Ng Siew Kee

The Oil Palm, its Culture, Manuring and Utilisation

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Contents

1. The Economic Importance of the Oil Palm

The oil palm, *Elaeis guineensis* JACQ., is only second in terms of production to coconut as a tropical perennial which produces vegetable oil. Its products, palm oil, palm kernel and palm kernel oil are important sources of foreign exchange earnings of many developing countries, the chief of which are Malaysia and Indonesia in South East Asia and Nigeria and Congo (Kinshasa) in Africa. In Malaysia, the oil palm is also a major element in agricultural diversification which aims to lessen the country's dependence on natural rubber. Although world production of palm oil constitutes less than 5% of the total production of all edible oils and fats, production of palm oil has been increasing, particularly in the past few years (Table 3), mainly due to rising production from Malaysia and the Congo. Other countries in Africa such as the Ivory Coast and Cameroons are expanding palm oil production to increase their export earnings, whereas countries in Latin America are establishing oil palm plantations to meet domestic oil requirements. Thus, it can be seen that the oil palm has become a significant sector of the economy of many developing countries and further expansion of production capacity can be envisaged.

1.1 Yield of oil

The oil palm is recognised as the most prolific producer of vegetable oil and this can be easily substantiated. Despite improvements in plant breeding and cultural practices of other oil crops, the relatively superior position of oil palm has not altered because research and development in the oil palm industry has not lagged behind. Thus, the previous comparison made by *Tempany [5]* and shown in Table 1 still holds. It can be seen that the oil palm produces the largest quantity of oil bearing products and secondly, the mesocarp of the fruit has one of the highest oil contents compared to the other crops.

From the above, it is evident that the oil palm produces the largest amount of oil and this is also the conclusion made by *Jacoby [4]* as given in Table 2.

It may be felt that the preceding estimates for short-term oil crops are rather on the low side and consequently the oil palm has been placed in an unduly favourable light. In view of overall advancements in crop science and practices since the above estimates were made, a new assessment of the current situation is made here and this is presented in Table 2. It needs to be stressed that the estimates of yields are based on the assumption that conditions of growth are favourable.

On marine clay soils of West Malaysia, yields of up to 6000 kg/ha/yr of palm oil have been obtained. Thus, to this day and in the foreseeable future, the oil palm still remains the foremost vegetable oil producer. If palm kernel oil were also taken into account, the position of oil palm would be further enhanced. However, in terms of world production, palm oil still lags behind the other major vegetable oils as shown in Table 3.

Table 1. Estimated yields of oil crops by *Tempany*

Crop	Oil bearing part	Production kg ha	Oil content %	Potential oil kg/ha	
Groundnut	kernel	770	48	380	
Soyabean	seed	770	17	130	
Sunflower	seed	880	50	440	
Rapeseed	seed	990	42	405	
Coconut	kernel	1460	68	994	
Oil palm	fruit	5500	25	1375	1537
	kernel	330	49	162	

Table 2. Oil content in oil bearing tissues (3) and estimated productivity of various crops

Crop	% Oil	kg/ha oil Jacoby	kg/ha oil Present estimate
Groundnut	40–45	340– 440	600–1000
Soyabean	16–19	230– 400	400– 600
Sunflower	32–45	280– 700	600–1000
Rapeseed	30–45	300– 600	800–1100
Coconut	60–65	600–1500	1100–1600
Oil palm	40–65	2500–4000	3000–5000

Table 3. Oils and fats. Estimated world production 1962–69 (1000 t*)

Oil	1962	1963	1964	1965	1966	1967	1968	1969
Groundnut	2 282	2 345	2 405	2 517	2 460	2 164	2 186	2 464
Soyabean	2 609	2 723	2 841	3 014	2 914	3 013	3 177	2 735
Sunflower	2 282	2 445	2 232	2 955	2 823	3 268	3 613	3 582
Cottonseed	2 282	2 345	2 405	2 517	2 460	2 164	2 186	2 464
Rapeseed	1 173	1 082	1 127	1 514	1 400	1 582	1 677	1 627
Coconut	2 114	2 200	2 214	2 145	2 355	2 023	2 117	2 113
Palm	1 186	1 186	1 200	1 223	1 227	1 150	1 309	1 477
Palm kernel	405	413	413	423	417	327	359	391
Total Edible vegetable oils	14 323	14 386	15 213	16 218	16 455	17 157	18 106	17 931
Total Animal Fats	11 095	11 332	11 741	12 100	12 073	12 582	12 814	12 723
Marine Oils	1 235	1 020	1 137	1 136	1 157	1 334	1 345	1 309
Grand Total	31 728	32 039	33 553	34 844	35 373	36 073	37 427	37 485

* t = metric ton.

1.2 World production

1.2.1 Palm oil

In the two years of 1968–69, there has been a significant expansion in production although the 1969 output constitutes only about 5% of total world production of oils and fats and about 10% of edible vegetable oils production. In the period 1960–69, total oils and fats production increased by an average of 2.9% per year. In the case of palm oil, the situation was more erratic. For 1964–66, the increase averaged 2.3% and in 1967, there was a sharp decline of 9.3% but in 1968 and 1969, production increased sharply by nearly 13% per year. It is further projected that for the 1970–75 period, palm oil output will have an annual growth rate of about 11.7% *[2]*.
As far as producing countries are concerned, Africa still predominates over the Far East although there has been a couple of internal changes. In palm oil production (Table 4), Malaysia has overtaken Congo (Kinshasa) and Indonesia since 1965–66 and is fast catching up on Nigeria. It should be noted that Nigerian production is only a very vague estimate as internal consumption and movements of oil are not known. However, in palm kernel production, Malaysia still lies far behind Nigeria and Congo (Kinshasa) as shown in Table 5.

Table 4. Palm oil production by countries (1000 t)

Country	1964	1965	1966	1967	1968	1969
Angola	18	15	15	15	15	
Cameroon	30	34	40	35	40	
Congo (Kinshasa)	165	125	147	179	210	
Dahomey	45	44	39	34	44	
Ghana	26	37	37	38	38	
Ivory Coast	28	28	30	32	35	
Liberia	12	15	16	17	12	
Nigeria	515	530	508	325	350	
Sierra Leone	39	39	40	41	42	
Indonesia	161	165	175	174	180	
Malaysia	123	150	190	225	280	326
Others	34	38	40	44	59	

Table 5. Palm kernel production by countries (1000 t)

Country	1964	1965	1966	1967	1968
Cameroon	35	38	37	38	49
Congo (Kinshasa)	110	75	80	95	105
Dahomey	56	55	49	43	56
Guinea	14	12	10	13	12
Ivory Coast	15	16	17	18	21
Liberia	7	12	12	14	14
Nigeria	408	462	435	250	225
Sierra Leone	53	50	56	–	66
Indonesia	33	34	33	39	42
Malaysia	31	36	44	51	63
Mexico	25	26	26	27	27
Others	83	87	85	89	83

Nevertheless, the rapidly rising trend of production of both oil and kernel in Malaysia is noteworthy. Malaysian production of palm oil has more than doubled from 1964 to 1968 and production for 1969 stands at 326 000 t.
In terms of export of palm oil, however, Malaysia has overtaken Nigeria as the biggest exporter in the world (Table 6) since Nigeria is known to consume a large part of her production. In so far as kernels are concerned, Nigeria still retains her prime position.

Table 6. Palm oil exports from principal countries (1000 t)

Country	1964	1965	1966	1967	1968
Angola	17.8	14.6	14.5	15.5	14.0
Cameroon	8.9	13.0	15.0	17.2	15.5
Congo (Kinshasa)	124	78.6	78.1	115	159
Nigeria	136	152	146	16.7	4.3
Indonesia	133	126	177	131	160
Malaysia	125	141	184	189	285

1.2.2 Palm kernel exports

The yearly exports of palm kernels from principal countries are shown in Table 7. Nigeria still leads the other countries by a long way with Sierra Leone being the second largest exporter. The sharp declines in total exports in 1967 and 1968 are due to the civil war in Nigeria but exports from the Far East increased. Kernel exports are much higher in West Africa than in the Far East because (a) the total production is exported and (b) kernels are extracted from nuts picked off the ground having fallen from bunches from which no palm oil is extracted. This situation is likely to continue for a very long time.

Table 7. Palm kernel exports from principal countries (1000 t)

Country	1964	1965	1966	1967	1968
Angola	17	14	14	17	12
Cameroon	24	24	17	20	26
Dahomey	56	17	6	4	8
Guinea	14	12	10	13	12
Ivory Coast	12	13	15	9	10
Liberia	7	12	12	14	14
Nigeria	400	422	400	165	162
Sierra Leone	53	50	56	12	65
Togo	14	15	17	13	13
Indonesia	33	33	32	38	40
Malaysia	18	19	24	25	36
World total	682	662	622	364	423

1.2.3 Palm kernel oil

Fewer countries export this commodity, the principal countries being Congo (Kinshasa) and Nigeria as shown in Table 8. Exports increased sharply in 1966 and 1967, mainly due to Nigeria which is somewhat contradictory to the palm kernel situation. However, Nigerian export fell in 1968 while Congo (Kinshasa) made up with an appreciable increase.

Table 8. Palm kernel oil exports from principal countries (1000 t)

Country	1964	1965	1966	1967	1968
Paraguay	32.3	3.2	4.2	4.1	6.0
Cameroon	1.3	1.1	0.9	1.0	5.0
Congo (Kinshasa)	44.3	31.3	32.3	41.7	54.8
Dahomey	0	16.7	11.7	16.4	21.0
Nigeria	0.9	1.0	32.6	37.8	27.3
World total	51.0	54.6	83.4	107.0	115.8

1.3 Importing countries

1.3.1 Palm oil

Europe is the largest purchaser of this product, the E.E.C. Group forming the biggest buying block (Table 9). North America takes a low second position. As far as individual countries are concerned, the biggest importers are West Germany, United Kingdom and Netherlands. However, the figures show no appreciable increase of imports over the period 1963–68.

Table 9. Palm oil imports into major countries (1000 t)

	1963	1964	1965	1966	1967	1968
Europe						
Germany, West	93	111	103	115	99	126
Netherlands	68	74	64	69	65	71
France	36	40	36	41	42	35
Italy	28	28	32	33	36	37
Belgium/Luxembourg	37	42	28	27	28	28
Total E. E. C.	262	295	263	285	270	297
United Kingdom	114	116	117	150	99	109
Portugal	14	16	14	16	16	14
Ireland	3	5	3	5	2	2
Asia						
Japan	17	18	16	20	22	28
India	37	36	7	11	8	1
Philippines	5	6	6	6	7	6
North America						
U.S.A.	11	3	3	34	29	47
Canada	12	6	9	12	10	8
Total	486	509	446	550	468	525

1.3.2 Palm kernels

As in the case of palm oil, Europe is the largest buyer with Netherlands, West Germany and the United Kingdom again in the forefront (Table 10).

Table 10. Palm kernel imports into major countries (1000 t)

Country	1963	1964	1965	1966	1967	1968
Netherlands	128	134	113	131	66	113
Germany, West	129	131	126	124	69	90
France	79	90	66	50	46	41
Belgium/Luxembourg	21	25	30	26	8	20
United Kingdom	211	194	207	168	98	52
Denmark	16	20	14	19	9	18
Poland	14	11	26	3	10	6
Portugal	16	21	17	11	6	10
Japan	26	25	22	23	19	23
Total	650	663	635	570	346	385

1.4 Prices

As far as the price of palm oil is concerned, it has not seen wide fluctuations from 1960–67 but in 1968 and most of 1969 there was a sharp decline. However, since the end of 1969, the price made a striking upturn and it appears that for 1970 at least, the recovery will be sustained. Comparative prices for the major vegetable oils (Table 11) show that soyabean oil prices and to some extent sunflower seed oil are closely related with those of palm oil, indicating the competitive positions of these three oils.

