mean (range)	S.D	Mean (range)	S.D.	Mean (range)
1990	3	2.80 (2.61 – 3.03)	0.14	0.17 (0.16 - 0.19)	0.01	0.78 (0.73 - 0.85)	0.04	1.09 (0.97 - 1.25)	0.12	0.21 (0.17 - 0.25)	0.03	91.32 (80.42 - 104.17)
1991	4	2.67 (2.62 – 2.72)	0.04	0.16 (0.15 - 0.17)	0.01	0.73 (0.62 - 0.83)	0.06	1.14 (0.98 - 1.26)	0.11	0.19 (0.12 - 0.22)	0.04	90.99 (74.64 - 102.10)
1992	5	2.65 (2.46 – 2.74)	0.09	0.16 (0.15 - 0.16)	0.01	0.76 (0.62 - 0.86)	0.07	1.14 (0.99 - 1.28)	0.11	0.19 (0.14 - 0.23)	0.03	91.91 (76.79 - 104.81)
1993	6	2.64 (2.47 – 2.88)	0.12	0.15 (0.15 - 0.16)	0.01	0.76 (0.69 - 0.87)	0.06	1.16 (0.89 - 1.45)	0.16	0.16 (0.11 - 0.22)	0.04	90.55 (71.12 - 112.73)
1994	7	2.54 (2.43 – 2.73)	0.08	0.15 (0.15 - 0.16)	0.01	0.79 (0.70 - 0.88)	0.06	1.10 (0.90 - 1.26)	0.13	0.15 (0.10 - 0.19)	0.03	86.94 (71.05 - 101.03)
1995	8	2.70 (2.62 – 2.82)	0.07	0.16 (0.16 - 0.17)	0.01	0.76 (0.67 - 0.82)	0.04	1.09 (0.90 - 1.28)	0.1	0.16 (0.11 - 0.19)	0.02	87.07 (71.11 - 100.49)
1996	9	2.69 (2.57 – 2.75)	0.05	0.15 (0.15 - 0.16)	0.01	0.84 (0.73 - 0.93)	0.06	1.09 (1.00 - 1.18)	0.06	0.13 (0.11 - 0.16)	0.02	86.56 (77.63 - 95.85)
1997	10	2.61 (2.47 – 2.70)	0.09	0.16 (0.14 - 0.25)	0.03	0.82 (0.76 - 0.93)	0.05	1.01 (0.73 - 1.16)	0.12	0.11 (0.09 - 0.17)	0.02	80.68 (63.15 - 95.54)
1998	11	2.69 (2.57 – 2.75)	0.05	0.15 (0.15 - 0.16)	0.01	0.84 (0.73 - 0.93)	0.06	1.07 (0.96 - 1.18)	0.07	0.14 (0.11 - 0.16)	0.02	85.91 (75.26 - 95.60)
1999	12	2.60 (2.47 – 2.70)	0.08	0.15 (0.14 - 0.16)	0.01	0.82 (0.76 - 0.93)	0.05	1.00 (0.73 - 1.16)	0.12	0.11 (0.09 - 0.17)	0.02	80.38 (63.15 - 95.54)
2000	13	2.61 (2.51 – 2.73)	0.07	0.15 (0.15 - 0.16)	0.01	0.62 (0.53 - 0.71)	0.06	0.76 (0.52 - 0.99)	0.13	0.18 (0.13 - 0.22)	0.03	68.13 (49.80 - 85.55)

Note: S.D - standard deviation.

TABLE 12. NUTRIENT CONCENTRATIONS IN FROND 17 (% dry matter)

Nutrient	Deficiency	...... Optimum	Excess
N	<2.30	2.40 - 2.80	>3.00
P	<0.14	0.15 - 0.18	>0.25
K	<0.75	0.90 - 1.20	>1.60
Mg	<0.20	0.25 - 0.40	>0.70
Ca	<0.25	0.50 - 0.75	>1.00