Table 11. Major oil prices U.S. ct/kg c.i.f. European ports

Year	Palm oil	Soyabean	Sunflower	Groundnut
1960	22.4	21.8	24.0	32.6
1961	22.9	27.7	31.2	32.8
1962	21.8	22.2	23.3	27.5
1963	23.1	21.6	23.5	26.8
1964	24.0	22.9	25.5	31.5
1965	27.3	27.1	29.0	32.6
1966	23.5	26.0	25.7	29.5
1967	22.4	21.6	21.1	28.1
1968	16.9	17.8	16.9	26.6
1969 (January–October)	16.7	18.7	19.6	32.8

Apart from the above vegetable oils, cottonseed and rapeseed oils, animal fats and fish oil can also compete with palm oil as shown by the following prices of these commodities in the sixties (Table 12).

Table 12. Prices of other vegetable and animal oils

	1960–68 U.S. ct/kg	1968 prices % of 1960–68 average	1969 prices % of 1960–68 average
Rapeseed	23.1	70	76
Cottonseed	25.7	111	93
Tallow	15.6	82	103
Lard	23.5	72	87
Fish oil	16.7	59	78
Palm oil	22.7	77	81

The preceding picture shows that on the long term basis, prices for most fats and oils have been trending downwards since the mid-1950's and this decline may continue. The decline reflects the increasing per capita supplies and the inelastic demand in the major cash markets.

1.4.1 Palm kernel prices

Unlike the case of palm oil, prices of palm kernel have trended slightly upwards from 1960–67 although the price also declined with that of palm oil in 1968–69 (Table 13).

Table 13. Palm kernel prices. European ports *[1]*.

Year	U.S. ct/kg
1960	14.4
1961	13.7
1962	13.6
1963	15.3
1964	15.1
1965	17.9
1966	15.5
1967	16.1

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2. Distribution of the Oil Palm

The oil palm is found in wild, semi-wild and cultivated states in the equatorial regions between 10° N and 10° S of three continents. However, fossil and historical evidence suggests that Africa, probably West Africa, is the original home of the oil palm *[3]*. It was introduced to South America with the advent of the slave trade in the early seventeenth century and abundant groves are found in Brazil. There is no record of direct introductions of the oil palm to the Far East from Africa. The earliest record shows that four palms, two from Amsterdam and two from Réunion or Mauritius were planted in Bogor, Java in 1848. It is believed that progenies of these palms were transferred to Deli in Sumatra and it was from seeds of the Deli palms that the first commercial plantation was started by *Hallet* in 1911. About this time, Deli palms were also established in Selangor, Malaya and seeds of these palms were used to commence the first estate known as Tennamaram in Selangor *[1]*.

A major difference between Africa and South East Asia is that in Africa, the oil palm occurs mainly in semi-wild groves *[4, 5]*. Prior to World War II only the Congo had plantations in Africa but after the War, plantations were also developed in West Africa. The oil palm groves are dominant in West Africa and have been propagated by hunters or new settlers in jungle clearings. Thus the palm became a common relic of abandoned villages, compounds and cultivated patches. With increasing population and settlement, expansion of palm groves occurred and they still constitute the major production unit in West Africa, the most important being in Nigeria, which until 1966 was the world's major exporter of palm oil. Other important centres are Sierra Leone and Cameroon. The extent of these groves is thought to be in the region of a few million hectares although no accurate measurement has been undertaken. Palms are mainly Dura but there is evidence of Tenera being planted in relatively recent times. Productivity of these groves is low with no modern upkeep practices such as manuring, weeding, pest and disease control. The density varies from very dense (up to 200 adult palms per ha) to very sparse; the oil extraction methods practised often provide oil of low quality though the bulk of Nigeria's grove-oil exports is marketed at below 3–5% f.f.a. Density, however, increases with land settlement as shown below:

Secondary rain forest/oil palm	30/ac 75/ha
Palm bush	30–60/ac 75–150/ha
Farmland palms	60–80/ac 150–200/ha

Obviously, yield increases with density. A survey near Abak in Nigeria *[2]* showed that yield increases from 1412 to 6094 kg/ha from a stand of 25–50 to 175 and above. Generally, yield is about 2750 kg bunches per ha per annum. Replanting with selected planting materials is a major instrument in raising yields.

As far as can be ascertained, the distribution of natural and planted oil palms is probably as follows.

West and Central Africa

Major countries	– Congo (Kinshasa), Congo (Brazzaville), Nigeria, Republic of Cameroon, Dahomey, Ivory Coast, Ghana, Sierra Leone, Guinea, Liberia, Togo, and Angola.
Minor countries	– Tanzania, Uganda, Zambia, Kenya, Madagascar.

South East Asia

Major countries	– Malaysia, Indonesia and Papua-New Guinea.
Minor countries	– Thailand and Ceylon.

South America (tentative classification)

Major countries	– Brazil, Colombia, Ecuador, Costa Rica, Honduras.
Minor countries	– Venezuela, Peru, Panama, Guatemala, Mexico and Nicaragua.

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3. Botanical Description of the Oil Palm

Morphologically, the oil palm comprises an extensive fibrous root system extending from the prominent bole of the base, an erect stem of 0.3–0.6 m in diameter which can exceed 16 m in height if more than 30 years old, and a crown nesting on top with 25–40 pinnate leaves.

3.1 The root system

The anatomy and composition of the root system of the oil palm has been studied by *Purvis [8]* and *Ruer [10]*. There are four types of roots distinguished viz. primary, secondary, tertiary and quaternary, the last two being commonly called feeder roots. Primary roots are mostly horizontal although some grow downwards for anchorage; they are 8–10 mm in diameter. Secondaries arise from the primaries and mostly grow

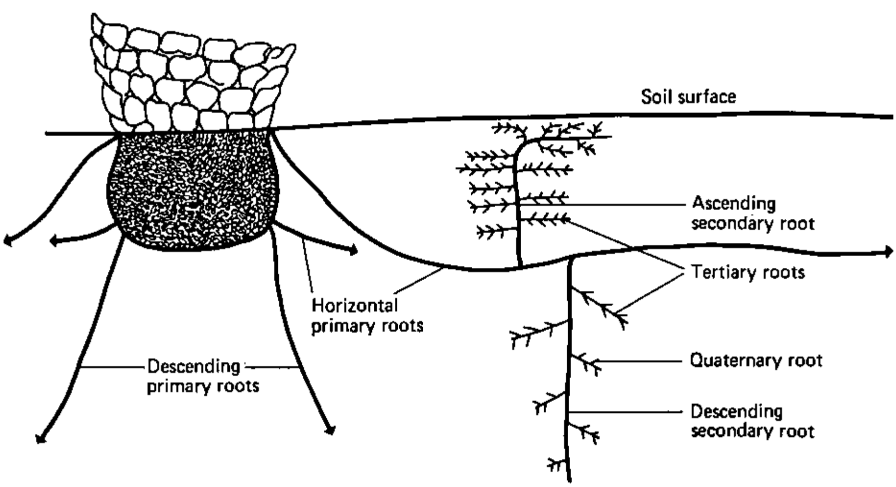


Figure 1. The root system of the oil palm
Source: *Purvis C.:* J.W.Afr.Inst. Oil Palm *1*, No.4 (1956)

upwards towards the soil surface and turn to grow horizontally. They are about 2–4 mm in diameter. Tertiary roots arise at right angles to secondaries and are about 1.5 mm in diameter. Finally quaternaries arise at right angles from tertiaries, being 0.5 mm in diameter (Figure 1).

Oil palm roots are known to traverse a long distance and *Lambourne* [6] traced the primary roots of mature palms to as far as 21 m from the palm base. However, as far as total roots are concerned, all the studies [3, 8, 9, 10] made show that the greatest quantity is found within 1.2 m of the palm base horizontally and within 0–30 cm of the soil surface vertically. As for the important feeder roots, its quantitative distribution depends on the age of the palm. In palms up to 2 ½ years in the field, most of the feeder roots are found within 2.4 m of the palm base, and in palms of 4 ½–8 ½ years, they are about evenly divided between 0–2.4 m and 2.4–4.8 m of the base. In mature palms of 10 ½–17 ½ years, the majority are located in the 2.4–4.8 m region (Tables 14 and 15).

Table 14. Distribution of tertiary roots in palms on a marine clay in West Malaysia. Number of palms with largest concentration of tertiary roots in each zone [3]

Age (yrs)	Number of palms	Distance from palm base (m)			
		0–1.2	1.2–2.4	2.4–3.6	3.6–4.8
1½	10	4	6	–	–
2½	10	2	6	2	–
4½	10	2	2	2	4
6½	10	2	2	2	4
8½	10	2	3	1	4
10½	10	–	3	2	5
14½	10	3	–	4	3
17½	10	–	2	4	4

Table 15. Distribution of tertiary and quarternary roots in 9 year old Tenera palms in Ivory Coast [10]

Radii of concentric circles from palm base (m)	Surface area of roots m²	Density g/m² soil g	Total quantity g
0.5–1.5	6.28	113.5	713
1.5–2.5	12.56	79.5	999
2.5–3.5	18.84	56.5	1064
3.5–4.5	25.12	45.5	1143

The primary root has a single layer of closely packed epidermal cells which are short lived. Beneath this is the lignified hypodermis which surrounds a cortex with well developed air lacunae. In the centre of the cortex are the vascular cylinders consisting of xylem and phloem and the pith or medulla.

A characteristic of the oil palm is the presence of pneumathodes which are similar to ordinary roots in origin but burst their epidermis and expose the cortex.

3.2 The stem

The stem of the oil palm is an erect and fairly uniform column and up to about 12–15 years of age, covered by persistent leaf bases. When the leaf bases slough off, scars are found to occupy a large portion of the stem surface. The outer region of living tissues is differentiated into a narrow cortex from the wide central cylinder. At the edge of the cylinder there are many small and large vascular bundles with a few bundles scattered in the central region. The vascular bundles consist of single strands of phloem tissues and xylem elements surrounded by parenchyma *[11]*.
At the top of the stem is the growing bud or apical meristem which lies in a basin like depression. The apex cuts off leaf primordia, the bases of which increase in diameter to keep pace with the increasing diameter of the node. The thickening process is complete before elongation of internode begins and this primary thickening process is responsible for nearly all the thickening that occurs in the oil palm.

3.3 Leaves

The arrangement of leaves with regard to the axis of the palm is known as phyllotaxis. A mature palm has about 30–40 leaves which are pinnate and the leaflets are arranged in two ranks on either side of the rachis. There may be 150–250 leaflets per leaf, which are 3–5 cm at mid-breath and 80–120 cm in length. On average, 24–26

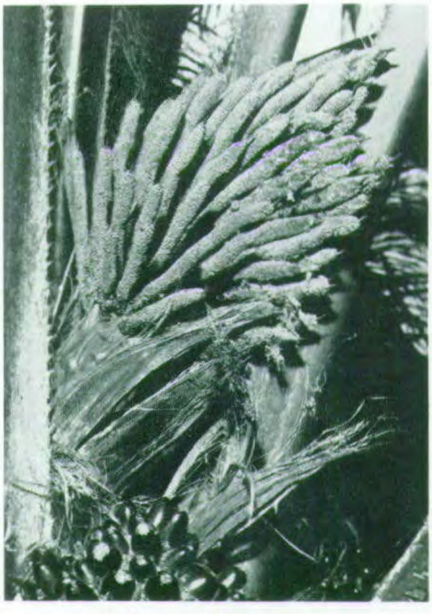


Figure 2. A male inflorescence at anthesis. Source: *Surre Ch. and Ziller R.:* Le Palmier à huile. Maisonneuve + Larose, Paris (1963)

leaves are produced per year. A leaf takes about 20–24 months to develop to the first open leaf stage and elongation is most rapid in the last 5–6 months [2, 5].

In mature palms, two sets of spirals of leaves can be seen, eight running one way and thirteen the other. If the spiral of eight ascends the palm in a clockwise direction, the palm is said to be left handed; if it ascends in an anti-clockwise direction, the palm is right handed. However, the direction of spiral ascent is not determined genetically.

The leaf is connected to the stem by a petiole which broadens considerably towards the junction with the stem. The petiole is about 1–1 ½ m in length and continues as the rachis on which the leaflets are borne. Leaf length varies appreciably but 7–8 m is common.

3.4 Inflorescence (Figures 2 and 3)

The oil palm is said to be monoecious, i.e. male and female flowers occur separately on the same plant. The primordium of each flower is a potential producer of a male and female organ though one or the other almost always remains rudimentary. *Beirnaert [1]* made the earliest study on floral composition of the oil palm. An inflorescence emerges at the axil of every leaf and is a compound spike or spadix carried on a stout peduncle enclosed in a woody spathe. The spikelets are spirally arranged from a central rachis. About a month after the inflorescence emerges above the base of the petiole, the outer spathe splits open. A further two to three weeks later, the inner spathe splits and the flowers more or less embedded in the spikes are exposed. There may be 100–300 spikelets and over 2000 individual flowers.

Figure 3. A receptive female inflorescence.
Source: *Surre Ch. and Ziller R.:* (1963)

The female flower consists of a perianth of six segments in two whorls, a tricarpellate ovary and a trifid stigma. The receptive faces of the stigma lobes are pressed on each other when young but open out when mature. The male flower is borne on a long peduncle and consists of long finger-like cylindrical spikelets, each of which comprises 700–1200 male flowers. The inflorescence is composed of a perianth of six minute segments, a tubular androecium with six stamens. Flowers begin to open from the base of the spikelet. In Malaysia flowers usually open within two days though during rainy weather opening may take four days. Most pollen is shed within 2–3 days after the beginning of anthesis and production ceases within 5 days. Pollination is generally thought to be by wind and development to maturity takes 5–6 months.

A widely varying number of female inflorescence is succeeded by an infinite series of male inflorescence, resulting in fairly indefinite sexual phases. The cause of this phenomenon is not very well understood at present but environment is said to have a major effect.

3.5 **Fruit** (Figures 4a and 4b)

The fruit is a sessile drupe varying in shape from nearly spherical to ovoid or elongated. In length it varies from about 2–5 cm. The Deli fruit of the Far East is usually considerably larger than the fruit of African Duras.

The fruit consists of a thin exocarp or skin, an oily pulp or mesocarp, a hard stony endocarp or shell, and an endosperm or kernel. The endocarp and the kernel constitute the seed. Oil occurs in both the mesocarp and kernel but palm oil is obtained from the mesocarp which contains about 11–21% of fibrous material.

The external appearance of the fruit varies considerably, especially at ripening. The commonest type of fruit is deep violet to black at the apex and colourless at the base before ripening. This kind of fruit is described as 'ordinary' or nigrescens. At ripening the colour varies from orange to red, believed to be associated with carotene content. A relatively uncommon type is green before ripening and this is called green-fruited or virescens. At ripening it changes to a light reddish orange colour. Fruit without carotene in the mesocarp is referred to as albescens, which is most uncommon.

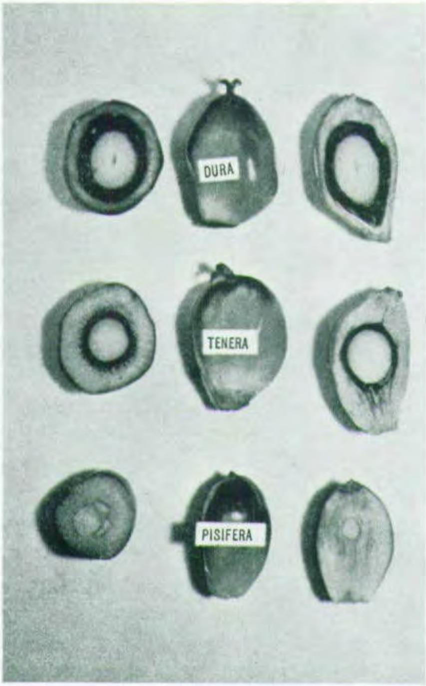
In internal structure the fruit shows considerable variation, the most important being in shell thickness. Fruit may be shell-less or have shells up to 8 mm in thickness. Internal fruit form is a genetic character *[4]* and can be described as follows.

(i) Dura: shell 2–8 mm thick, low to medium mesocarp content of 35–55% but in the Dura of the Far East, this may be as high as 65%. No fibre ring.

(ii) Tenera: shell ½–4 mm thick, medium to high mesocarp content of 60–95%, fibre ring, hybrid of shell-less pisifera and the common thick shelled Dura form.

(iii) Pisifera: shell-less.

The term macrocarya, which refers to dura palms with thicker shells, i.e. 6–8 mm, found in the Congo and West Africa, as distinct from the less thick shelled Deli Dura of the Far East, has largely gone out of use.



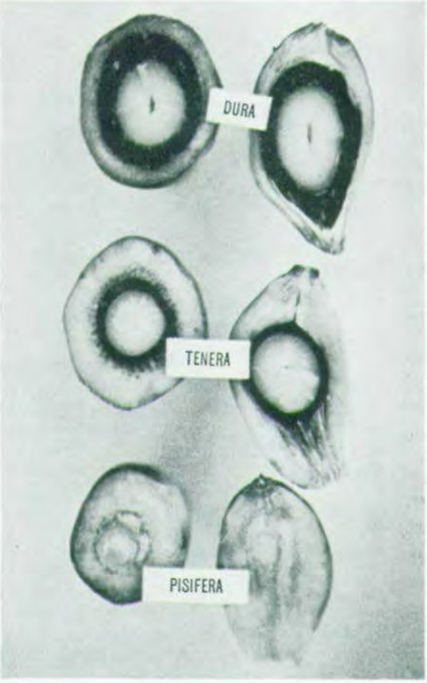


Figure 4a + *Figure 4b*. Fruit forms of the oil palm

3.6 Seed

The oil palm seed is the nut that remains after the oily mesocarp is removed. It consists of a hard shell and in most cases one kernel although two or even three may be encountered. Nut sizes vary greatly but commonly the length is 2–4 cm. The shell has fibres passing longitudinally through and adhering to it. Each shell has three germ pores corresponding to three parts of the tricarpellate ovary. Inside the shell lies the kernel which consists of layers of hard oily endosperm, greyish white in colour surrounded by a dark brown testa covered with a network of fibres. Embedded in the endosperm and opposite of the germ pores lies the embryo about 3 mm in length. In germination the embryo after emerging from the germ pore swells to form a button from which the radicle and plumule are differentiated. Germination is hypogeal.

3.7 American oil palm – Corozo oleifera

Formerly called *Elaeis melanococca* (this name apparently regaining favour), this palm is found in the tropical parts of South America and has certain morphological features quite distinct from the African or Asian oil palm. The leaflets are in one plane only and the trunk is at first erect but later becomes procumbent. Fruit bunches are smaller; so are the fruitlets which are yellow to bright red in colour. A high proportion of the fruitlets are parthenocarpic and there is no fibre ring in the mesocarp. It appears that this palm has some potential in long-term breeding programmes of the oil palm because of its reduced height and apparent resistance to diseases. Hybrids of guineensis and melanococca presently exist in the more important oil palm breeding stations in Africa and the Far East.

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4. Ecological Requirements of the Oil Palm

4.1 Climate

4.1.1 Temperature

According to *Hartley*, for high production, mean maximum temperature should be 29–30° C and mean minimum about 22–24° C. These conditions are found in most parts of the tropics. However, in high altitudes, temperatures can fall below 21° C and in the inland areas of Congo, night temperature is also below 21° C. Such low temperatures are said to reduce crop considerably by affecting bunch development. With young seedlings, there is evidence that below 15° C, cessation of growth occurs.

4.1.2 Rainfall

This is the most important element of climate for the growth of the oil palm. Present knowledge and experience indicate the optimum rainfall to exceed 2000 mm per year and this should be well distributed throughout the year, i.e. there is no long dry season.

While highest yields are obtained with the most favourable conditions set out above, the oil palm has been profitably cultivated in regions where rainfall is poorly distributed or very high, and where temperatures are low in certain months. This is because of botanical and social-economic reasons. The oil palm is well adapted to areas of summer rainfall and winter drought. Though bunch production is reduced by drought conditions, three months without rain does not markedly reduce the health of the palm and the growth of the bud continues but spear leaves tend to remain unopened until the onset of wet weather. During the dry period, midday stomatal closure prevents excessive loss of moisture. Further, the oil palm is such a high producer of oil that even under poorer environmental conditions, production may still be relatively economic. Nigerian plantation production of 1.2 t oil, 0.06 t kernel per ha/annum is still superior to output from coconuts *[4]*.

The limitation of rainfall is prominent in West Africa where drought of 2–4 months' duration occurs in Nigeria and Dahomey. In such areas, there is a tendency for large fluctuations in yield from year to year, with a very low yield occurring at intervals of

Table 16. Rainfall data of oil palm regions in South-East Asia, Africa and Latin America

Month		West Malaysia		Sumatra		Ivory Coast	Dahomey	Nigeria		Congo (Kinshasa)	Colombia
		Telok Anson	Ulu Remis	Medan	Marihat Baris	La Mé	Pobé	Benin	Umudike	Yangambi	Barrancabermeja
J	ins	9.39	11.09	5.4	12.25	1.54	0.67	0.41	0.86	3.35	2.40
	mm	238	282	114	311	39	17	10	22	85	61
F	ins	7.43	6.28	3.6	8.79	2.52	1.89	0.99	1.99	3.90	2.92
	mm	189	160	91	223	64	48	25	51	99	74
M	ins	9.46	10.33	4.1	11.31	4.96	4.57	3.53	4.46	5.83	4.61
	mm	240	262	104	287	126	116	90	113	148	117
A	ins	10.33	9.67	5.2	12.02	6.11	5.91	6.38	8.03	5.91	9.65
	mm	262	246	132	305	155	150	162	204	150	245
M	ins	6.78	8.08	6.9	11.66	10.72	7.13	7.61	10.50	6.93	12.49
	mm	172	205	175	296	274	181	193	267	176	317
J	ins	4.37	5.44	5.2	8.43	17.81	8.04	9.90	10.76	5.00	10.72
	mm	111	138	132	214	452	204	250	273	127	272
J	ins	4.20	6.27	5.3	7.92	8.27	4.65	12.63	12.28	5.75	7.68
	mm	107	159	135	201	210	118	321	312	146	195
A	ins	5.20	6.53	7.0	10.91	1.54	2.01	7.92	9.96	6.66	11.32
	mm	132	166	178	277	39	51	201	253	169	287
S	ins	6.86	7.07	8.3	14.11	3.74	4.61	11.62	12.21	7.09	14.42
	mm	174	180	211	358	95	117	295	310	181	366
O	ins	10.96	9.40	10.2	17.81	7.60	6.15	9.07	10.30	9.26	18.08
	mm	278	239	259	452	193	156	230	262	235	459
N	ins	11.39	8.75	9.7	16.19	7.17	1.85	2.66	3.32	7.21	12.06
	mm	289	222	246	411	182	47	68	84	183	306
D	ins	10.55	9.71	9.0	11.50	3.62	0.47	0.40	0.69	4.85	4.69
	mm	268	247	229	292	92	12	10	18	123	119
Total	ins	96.92	98.71	79.9	142.90	75.69	47.95	73. 12	85.36	71.79	111.03
	mm	2513	2507	2032	3627	1921	1217	1857	2168	1822	2818

4–6 years (1). Rainfall in Malaysia and Sumatra is slightly higher than that of West Africa but it is better distributed. Rainfall patterns in the Congo and Central America are more comparable to those of the Far East (Table 16).
Estimates of evapotranspiration according to *Thornthwaite* show that in Malaysia *[7]* and the Congo, there are one to three months when potential evapotranspiration (P.E.) exceeds rainfall but the negative values are small, being less than 50 mm. However, in Benin in Nigeria, for 5 months P.E. exceeds rainfall for 3–5 months by greater than 100 mm. It is due to this difference in distribution that such a marked difference in fruit production occurs as shown in the Ivory Coast where *Desmarest* increased yield from 5.5 to 22 t/ha/yr by irrigating young palms during the dry period so that total rainfall was raised from 1110 mm to 2250 mm. He showed a negative relationship between annual moisture deficit and yield of fruit bunches (Figure 5).