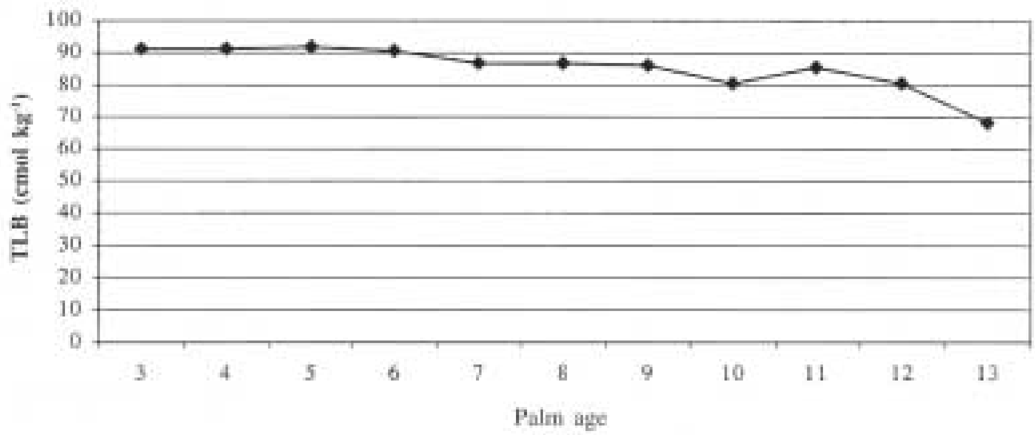


Figure 11. Total leaf bases variation with palm age.

TABLE 13. PERCENTAGE OF LEAF POTASSIUM AND MAGNESIUM TO TOTAL LEAF BASES

Year	Palm age	TLB (cmol kg^{-1})	(X/TLB) x 100 K	(X/TLB) x 100 Mg
1990	3	91.32	21.87	18.57
1991	4	90.99	20.50	17.14
1992	5	91.91	21.01	17.03
1993	6	90.55	21.43	14.78
1994	7	86.94	23.24	13.84
1995	8	87.07	22.41	14.95
1996	9	86.56	24.79	12.56
1997	10	80.68	25.99	11.69
1998	11	85.91	24.87	12.94
1999	12	80.38	26.09	11.73
2000	13	68.13	23.11	21.16

where X = partial TLB of K, Mg and Ca.

TABLE 14. SOIL EXCHANGEABLE BASES AND NUTRIENT RATIOS

Year	Soil exchangeable cation ($cmol\ kg^{-1}$)			Ratio	
	K	Ca	Mg	Ca/Mg	Mg/K
1990	0.75	16.20	0.86	18.84	1.15
1991	0.68	14.25	1.34	10.63	1.97
1992	2.13	22.06	1.81	12.19	0.85
1993	1.39	18.19	1.83	9.94	1.32
1994	2.16	21.87	1.93	11.33	0.89
1995	1.34	14.89	1.96	7.60	1.46

Foster in 2000 reported higher TLB values on inland soils of Peninsular Malaysia and volcanic soils in Papua New Guinea and compared them to the coastal soils of Peninsular Malaysia and volcanic soils of North Sumatra. There were large differences in the concentration of exchangeable Ca in the soil and in the ratios of soil exchangeable Ca to the soil exchangeable bases. *Figure 12* clearly indicates that the variation in leaf Ca in coral soils is similar to the TLB pattern but not compared to the rest of leaf nutrient bases. This provides further evidence on the effect of high Ca in the soil which is directly influenced by the TLB.

The high Ca in the coral soils is the main factor contributing to imbalance of other nutrients in the soil and plant tissues. All the nutrient ratios involving Ca have been greatly affected, such as the ratios of N/Ca, K/Ca and Mg/Ca. *Tables 15* and *16* show the leaf nutrient ratios obtained on coral soils compared to the general ratios recommended for oil palm. The leaf N/Ca, K/Ca and Mg/Ca ratios of palms planted on coral soils are generally lower than the recommended leaf nutrient ratios indicating the exceptionally high supply of Ca in these soils. Non-ideal leaf nutrient ratios will be the main factor contributing to the imbalance of nutrients, which subsequently will affect the general palm physiology and metabolism.

CONCLUSION

Excessive levels of Ca in the palm tissues are rarely detrimental to palm growth. However, the results from this study show that Ca is the main factor contributing to the imbalance in soil nutrients which in turn affects the nutrient availability and uptake by the palms. It antagonises K and at the same time behaves as a dominant cation in the coral soils suppressing other cations including Mg.