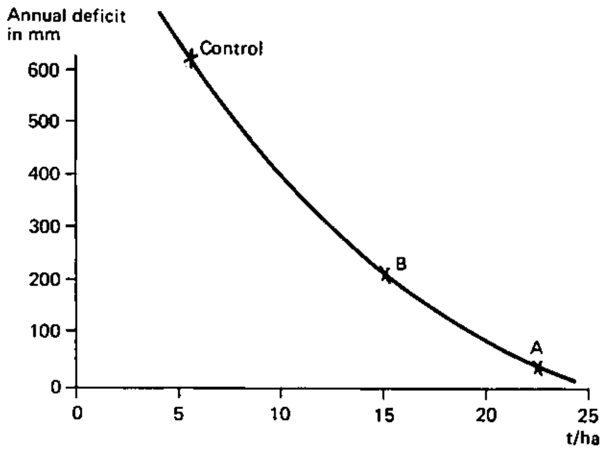

Figure 5. Relationship between moisture deficit and fruit bunch production
A – Irrigation to saturation
B – Irrigation only after stomatal opening
(Desmarest [3])

However, potential evapotranspiration is only an indication of balance, the actual moisture shortage also depends on other factors such as the water holding capacity of the soil. Moisture stress exerts a greater effect on plant growth on sandy or shallow soils than clayey and deeper soils. Data on the actual moisture regime in the soil during dry months are not available but the general indication is that a large deficit occurs in West Africa.
As far as very high rainfall is concerned as found in the East Coast of West Malaysia, little is known but it is possible that a greater incidence of disease, poorer pollination, waterlogging or excessive leaching of nutrients will retard growth and yield.

4.1.3 Solar radiation

For optimal production, it appears sunshine should be constant and amount to at least 5 hr/day in all months and up to 7 hr/day in some months. Inadequate sunshine reduces nett assimilation rate and production of female inflorescence. Because of this, the oil palm is called a light loving plant. Relative to rainfall, solar radiation is a less important factor although in West Africa, sunshine hours are below the lower limit for about three months from July to September (Table 17), particularly in the Cameroons.

4.2 Soil

Terrain is of great importance in oil palm development. Although the oil palm can be successfully planted on hilly land with slopes greater than 20°, in order to avoid greater cost of establishment and problems of harvesting as well as extensive erosion, flat or gently rolling or undulating land is most desirable. Preferably, no extensive areas should have slopes exceeding 15°.

The oil palm can be found on a wide range of soils ranging from loamy sand to heavy clays and deep peats. However, there is evidence that within a certain set of climatic conditions, soil variation can cause appreciable differences in yield due mainly to impeded drainage leading to disease, shallow rooting and moisture stress because of shallow soil profile *[6]*. Fertilisers can be applied to correct nutrient shortages but physical limitations such as impenetrable soil layers and poor water retention are difficult to rectify. Thus, physical soil properties like depth, texture and structure of the soil decide the suitability of a soil for oil palm planting.

As the palm can grow to a height of more than 8 m in its normal life cycle in a plantation, firm anchorage in the soil is necessary. Although the majority of its roots are found within the first 60 cm of the soil an appreciable quantity, mainly of anchorage roots, still occurs down to 90 cm or more. Thus soil depth should be at least 90 cm and no physical barrier or permanent water table should occur above it. Oil palm roots are fibrous and ramification is best in an open soil. As water is such an important element in growth processes, the soil should have a good capacity for retaining

Table 17. Sunshine at centres of oil palm cultivation (hrs/day)

Month	West Malaysia		Sumatra	Ivory Coast	Dahomey	Nigeria	Congo
	Kuala Lumpur	Chemara, Johore	Medan	La Mé	Pobé	Benin	Yangambi
J	6.2	3.5	5.4	5.2	6.0	5.6	6.6
F	7.4	5.1	7.1	6.1	7.0	6.0	6.8
M	6.5	5.0	7.0	6.5	6.4	4.9	6.0
A	6.3	5.7	7.2	6.4	6.1	5.3	6.1
M	6.3	6.1	7.7	5.2	5.9	5.4	6.0
J	6.6	5.1	8.1	2.9	4.7	4.2	5.5
J	6.5	5.4	8.1	3.3	3.3	2.6	5.0
A	6.3	5.0	7.5	3.2	3.3	2.4	4.4
S	5.6	4.1	7.0	3.1	3.7	2.6	5.2
O	5.3	4.4	6.2	5.0	5.2	4.2	5.1
N	4.9	3.9	5.9	5.7	6.4	6.0	5.5
D	5.4	3.7	5.4	5.9	6.6	6.4	5.7
Mean	6.1	4.8	6.9	4.9	5.4	4.6	5.6
Total/yr	2230	1729	2508	1781	1963	1692	2054

Source: *Hartley [4]*.

water. A good soil is one which permits extensive root development and firm anchorage and which also stores plentiful supplies of water and plant nutrients. A well-drained sandy clay loam or clay loam soil with a friable consistency meets these requirements. A heavy clay soil is also suitable provided it is well structured and not compacted. As the oil palm is thought to have a swamp origin, a well drained alluvial soil is probably best.

Chemically, most soils planted to oil palms are found in the acid range from neutrality down to pH 4. There is little information on the effect of alkalinity on oil palm growth but in view of the likely suppression of uptake of potassium and other nutrients, alkaline soils are probably unfavourable for oil palm planting. On the other extreme, highly acid soils of less than pH 3.5 such as the acid sulphate soils *[2]* are also not suitable for large scale development.

A soil rich in available and potential plant nutrients is good if attainable but the inherent fertility of a soil is of lesser importance because profitable production can be achieved by the use of inorganic fertilisers. In West Malaysia, *Ng [5]* considers the recent marine clays to be the best but a wide range of soils derived from igneous and sedimentary rocks of a lower nutrient status is also quite suitable. The unfavourable soils include laterites, sands, deep peats and acid sulphate soils. The major criteria for assessing soil suitability for large scale oil palm planting in Malaysia are slope, depth of soil, texture, structure, pH and general nutrient status.

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5. Planting of Palms (Figure 6)

Up to about 1960, plantations, particularly those in Malaysia were made up of Dura materials but since then Tenera (Dura × Pisifera) seeds became available from breeding work and today Tenera material is exclusively used in new plantings. This is because the new material contains more mesocarp which gives about 20% more oil per hectare than the Dura.
The operations of planting can be conveniently divided into two aspects, viz:

1. Seed germination and nursery techniques.
2. Field planting.

Figure 6. An FLDA (Federal Land Development Authority) – Scheme in Malaysia

These techniques and their organisation and control for large scale plantings are described in detail by *Bevan, Fleming and Gray [3]* and *Bevan and Gray [4]* respectively.

5.1 Seed germination and nursery preparation

5.1.1 Germination

Seeds are obtained by depulping individual fruit in a rotatory device developed by the 'Institut de Recherches pour les Huiles et Oléagineux' (I.R.H.O.). It has a hexagonal framework which can be made of angle iron round a central steel shaft. It rotates at about 30 r.p.m. and can depulp at the rate of 6000 fruits per hour. After depulping, the seeds are dipped for three minutes in a fungicidal and bactericidal solution.
For most successful germination, proper moisture content, aeration and a relatively high temperature of 38–40° C are required. Previous methods of germination either in sand beds or Congo chests have been superseded by the commonly known Dry Heat Method in which an electrically heated germinator is used *[13]*. The germinator was originally developed by the West African Institute for Oil Palm Research (now the *Nigerian Institute for Oil Palm Research*). Temperature and humidity conditions are controlled in the germinator. The germination success at 85–90% is definitely superior to previous techniques and a further advantage is that the incidence of brown germ disease believed to be caused by thermophilic fungi is considerably less. The disease attacks the shoot and roots. To avoid this, moisture is kept at 18% of dry matter which inhibits too rapid germination at the high temperature.
After soaking for 7 days and drying off in the shade for 24 hours, seeds are kept in polythene bags and stacked side by side on galvanised wire shelves for 80 days. In Malaysia, 40 days has been found generally sufficient for Deli dura seed. After the heating period, the seed is re-soaked for 7 days and air-dried for a short period to bring it to the saturation moisture contents of 21–22% for dura or 28–30% for tenera seed. The seeds are then re-bagged and kept at ambient temperature, no superficial moisture being allowed in the bags. Approximately 10 days later, the radicle emerges and continues to grow for about 30-40 days but germinated seeds are not allowed to develop to this stage in the bags. Instead, the newly germinated seeds are removed from the bags at weekly intervals and are despatched to growers around 4 days from the commencement of germination, to minimise damage to root tips during transit. On arrival at the plantation, the seeds should remain in the bag at room temperature until planting out in the pre-nursery about 10-14 days later.
The capacity of a germinator can vary fairly widely according to requirements but in practice, it is probably in the region of 200000 seeds or more.

5.1.2 Pre-nursery

Germinated seeds are first raised in a pre-nursery which should be located near the main nursery to reduce cost during transplanting and to make the best use of water supplies in the main nursery. A medium textured soil such as a loam is desirable and if only clay is available, it should be mixed with river sand at a ratio of 3:2. Insecticides should not be mixed with the soil as the young germ will be killed. Water can be applied by a watering can or an overhead sprinkler unit if the area to be planted exceeds 4000 ha. Three main systems are used for planting germinated seeds, viz: (a) baby polybags, (b) beds or trays and (c) large polybags.

– *Baby polybag system.* The polythene bags are 15 cm wide and 23 cm deep lay flat, and 250 gauge is suitable. Bags are filled with about 1.6 kg of soil to within 1.2 cm from the top and placed under shade in rows 10 bags wide. A small hole in the surface soil is made with the finger and the germinated seed planted with root pointing downwards and the seed covered by about 1.2 cm of soil. Major advantages of the baby polythene technique compared with beds or trays are (a) less shock to seedlings when transplanting to the main nursery and (b) less labour intensive when seedlings are planted out 4–5 months later at the 4th–5th leaf stage.

– *Pre-nursery beds or trays.* The beds are 2.3 cm deep, 1.2 m wide and any convenient length filled with loamy soil and shaded. Timber or brick can be used for the longer side and the ends must be removable to provide easy access for transplanting. There should be drainage outlets at 1.5–1.8 m intervals along the bed. Planting of germinated seeds follows the same procedure as used for baby polybags.

This technique is no more commonly in use in modern planting; it is superseded by the polybag systems.

– *Single stage large polybag system.* In this system, the germinated seed is planted directly into large polybags which are 38 cm wide and 50 cm deep lay flat and of 500 gauge. The lower half of the bag is perforated. The seedlings remain in the bags until field planting, generally 12–14 months later. Each bag holds about 15 kg of soil. The bags should be placed together in rows three bags wide. At approximately 6 months when the leaves of the young seedlings are about touching each other, the bags are rearranged at a 1 × 1 m triangle spacing. Shade should be provided until the two leaf stage. This system requires more labour and watering in the first four months compared with the baby polybag system but *Hew and Tam [8]* showed that a faster rate of growth could be achieved and the total period in the nursery may be reduced by as much as two months. Production is therefore also slightly advanced. However, more rigorous roguing of runts or sterile palms has to be carried out.

5.1.3 Two leaf bare root seedlings

If such seedlings are supplied, which is less common, they should be planted immediately on arrival and 13 × 23 cm bamboo baskets or 38 × 50 cm polybags can be used. Considerable care has to be exercised in planting and it is best to fill the bag and cover the roots by stepwise filling and consolidating rather than in one operation.

5.1.4 Maintenance in the pre-nursery

Daily watering is necessary to maintain the soil in a moist but not saturated condition. Weeding and light scratching of the soil surface is also practised. To encourage healthy growth, plants are watered weekly with a weak solution of ammonium sulphate, urea or compound fertiliser with a formula of 15:15:6:4 from the one leaf stage to transplanting time. However, more frequent application may be made if seedlings appear yellowish green. Urea is applied at the rate of 14 g in 4.5 l of water per 100 seedlings. In the case of the compound fertiliser, 14 g is used in the same volume of water and number of seedlings during the 1–3 leaf stage but at the 4–5 leaf stage, 14 g is used weekly. To prevent scorching, leaves must be subsequently washed down with a spray of water.

A round of culling is usually carried out prior to transplanting. Abnormal plants with twisted shoots or leaves which are narrow, markedly crinkled or rolled and spiny or diseased are eliminated. The percentage culled should not exceed 10%.

5.1.5 Main nursery

Two main types, polybag and field nurseries can be used although in Malaysia the polybag system has become more popular. Water availability is the crucial factor in deciding on the type of nursery. Where water is easily available, the polybag has several important advantages the chief of which are: flexibility in site selection with regard to soil and drainage, less soil cultivation, much lower labour requirement at transplanting from nursery to field and less transplanting shock.

5.1.6 Polybag nursery (Figure 7)

As stated earlier, a good supply of water is essential. Terrain is not critical but a level site is desirable. As for pre-nurseries, a loamy soil is preferable. Black polythene bags, 38 × 50 cm lay flat with perforations are generally used. When transplanting seedlings from pre-nurseries, bags should be initially filled to a level that allows the seedling plus its block of earth to be suspended in the bag with its collar about 1.2 cm below the rim. The rest of the vacancy is then filled. The baby polybag or bamboo basket has to be removed before the seedling is transferred to the bigger polybag. Seedlings raised in prenursery beds should be dug out with a transplanting tool which cuts out the seedling with a block of earth of 10 × 10 cm and 23 cm deep. This is done by pushing the open end of the tool into the bed to its full vertical depth and width and the uncut edge of the block of earth is cut with a knife.

The polybags with the transplanted seedlings should be regularly watered, at least four times a week. Under dry conditions, about 9–18 litres of water is required by each plant weekly.

Manuring of seedlings is described in a separate chapter. Seedlings stay in the polybags for about 8–9 months before being transplanted in the field. Prior to that, a further culling of runt palms should be carried out. These palms include those which have (a) erect fronds and acute angled pinnae commonly referred to as sterile, (b) flat top appearance, (c) short and limp form and (d) fused pinnae. Such runts should not normally exceed 10%.

Figure 7. A polybag nursery

5.1.7 Field nursery

The field nursery site should be close to the planting area and the soil texture and structure should enable a good ball of earth to be retained when digging out. It should also be on flat or undulating terrain with good drainage. The site has to be cleared of all timber and debris and disc ploughed to a depth of about 30 cm.

The bags and baskets holding the seedlings from the pre-nurseries have to be removed carefully to avoid root damage before planting in the hole. Planting holes in the field nursery should be about 30 × 30 × 30 cm and the planting distance is 1 × 1 m. To facilitate adequate inspection, paths should be provided by leaving one row out of every ten unplanted. Transplanting is best done in cooler weather in the early morning or late afternoon. Until the transplanted seedlings are well established, daily watering must be carried out.

While the plants are in the field nursery, it has been shown that root pruning encourages growth in the field. *Gunn, Sly and Chapas* [7] showed that root pruning stimulates and increases root development within the ball of earth before transplanting, and reduces transplanting shock. The practice is performed at 5 and 3 weeks before field planting with a sharp garden spade of 25 cm depth. In the first operation, a clean vertical cut is made on two adjacent sides, 20 cm away from the palm base. In the second operation, the remaining two sides are cut but a gap of 13 cm is left uncut.

After about 9–12 months in the field nursery, the palms are ready for transplanting in the field. Removal of the palms is a laborious procedure. Firstly, the older and lower fronds are closely pruned and the younger and upper fronds lightly pruned so as to leave a diamond shaped pattern. The fronds are lightly tied to facilitate access during travelling. Secondly, the palms are dug out with a garden spade and in the operation damage to young roots must be avoided. Two spades are used and are inserted on opposite sides of the palm, outside the cuts made during root pruning. Thirdly, the palms are lifted out carefully on to a gunny sack in which the ball of soil is wrapped and tied, and placed on a metal tray for transportation.

5.1.8 Age of palms at field planting

The best age for planting out nursery palms is not absolutely known but there is general agreement that palms of less than 9 months old are too young and more vulnerable to attack by pests and diseases while too old palms of greater than 18 months incur greater labour costs and transplanting shock although the period of immaturity in the field is somewhat reduced. Hence, a compromise of 12–14 months from the germinated seed stage is generally recommended.

5.2 Field planting

While pre- and main nursery seedlings are being raised, activities must also be afoot to prepare fields for planting the nursery palms. Before field planting can be implemented, two important operations have to be carried out and these are (a) land preparation which includes clearing, drainage, terracing and construction of a transport system and (b) cover cropping.

5.2.1 Land preparation

– *Clearing for new planting and replanting.* The method of clearing depends on the nature of the existing stand and terrain. In most areas, existing stands comprise either jungle or perennial crops of rubber, coconut or oil palm. As the existing timber and root systems present a potential source of pests and diseases to the palms, it is considered most desirable to remove them as much as possible. In the Far East where the oil palm is planted on plantation lines, there has been no social or economic need to attempt to replant old oil palms by underplanting and selective thinning as may be necessary in oil palm groves.

If the area is under forest, it is generally cleared by contract work and the operations consist of under brushing or slashing the lower growth, felling of trees, burning during the drier season about 6–10 weeks after felling, pruning of timber up to 15 cm diameter, stacking them and reburning, and terracing and silt pilting where necessary *[10]*. All these operations take about 5–6 months and it is important that the felling should be so timed that burning coincides with a non-rainy season of the year. Long term rainfall records, if available, are useful as guides in this connection. It cannot be over emphasised that proper programming and phasing of land clearing is a critical aspect of land development and a critical path technique is advantageous. The general practice of felling manually by chainsaw is still cheaper than mechanical clearing *[2]*. However, if catch cropping is intended, mechanical clearing facilitates such cultivation. In savannah country, mechanical land preparation can be practised *[15]*.

– *Replanting after rubber.* The common method of clearing rubber is to fell and de-stump by bulldozer where terrain permits. Trees near drains have to be winched out. De-stumping is desirable in order to eliminate potential breeding sites of insects, particularly the beetle, Oryctes rhinoceros, which can cause serious damage to immature palms. If terrain is hilly or if de-stumping is not considered worthwile, trees can be felled by chainsaw as close to the ground as possible leaving about 23 cm of stump above the ground.

The felled trees should be pushed into broad windrows to facilitate a good burn and provide access for a second burn. The felled timber should dry out adequately in 6–10 weeks and be ready for the first burn. Then the remaining material is pruned, stacked and burnt for a second time and this should remove all the debris.

– *Replanting after coconuts in Malaysia.* A serious problem with oil palms replanted from old coconut areas has been the incidence of basal stem rot caused by Ganoderma spp. This usually appears most prominent in palms of 10 or more years after planting and palms markedly decline in yield and succumb in a few years. *Turner [17]* has found that the disease is most severe where coconut trunks were buried in the soil. These later become the major sources of infection. The recommended practice is to winch out and push together the old coconut stand, cut up into lengths of about 5–7 m, stack them in such a way that there is a clearance of about 0.6 m to place the coconut shells which are used as starter fuel. Unlike jungle and rubber, coconut palms can be burned soon after felling but it is necessary to restack and burn 3–4 times. Burning the trunks also removes the habitat of Oryctes. In addition, it is advisable to cross plough and harrow in order to break up as much of the old root system as possible.

On heavy soils, mechanical operations can cause soil compaction resulting in poor soil aeration. This induces a yellowish green colour in the leaves of young palms but fortunately, this is usually a temporary setback in the first year.

Where mechanical equipment is limited but labour plentiful, the trunks can be cut into shorter lengths of 0.6 m and split, and these are heaped for burning at the rate of 2–3 palms per heap.

– *Replanting after oil palms in Malaysia.* As in the case of coconuts, to remove potential sources of Ganoderma and Oryctes, it is best to uproot the old stand, remove or burn if possible. Burning success is more difficult to achieve but if weather conditions are dry for a sufficiently long period, a satisfactory burn can be obtained. The fibre waste from the mesocarp is a good aid in burning.

5.2.2 Drainage and terracing

Where oil palms are planted on alluvial flats, some degree of drainage is always necessary to remove excess water during periods of heavy rain but the intensity of drainage depends on the relief of the area, the permeability and water retention capacity of the soil. For the marine clays of West Malaysia, experience shows that satisfactory drainage can be obtained by spacing main drains at about 1320 m apart with submains running at right angles to these at 350–440 m intervals. Within individual fields, the intensity depends on actual conditions obtaining and can vary from a drain every second avenue to a drain every 8th avenue. However, it is advisable to start with a low intensity. The dimensions of these drains are given in Table 18.

Table 18. Dimensions of major drains (m)

Type	Width		Depth
	Top	Bottom	
Main drains	5.3	1	2.7
Secondary mains	2.7	0.7	2
Field	1.3	0.3	1.2

Where the terrain is not flat, the necessity for conservation practices depends on the steepness of the land. On undulating to rolling terrain (2–12° slope), terracing is generally not necessary although with sandy loams, silt pits are advisable. Where the terrain is hilly (12–20° slope) or steep (20–25° slope), terracing is necessary, particularly for the steeper land. The terraces should be 3–4 m broad and spaced at 10 m apart, which should accommodate a density of 140/ha. On very steep land (> 25° slope) although palms can be satisfactorily established *[14]*, this is restricted to soils with deep profiles. On soils derived from quartzites and grey shales, terracing is physically hazardous as parent rocks are often exposed. In view of these limitations, large platforms are preferable to terraces. Nevertheless, two serious problems confront planting on very steep land and these are (a) soil erosion and terrace maintenance and (b) difficulties of harvesting, collection and transport with implications on oil quality. The complete success of large scale planting of oil palms on steep land has not really been proven and merely from a conservation viewpoint, it is advisable not to develop steep land for oil palms, unless such land forms only inseparably small units in a plantation.

5.2.3 Establishment of transport system

For all the field operations of planting, upkeep, harvesting and collection, an efficient system of communications is necessary. In Malaysia, both rail and road systems have been used but *Bevan et al. [3]* showed that a rail system is more costly than a road system. These findings are shown in Table 19.

Table 19. Estimated costs of rail and road transport systems (M$/ha / 3 M$ = 1 U.S. $ /)

Transport system	Size of plantation (ha)		
	2000	4000	8000
Railway with tipping wagons	664	682	672
Railway with steriliser cages	689	679	672
Road	254	259	262

Thus, practically all new plantings in Malaysia use road systems. One major advantage of the road system is that expenditure can be phased out whereas for the rail, full costs have to be incurred at the outset. Another is that the roads can be built according to requirements of establishment and harvesting.

5.3 Establishment of cover crops (Figure 8)

The practice of cover crops has become an established field practice after the World War II in tropical plantation agriculture. The principal purpose is the control of soil erosion which can wrought irrepairable damage to the land under conditions of torrential rainfall, particularly on hilly terrain. Other secondary reasons include the improvement of soil organic matter and nutrient status, better soil aeration and conservation of soil moisture.

Figure 8. Young palms with legume cover

Of the types of covers which can be used, legume creepers have been shown to have the greatest benefial effects on plant growth and soil fertility. Work by *Watson et al. [18]* at the *Rubber Research Institute of Malaya* indicates that in the 4th and 5th years of growth, leguminous covers may return a nett equivalent of about 1000 kg/ha of sulphate of ammonia to the soil, which could be utilised by the planted crop. Through the litter, there was also better cycling of other nutrients. The main effects of the legumes are better girthing rate and earlier maturity and tappability of rubber. This was also the main finding of *Mainstone [9]* who, however, attributed part of the benefit to improvement of soil aeration as evidenced by a greater abundance of roots on the poorly structured soil with which he was experimenting.