For the nutrients in the soils to be made more available to the palms, especially during the dry season, it is recommended that soil moisture conservation measures be carried out. These include planting leguminous cover crops, mulching using empty fruit bunches both during planting and in the mature years, maintaining soft grasses and a better spread of pruned fronds in the field. It is pointless to use higher rates of muriate of potash and kieserite fertilizers to overcome the K and Mg deficiencies respectively when excessive Ca is not attended to.

With proper agro-management inputs, performance of oil palm on coral soils is as good as on some of the mineral soils in the country. This is evident from the FFB yield of 24.05 t ha^{-1} obtained last year.

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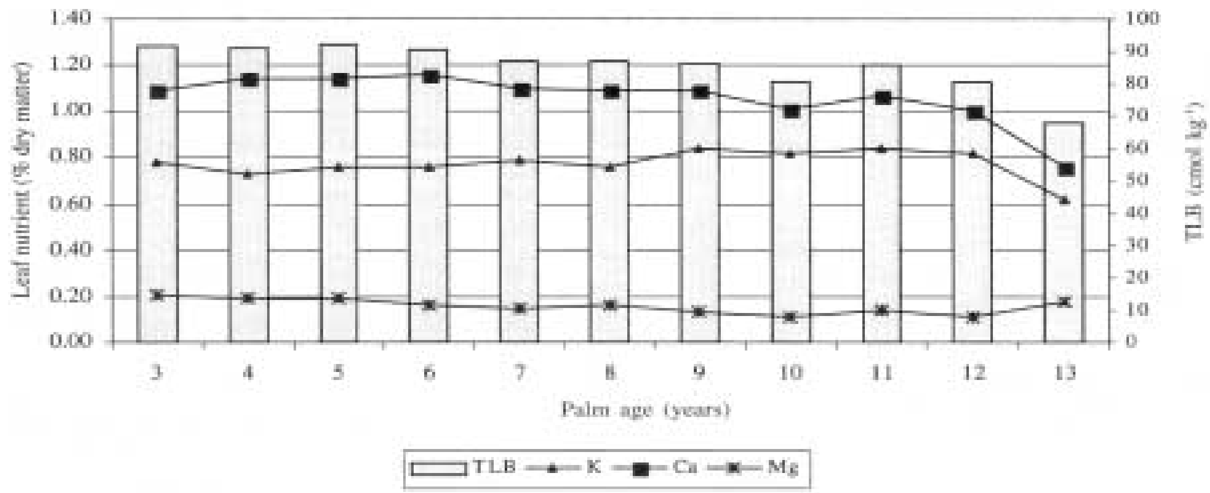

Figure 12. Variation of nutrient bases to total leaf bases.

TABLE 15. RECOMMENDED LEAF NUTRIENT RATIOS

Nutrient ratio	Range of values
N/K	2.5 – 3.0
N/Mg	14 – 18
N/P	11 – 17
N/Ca	4 – 9
K/Mg	4 – 10
K/Ca	2 – 5
Mg/Ca	0.25 – 0.55

Source: Zulkifli (2000).

TABLE 16. LEAF NUTRIENT RATIOS ON CORAL SOILS

Year	Leaf nutrient ratio						
	N/K	**N/Mg**	**NIP**	**N/Ca**	**K/Mg**	**K/Ca**	**Mg/Ca**
1990	3.59	13.33	16.4 7	2.57	3.71	0.72	0.19
1991	3.66	14.05	16.69	2.34	3.84	0.64	0.17
1992	3.49	13.95	16.56	2.32	4.00	0.67	0.17
1993	3.47	16.50	17.60	2.28	4.75	0.66	0.14
1994	3.22	16.93	16.93	2.31	5.27	0.72	0.14
1995	3.55	16.88	16.88	2.48	4.75	0.70	0.15
1996	3.20	20.69	17.93	2.47	6.46	0.77	0.12
1997	3.18	23.73	16.31	2.58	7.45	0.81	0.11
1998	3.20	19.21	17.93	2.51	6.00	0.79	0.13
1999	3.17	23.64	17.33	2.60	7.45	0.82	0.11
2000	4.21	14.50	17.40	3.43	3.44	0.82	0.24

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