However, opinion on the advantages of legume covers is not quite unanimous; some plantations prefer the use of grasses or naturals, largely because of the high cost of establishing and maintaining pure legumes in the early years after establishment. For rubber, *Pushparajah and Chellapah [12]* obtained evidence recently that on a deep and well structured soil, naturals or grasses plus the use of additional nitrogenous fertilisers could obtain the same growth and yield as legume covers. No doubt, such experimentation needs to be performed on other representative soil types. These results for rubber, however, cannot be easily extrapolated to oil palms as the nutritional requirements are rather different.

Investigations on covers in oil palms have been few and the little information available indicates that yield levels can influence the choice of covers. Thus, in Nigeria *[1]* a 13 year experiment showed that leguminous covers did not give larger yields over 8 years than weed cover regularly hoed. It is possible that water deficit prevented the palms from the benefit of the cover. On the other hand, *Gray and Hew [6]* in Malaysia showed that even on the relatively fertile coastal clay, *Puereria* and *Centrosema* covers gave more than 6% higher yields than grasses over 4¾ years of harvesting. The lowest yields were obtained with *Mikania* cover as shown in Table 20.

It was estimated that based on a selling price of M$600 per tonne of palm oil and $300 for kernel, the total additional profit obtained by the legume covers compared to grasses for the period amounted to $327 per acre or $817/ha. These findings suggest that on low nutrient status soils, a greater benefit from legume covers can be envisaged.

Legume covers can be sown in drills after the second burn in land preparation. On contoured land, the seeds are sown between the terraces. Generally, three drills, 1.5–1.8 m apart are sown between avenues and a further three drills are sown at right angles to the main drills. For creeping legumes, a suitable sowing rate is 2.2 kg of *Puereria phaseoloides* and 3.3 kg *Centrosema pubescens* per hectare. Commonly, *Calopogonium mucu-*

Table 20. Effects of covers on fruit bunch production over 2½–7¼ years of young palms on marine clay (t/ha)

			As % of legume cover plot	
	With fertiliser	No fertiliser	With fertiliser	No fertiliser
Grass	110.8	110.9	92.4	92.5
Mikania	106.5	94.1	88.8	78.8
Nephrolepsis	116.7	103.3	97.3	86.1
Puereria-Centrosema	119.9	117.8	100	98.2

noides is also included in the mixture at half the rate of Puereria. In some cases, a bushy cover, *Flemingia congesta* is used. To improve germination rate and accelerate establishment, seeds are either soaked in dilute acid or scarified mechanically. To promote good establishment, fertilisers are recommended. A compound 15:15:6:4 fertiliser has been found by practice to encourage growth and this is applied at 1–3 weeks after germination at 14 g per 2 m of drill. During the first 18 months of growth, rock phosphate is broadcast at 62 kg/ha at 3–4 month intervals making a total of about 245–370 kg/ha. Thereafter, the rate of application is 122–245 kg/ha.

To establish a pure legume cover in Malaysia and perhaps Indonesia stringent weed control is necessary, particularly in the first 6 months when hand weeding at fortnightly intervals is needed. Thereafter and up to about 2½–3 years, monthly rounds are adequate. This form of weed control is expensive, costing M$200–250 per ha per year, and for this reason, legumes are not favoured in some quarters. However, if legume covers were established, it would be rather unsound not to maintain it clean for a minimum of two years in order to enable the cover to fix the nitrogen that is aimed for.

In other oil palm countries, however, *Puereria and Calopogonium* establish much more easily and it may then be necessary to control *Puereria* from smothering young palms.

5.3.1 Lining and holing

These two operations have to be completed before field planting can begin but in Nigeria, it has been shown that holing is not necessary on the Acid Sands. Lining is carried out prior to the establishment of leguminous covers by surveying techniques, dependent on the planting density decided upon. In Malaysia, holing is done immediately before planting. Holes should be adequately large, an 45 × 45 × 38 cm hole is satisfactory for most soils. Where the soil is lateritic or gravelly, a bigger hole should be used. On peats, which gradually subside due to physical shrinkage and chemical oxidation, a 'hole within a hole' technique is advisable. The outer hole is 1.2 × 1.2 × 0.3 m deep and the planting hole is dug in the centre of the outer hole.

5.3.2 Planting density

A universally accepted optimal planting density for oil palm has not been experimentally derived. In the Ivory Coast, *Prévot and Duchesne [11]* obtained the maximum yield with a density of 139 palms/ha although when the figure was reduced to 125, there was only a drop of 1% in yield. *Surre [15]* claimed that the optimum economic density is always below the optimum density for production. In Malaysia, planting density ranges from 122–148, previous practices favouring the lower density. However, *Bevan et al.* consider that the range of 140–148 per hectare is suitable. Recent growth analysis carried out in Malaysia *[5]* also supports a higher planting density and 148 seems most appropriate.

5.3.3 Planting out

Experience has shown that palms must be planted at nursery level since deep planting buries the young bud and causes severe retardation in growth. It is important to firm soil carefully around the ball of earth in stages until the hole is filled. With polybag palms, the side of the bag should be split and the bag removed.

Field planting is best done to coincide with the onset of a wet season as prolonged dry spells after planting can retard growth considerably. Ground rock phosphate at 56–112 g per palm is sprinkled over the bottom and lower side of the planting hole. With field nursery palms, the ball of earth should be wrapped in a gunny sack during transportation and if it is shattered, a mound of soil should be made in the bottom of the hole and the palm placed upon it.

In the first six months after planting, supply may be necessary due to failure of establishment but casualties should not exceed 2–3%.

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6. Agronomic Practices

This heading concerns all the husbandry or cultural practices followed in raising and maintaining palms in the field but for convenience and because they form large topics in their own, manuring and pest and disease control are treated separately. So the cultural practices considered here are as follows:

(a) Weed control
(b) Castration
(c) Assisted pollination
(d) Pruning
(e) Inter-cropping

In discussing these separately, it cannot be over-stressed that they are closely inter-related with manuring and plant protection measures.

6.1 Weeding

6.1.1 Immature areas

Weed control is relatively more critical in the immature period in order to reduce competition for nutrients and water to a minimum. Control mainly consists of weeding the clean circle and some of the inter-rows. Clean circle weeding usually begins soon after field planting with an initial circle of 2–3 m in diameter. This is gradually enlarged until at about 2½–3 years when harvesting begins, the diameter reaches 3–4 m. Hand weeding is generally practised in young palms because of the risk of damage by certain herbicides which either scorch the leaves or cause the spear and the upper leaves to twist or fasciate. *Sheldrick [13, 14]* found that on 8–12 month old seedlings, dalapon and 2,4-D had the most damaging effect causing leaf distortion and fasciation and death at high concentrations, while paraquat and aminotriazole caused chlorisis. Simazine and monuron appeared safe at low rates. However with manual weeding, care must be exercised that young roots are not damaged or a saucer-like depression produced around the palm. In the early stages, monthly rounds are necessary but this can be relaxed progressively with time. At about 15–18 months in the field, the lowest whorl of leaves only can be pruned to facilitate access to the palm base.

In Malaysia, where legumes have been established, noxious weeds such as Mikania, Eupatorium and grasses have to be removed manually by maintaining fortnightly rounds of selective weeding in the first six months and monthly rounds thereafter. In Africa, such weeding for cover establishment is much less frequent. Sporadic lallang *(Imperata cylindrica)* can be controlled by wiping with a commercial oil.
However, in view of the higher cost of manual weeding, selective weeding in 1–2 year old plantings may be done by using appropriate herbicides such as paraquat and a mixture of MSMA and diuron although care should be exercised in spraying to avoid damage to fronds. More recently in Malaysia, *Seth [12]* reported that a combination of 0.27 kg/ha paraquat plus 0.27 kg/ha diuron plus 1.8 kg/ha of MSMA provided lasting control of *Paspalum conjugatum, Panicum nodosum, Axonopus compresses* and *Digitaria species* in weeded circles.

6.2.1 Mature areas

For ease of fruit collection as well as fertiliser application, a clean circle of about 2–3 m radius around the palm base should be maintained by alternate rounds of clean weeding manually and spraying with herbicide at 3 monthly intervals. In additions, harvesters' paths also need to be cleared by slashing or spraying with herbicides. In Malaysia, *Palmer [9]* reported that diuron at low rates gave adequate control although the addition of paraquat improved control during the first 6–8 weeks. *Ramachandran et al. [11]* found that alternate rounds of spraying with paraquat and MSMA/sodium chlorate mixture at 4 monthly intervals gave satisfactory control of circles at economical costs. Work in West Africa *[15]* indicates that of the newer chemicals, the urea derivatives and triazines appear most promising. Where *Eupatorium* or lallang occurs in patches, they can be eradicated by 2,4-D and dalapon respectively.
The various herbicides, their chemical names and uses are given in Appendices 1 and 2. Where grasses are controlled by mechanical mowing it has been found (Hew & Tam, priv. comm.) that this has a depressive effect on leaf nitrogen and phosphorus but the actual cause is not known.

6.2 Castration

This practice has become quite common in plantations in Malaysia and consists of the removal of young male and female inflorescences and bunches. This is carried out on monthly rounds beginning from about the 14th month to the 27th month after planting in the field. Harvesting is thus delayed somewhat but it does appear to render the following advantages:
(a) a higher yield at beginning of harvesting thus making better use of the factory,
(b) higher oil to mesocarp contents from the beginning of harvesting,
(c) a likely improved rate of growth by diverting assimilates to vegetative dry matter production during the pre-harvesting period,
(d) a more uniform stand tends to result and more uniform bunches,

(e) a lower incidence or complete absence of Marasmius bunch rot, less rat damage due to the removal of uneconomic and un-harvested fruit bunches under Malaysian conditions.

Similar advantages have also been found in West Africa by *Ochs and Bréchas [10]*. The cost of castration is not high as one worker can castrate approximately 120–150 palms a day.

6.3 Assisted pollination

Inflorescences on oil palms appear in phases of male followed by female or vice versa and it is unusual to find ripe male and receptive female inflorescence on a palm at the same time. Cross pollination is the means of fertilization and *Jagoe [7]* showed that pollen was disseminated more by wind than insects and wind dispersal was reckoned to be less than 33 m. Recent investigations by *Hardon and Turner [4]* indicated that the distance of pollen disposal was greater than previously thought, and rain could cause an immediate drop in pollen density. However, pollen densities were influenced more by the number of rain days than total rainfall. The viability of pollen in female flowers was estimated to be six days. It is now well established in Malaysia that in the early years of bearing, the production of male inflorescence of Tenera material tends to be low and this results in poor fruit set or aborted bunches. This can cover hundreds of acres and a substantial shortfall of yield can occur. It has been shown that this situation can be prevented by supplying pollen artificially, commonly known as assisted pollination *[2]*.

Experience of the practice has given conclusive evidence that much better fruit set and larger bunches can be obtained, thus preventing any loss of potential crop due to inadequate pollination. Simple indices such as pollen density which may indicate the need for assisted pollination are being sought but so far no direct relationship between pollen density and percentage fruit set has been found *[4]*. Therefore, a field criterion, the presence of a significant number of bunches with poor fruit set over a period of 2–3 months is used.

Direct experimental evidence of the benefits of assisted pollination is not yet available because of the appreciable problems confronting experimentation and the need of properly isolated areas. However, *Gray [3]* showed that in five fields, about 5–6 months after the commencement of assisted pollination, monthly yields increased from about 0.5–0.75 t to 1.2–2.7 t per ha during the first year of harvesting of DxP palms.

Fears had been expressed that continuous assisted pollination might bring about a reduction in yields in later years due to a more rapid exhaustion of nutrients. However, *Gray* presented evidence to show that on the coastal clays of West Malaysia, provided increased fertilisers were applied as guided by leaf analysis, no reduction in yield over a 7 year period was discerned. Thus, if additional fertilisers are supplied especially on soils of low nutrient status, there is no theoretical reason why yield levels in the long term should be depressed by assisted pollination. A further point to be borne in mind is that if assisted pollination were not carried out in the early period, palms would tend to remain longer in the female inflorescence phase resulting in low yields over a longer period.

Pollen can be collected from ripe male inflorescences of similar plantings, sun or oven dried and mixed with fine talc in the ratio of 1 to 10. One g of the pollen mixture should be adequate to pollinate one female inflorescence. The pollen mixture is dispersed over the inflorescence by means of a hand puffer if access is easy, or a lance puffer if access is difficult. For taller palms, a motor blower has been used. Pollination should be carried out at 8–10 rounds per month.

In so far as the length of time assisted pollination needs to be continued, it is difficult to be categorical but it is unlikely that it needs to be longer than 5 years of harvesting. However, to gauge the need, it is advisable to lay aside control plots of 2 ha in 40 ha fields or blocks and observe the condition of fruit set in these controls.

The above largely applies to Malaysia for in West Africa, it has not been found necessary to assist pollination as abundant supplies of air-borne pollen are almost always available everywhere.

6.4 Pruning

A desirable objective of pruning is to retain as much photosynthetically active tissue as possible, while providing sufficient access for cultural practices such as weed control, castration, assisted pollination and harvesting. The practice of leaf pruning is more vigorously followed in the Far East than in Africa or elsewhere.

For palms not yet in bearing, at about 18 months, the lowest whorl of leaves is removed to facilitate circle weeding and castration. Thereafter, only very light pruning should be allowed for purposes of castration or assisted pollination. In the Far East, the first systematic pruning can be carried out when the lowest ripe bunch is about 60 cm above the ground. Care should be taken that the whorl of leaves immediately below the ripe bunches is not pruned.

After three to four years, pruning should be confined to those fronds which obstruct bunch cutting and loose fruit collection. The most common practice is to leave at least a whorl of leaves below the ripe fruit bunch.

Pruning experiments carried out in Nigeria *[16]* show that pruning every 6 months all leaves up to the one subtending the lowest bunch yielded 7018 kg/ha while annual pruning of dead leaves only yielded about 20% higher at 8316 kg/ha. Heavier pruning up to a flowering inflorescence was lowest at 6633 kg/ha. These results are also supported by leaf area studies in Malaysia by *Hardon et al. [5]* who found that yield increased with leaf area of palms up to a maximum at about 10 years when the relationship levelled off, the leaf area index being about 5 at the highest point. Thus, the dangers of over pruning of palms are clearly evident from the above results.

6.5 Inter-cropping

Where the oil palm is cultivated in smallholdings as in West Africa, inter-cropping is an established part of land use. Crops such as dry or hill rice, cassava, maize, yams and legumes are most common as they are sources of food to the cultivators. Such cropping is prevalent in the so-called 'farmland with palms' in West Africa. In most of these areas, there is a steady decline in soil fertility with suppressive effects on palm production as nutrients removed are not ploughed back. Experiments conducted in Congo and Nigeria *[17]* indicate that such cropping can probably be sustained for 2–3 years on forest land only but not on previously cultivated land. Bunch yields over the first three years were about 20% higher with inter-cropping although in Nigeria over 19 years, there was no advantage. It seems clear that satisfactory levels of both food crops as well as oil palm can only be sustained if sufficient fertilisers and other inputs are provided. Such inter-cropping is only possible in the first three years of planting as there will be insufficient light for the inter-crops after that.

In the Far East, oil palms are cultivated on a plantation scale and therefore economic circumstances are quite different. Inter-cropping with food crops necessitates mechanical clearing which increases capital expenditure and the uncertainty of markets and prices have deterred any extensive cultivation of inter-crops. In recent years, however, low prices had engendered more interest in inter-cropping and *Chandapillai and Yeow [1]* showed that on undulating land, economic production of groundnuts is feasible. However, many questions on markets for large scale production, proper crop rotation systems and long term effects on the oil palm remain unanswered.

As for mixed cropping with other perennials, the most probable ones are coffee and cocoa. In both West Africa and Malaysia, it has been the experience that oil palm provides excessive shade for cocoa and early trials were not very successful *[8]*. According to *Hartley [6]*, on the Acid Sands of West Africa, satisfactory yields of coffee and cocoa could not be obtained alongside with oil palm. On the other hand, in the Congo basin, it was found that three crops of coffee amounting to 3 t per ha could be obtained in the immature period although under mature palms, yields of only 135 kg dry beans were got. In Sierra Leone, results seem to indicate that interplantings of coffee between wide spacings of oil palms on an alluvial soil gave a higher combined yield of bunches and beans in the early years than the two crops planted separately.

In Malaysia where yields are high, it is doubtful whether part of the production would not be sacrificed if another perennial is to be planted with oil palm.

Appendix 1

Common and Chemical names of some Weedicides

Type	*Common name*	*Chemical name*
Contact	Sodium chlorate	Sodium chlorate
Contact	Sodium arsenite	Sodium arsenite
Contact	TCA	Trichloroacetate
Translocated	2, 4-D	2, 4-dichlorophenoxy acetic acid
Translocated	2, 4-D amine	Amine derivative of 2, 4-D
Translocated	MCPA	4-chloro-2-methylphenoxyacetic acid
Translocated	2, 4, 5-T	2, 4, 5-trichlorophenoxyacetic acid
Translocated	Dalapon (Dowpon)	2, 2-dichloropropionic acid
Translocated	Amitrol (Aminotriazole)	3-amino-1, 2, 4-triazole
Contact/translocated	MSMA	Monosodium methyl arsonate
Mainly contact	Diquat	1:1 ethylene – 2:2 dipyridilium dibromide

Type	*Common name*	*Chemical name*
Mainly contact	Paraquat (Gramoxone)	1, 1-dimethyl 4, 4-bipyridilium dimethyl sulphate
Translocated	Atrazine	2-chloro-4-ethylamino-6, isopropylamino-s-triazine
Translocated	Simazine	2-chloro-4, 6-bis (ethylamino)-s-triazine
Translocated	Monuron (CMU)	3-(p-chlorophenyl)-1, 1-dimethylurea
Translocated	Diuron (DCMU)	3-(3, 4-dichlorophenyl)-1, 1-dimethylurea
Translocated	Fenac	2, 3, 6-trichlorophenylacetic acid
Translocated	Lasso	2-chloro-2, 6-dimethyl-N-(methoxymethyl) acetanilide

Appendix 2

Principal uses of some herbicides

	Herbicid	*Control*
A. *As foliar application*	2, 4-D and MCPA	Selective translocated spray on broadleafed plants. Do not affect grasses or hard woody species at normal rates.
	2, 4, 5-T	As for 2, 4-D but controls many broadleafed weeds not affected by 2, 4-D or MCPA.
	Arsenicals, e.g. sodium arsenite, MSMA	Non-selective, control all types of vegetation.
	Sodium chlorate	Non-selective, as above.
	Dalapon	Controls grassy but not broadleafed weeds, absorbed by roots and leaves.
	Diquat/Paraquat	Controls broadleafed and grassy annuals, but mainly contact effect on grasses.
	Amitrol	Controls hard to kill perennials, usually used in a mixture with other chemicals, does not persist in soil.
	Atrazine	Controls both broadleafed and grassy weeds, also used as a soil treatment.
B. *As soil application*	Atrazine	Prevents seedling growth for varying periods according to dosage rate.
	Diuron	Controls germinating seeds and young seedlings, best effect with high soil moisture.
	Fenac	Controls germinating seeds and young seedlings. Long persistence.
	Simazine	Controls germinating seeds and young seedlings.

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7. Diseases and Pests

The oil palm, like any other agricultural crop, is beset by problems of diseases and pests which, if uncontrolled, can lead to its death.
Diseases such as vascular wilt, bacterial bud rot, dry basal rot and Ganoderma trunk rot have been devasting in Africa while in the Far East, basal stem rot is equally destructive. Pests are becoming increasing important and while some control measures are available, more long term investigations are necessary. Disease and pest problems are dealt with according to the period of growth of the palm. Diseases are predominantly of fungal origin. More detailed works on diseases and pests have been published recently *[12, 17, 18]*.

7.1 Nurseries

Pre-nursery

7.1.1 Diseases

Leaf diseases are more prevalent in Africa than in the Far East and are described below.
Freckle: This is a serious disease of nursery seedlings in West Africa. First indications of infection are small hyaline spots surrounded by a yellow green halo on the youngest leaves. These increase in size and turn dark brown and slightly sunken at the centre. Conidiophores and conidia are formed in the brown lesions and these can cause secondary infection. Consequently, the dark lesions can coalesce. The fungus responsible is *Cercospora elaeidis*. Fortunately, it can be partially controlled by spraying with Dithane 45, Captan or Cuman. This disease also extends to field plantings.
Seedling blight caused by *Curvularia masculans*, and Anthracnose caused by *Glomerella cingulata*. There are similarities between the diseases. First symptoms appear on the youngest opened leaves as minute, chlorotic spots which later become bigger with a reddish-brown centre. As leaves mature, these spots develop a yellow to orange halo around the margin. In seedling blight, the spot is of variable size and has a brown dead spot with concentric rings within the yellow to orange halo. In Anthracnose, the spots are confined to areas between veins and are small and reddish

brown in colour inside the yellow to orange halo. Anthracnose can also be caused by species of *Botryodiplodia* and *Melanconlum* in Nigeria whereas in Malaysia, it is mainly due to Glomerella.
Mild infections have no apparent effect on seedling growth but in severe cases entire leaves may be killed. Excessive watering favours the incidence of Anthracnose. Dead or dying leaves should be removed. For control, carbamate fungicides such as Zineb for Anthracnose, Thiram, Zineb or Captan for *Curvularia,* should be sprayed.
A further disease that can affect nursery seedlings is a root disease called blast, caused by a species of *Pythium*. The cortex of root is destroyed leaving the stele. Leaves become dull green and then brown and dessicated and the plant eventually dies. Lowering soil temperature by shading, watering and mulching helps to reduce the infection.

7.1.2 Pests

Nursery palms are attacked by a fairly wide range of pests from mites, insects to rats. Most are leaf eating insects but rats are the most damaging as whole plants are destroyed. The more common pests, their damaging habits and control measures are given in Table 21.

Table 21. Major pests of nursery palms and control measures

Pest	*Damage*	*Control*
1. Insects		
a) Red spider mite *(Oligonychus spp.)*	Causes pin sized chlorotic spots over upper leaf surface.	Spray with Rogor 40.
b) Night flying beetles *(Apogonia spp.)*	Small round holes over entire leaf.	Lead arsenate sprays.
c) Grasshoppers *(Valanga nigricornis)*	Cut out large lobes of leaf tissue.	As above.
d) Crickets *(subterranean)*	Cut into base of spear and feeds on bulb.	Drench soil with dieldrex.
2. Snails	Eat tender leaf tissue.	Bait with metaldehyde.
3. Rats	Eat in stem base and may destroy seedling.	Use poison bait containing Tomorin or Warfarin.

Besides the above, symptoms of disorder due to fertiliser scorch or copper fungicides may also occur.

7.2 Field palms

Disease and pest problems change somewhat in field plantings as a new environment sets in although some of the nursery problems merely extend into the field. On the whole, pests pose greater threats but in certain conditions, diseases such as *Ganoderma* can prove to be fatal.

7.2.1 Diseases

The most prevalent diseases, in chronological order are spear rot, bunch rot, upper stem rot, basal stem rot, and in West Africa, vascular wilt and dry basal rot.

Spear rot is most common in 2–3 year old palms but occurs sporadically and is not clearly associated with husbandry practices or soil conditions. However, palms generally recover from the malady. The brownish rot appears on the spear tissue, usually about half way along its length. The older spears bend over while fronds are curved with leaflet stumps remaining in the region where rotting occurred in the spear stage. The actual organism responsible has not been authentically identified. As a measure of control, the diseased spear tissue is excised to prevent infection of newly emerging spears.

Bud rot: This disease attacks the spear bases and the bud of mainly young palms and is often associated with insect damage. The central spear can easily be pulled out of the bud and a foul odour detected. If the bud is affected, usually the palm dies but if not, new leaves will develop although they are short and compacted giving the 'Little Leaf' appearance. In Malaysia, the cause of bud rot has not been established but in West Africa, Duff *[3]* showed that bud rot/little leaf was caused by a bacterium of the genus *Erwinia*.

Upper stem rot: This is not a serious disease and is found on palms over 8 years old in the Far East. In Malaysia, this disease was first studied by *Thomson [13]* who found that in some cases palms might not show any foliar symptoms in the often advanced stages. However, later work *[16]* indicates that it is common to find on diseased palms symptoms similar to those caused by root diseases. Lower leaves first become yellow and die from the tip to the base. This condition progresses to the middle of the crown and finally the spear leaves are affected. Initially, the stem tissues show a brown rot while the roots of the palm are not affected.

The fungus responsible for this disease is *Fomes noxious*. The mode of infection is by means of spores which colonise the cut surfaces of leaves or pruning wounds and invade the leaf bases and stem. Fructifications are greyish brown in colour with a velvety brown margin, usually found at least 2 m up the stem. Palm stems may snap off prior to the appearance of these fruiting bodies. *Navaratnam and Chew [7]* found that the disease was more associated with potash deficient palms.

Sound nutrition may mitigate against the occurrence of the disease. In mild cases the infected tissue can be cut out and the exposure painted with coaltar *[16]*.

Bunch rot: This disease is found in the Far East and is caused by a fungus, *Marasmius palmivorous* and occurs most frequently at the commencement of harvest and in areas where pollination is inadequate. It is most prevalent during wet weather and appears as white mycelia running over and between the fruits. On leaf stalks, it is found at the base. Normally, the fungus attacks fruits at about ripening when the mycelia penetrate the pericarp and consequently, oil quality is impaired. Fruiting bodies are abundant and have a white cap 5–7 cm across but in dry weather, the cap is pinkish and smaller.

Control consists of removing the poorly pollinated and sterile bunches by sanitation rounds, particularly before the wet season and introduction of assisted pollination.

Figure 9. Symptoms of Basal Stem Rot on a 7 year old palm, showing death and desiccation of the lowermost leaves and an accumulation of unexpanded spear leaves.
Source: Diseases and Disorders of the Oil Palm in Malaysia. *Turner P.D. and Bull R.A.:* Incorp. Soc. Planters, Kuala Lumpur (1967)

Ganoderma trunk rot or basal stem rot (Figure 9): The disease known as *Ganoderma* trunk rot is endemic in Africa but in Malaysia it is known as basal stem rot and attained significance in post-war plantings particularly on alluvial soils and this led to a sizable amount of investigations into its nature and factors influencing its occurrence. In Malaysia, the disease usually affects palms of 10 years of age or more; in Africa it is a disease of senescence in the palm groves and so far has not been a serious plantation disease. According to *Turner [15]*, at least three species of Ganoderma have been recorded, viz. *G. applanatum, G. lucidum* and *G. pseudofferum,* of which the most common is *G. lucidum. Navaratnam [5]* was successful in inoculating oil palms with a pure culture of *G. lucidum.*

The ultimate effect of the infection is to cut off supplies of water and nutrients to the aerial parts of the palm. The first indication of infection is the production of a number of unrolled fronds or spears in excess of the normal 2–3 per month. The upper fronds become pale yellowish green in colour while the lower ones become brown from the tip backwards, die and droop or fracture. Eventually, the whole crown dies with rolling of the stem base. If the infection is restricted to the central core of the stem, the palm may fall before fructifications are produced.

Fructifications first appear as small white buttons at the stem base. These gradually develop into typically shell-like brackets with a brownish shiny surface and dull white under surface. The bodies arise directly from the side of the diseased tissue. Fruiting bodies are perennial and a new sporophore is sometimes formed one below another that is dead. The internal symptoms show a characteristically yellow zone at the edge of the infected area within which occur the reaction zones or dark brown bands. Within these brown bands or lines, the tissue is brittle and much lighter brown in colour and contains mycelia. The rot is typically dry. Infection can be mainly in the centre of the trunk, lateral or both.

In Malaysia, *Turner [14, 15]* found that the incidence of *Ganoderma* is related to the previous crop. The malady was light in the case of areas planted from forest or rubber, maximum infection being 2.2% and 5.5% respectively for palms of 5–17 years old. Means were all less than 2%. For old palms, it was found that the incidence increased with age, from 3.7% at 21 years of planting to over 25% at 35 years or more. This implies that the incidence in palms replanted from oil palms could be expected to be greater. Another crop which would favour the incidence of *Ganoderma* is coconut. It was found that on ex-coconut fields on coastal alluvial soils, from about 10 years of planting onwards, the incidence increased from 17 to over 40%.

It was thought that from about the second to eighth year, the fungus would colonise stumps of coconuts, especially the bole and from 8–10 years, the pathogen would grow along oil palm roots. From then on, the fungus would establish itself within the base of the stem.

There is no known control of the disease but preventive measures are possible. At the time of land clearing, all potential sources of infection from old stem and roots of coconut or oil palms should be destroyed. Infected palms should also be removed and burnt.

Vascular wilt: This disease is found in West Africa *[21]* and the Congo and is not known in the Far East (Figure 10). In mature palms, lower leaves lose turgidity and change colour from green to brown at the tip first. They then break at some distance from the base and hang down around the upper part of the trunk. These symptoms appear gradually in middle fronds producing a tent of dessicated brown broken leaves. New leaves are much reduced in size and it may be some years before all leaves of affected palms dry out completely. In young palms, a condition known as 'lemon frond' first develops in a middle frond.

The disease is caused by *Fusarium oxysporium* which gains entry into the palm via the root tip from the soil. It cannot be controlled easily or economically by fungicides as the fungus is soil borne. However, selection of resistant palms by I.R.H.O. and Unilever Plantations holds good promise *[12]*.

Dry basal rot: The pathogen responsible for this disease is a fungus *Ceratocystis paradoxa [9]:* Rotting of fruit bunches in a normal palm is the first symptom followed by a sub-medium fracture of the rachis of lower leaves which then wither and die. This condition then progresses upwards to the youngest spear leaves and is due to the cessation of water and nutrients because the basal trunk tissue is destroyed. In cross section, there is a clearly defined transition zone between the diseased and healthy tissues. There are two types of conidia, the thin walled hyaline cylindrical microconidia and the thick walled dark chain-like macroconidia. The fungus enters the palm either via the roots or cut leaf bases. In Nigeria this disease has been locally devastating.

Dry basal rot is not common in Malaysia.

In Africa, *Wardlaw [22]* found that root and trunk rot could also be caused by the fungus, *Armillaria mellea*. The fungus originates in old infected stumps of certain forest

Figure 10. Vascular Wilt on a 16 year old palm. The rachides of the leaves show a sub-median fracture and the leaves then form a cloak around the stem of the palm.

Source: *Robertson J.S., Prendergast A.G. and Sly J.M.A.:* J.W.Afr.Inst. Oil Palm Res.4, No.16 (1968)

species. It enters the roots of adjacent palms and exploits the cortex of the root and then passes into the cortex at the base of the trunk. The rhizomorphs then spread around the trunk causing rotting and eventual falling away of the leaf bases, and inward and upward rotting of the trunk. Mushroom-like fructifications are abundant on the trunk and near the ground during the wet season. External symptoms include chlorosis and wilting and breaking of fronds, not unlike those of vascular wilt. Palms of 4–10 years of age are more susceptible and death can occur within 2–3 years.
Control measures include elimination of sources of infection and felling and removal of palms in severe cases.

7.2.2 Pests

Pests of field palms comprise a fair number of insects, small mammals and birds; the mammals and some of the insects can lead to complete destruction of the palm. Most insect pests devour green leaf tissue while the small mammals attack the bud tissue and fruit. The ensuing accounts on major pests of Africa and South America have been largely drawn from the text of Hartley.

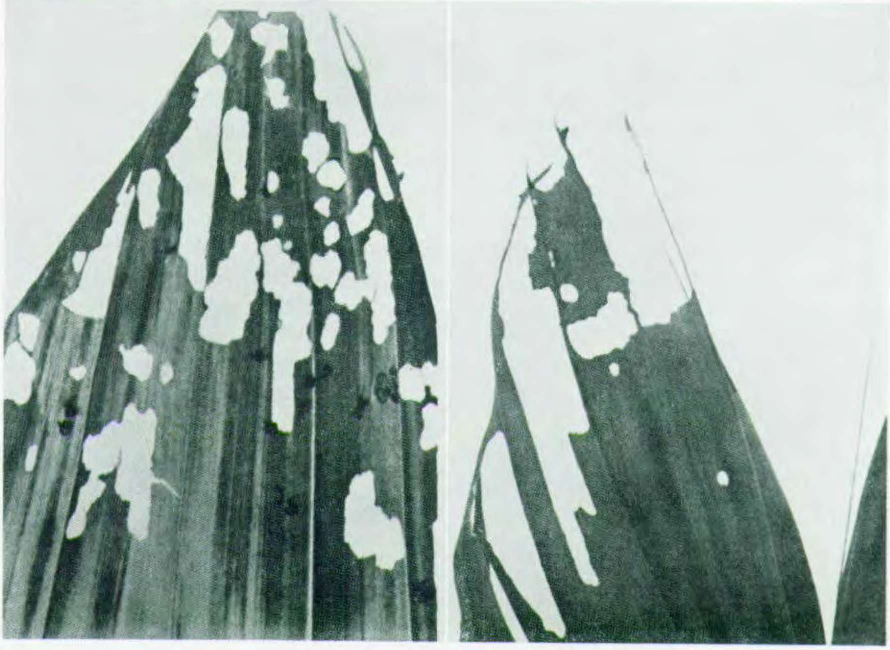

Figure 11. Leaf of nursery palm damaged by cockchafers by Apogonia (left) and Adoretus (right). Source: *Wood B.J.*: Pests of Oil Palms in Malaysia and their Control. Incorp. Soc. Planters, Kuala Lumpur (1968)

– *Coleoptera (Beetles)*

The common beetles which attack palms are:

(a) Cockchafers or night flying beetles (Figure 11): These nocturnal beetles are common in Malaysia, the species being *Apogonia expeditionis* and *Apogonia cribricollis*, a small black beetle approximately 9 mm long. The other species is *Adoretus compressus*, which is a leathery brown beetle about the same size as *Apogonia*. Both these beetles eat out round or jagged holes over the entire leaflet surface and in a severe attack, leaflets are almost devoid of laminae. They feed between dusk and dawn and during the day, hide themselves in the soil around the palm.

The pest can be controlled to varying degrees of success with insecticides such as Dipterex, lead arsenate or BHC.

Recently in West Malaysia, *Wood and Ng [20]* reported that young palms could be completely destroyed by another species of cockchafer *Psilopholis vestita*, the attack affecting individual palms within a field of about 25 hectares. The havoc is wrought by the grubs or larvae which feed extensively on the root system of the palm. Consequently, the palm turns yellow resembling nitrogen deficiency and the spear leaves fail to unfold and eventually the palm withers and dies.

The adult is a large brown beetle and the sexes cannot be distinguished by external appearance. The eggs are laid in the soil and the larvae or grubs are white fleshy C shaped which mature in about ten months. Grubs are mostly found in the first 15 cm of soil although they can be located as far down as 45 cm. It is these grubs that feed on the roots and if unchecked go on to destroy the palm. This cockchafer is different from the smaller leaf-eating cockchafers such as Adoretus compressus.

Complete control of the pest has not been obtained but grub population can be significantly reduced by a combination of rotavation and soil drenching with 4.5 l/palm of dilute solution of Telodrin (0.025% a.i.), aldrin (0.05% a.i.) or heptachlor (0.5%). Although expensive, this measure can remove the risk of palm death.

(b) Rhinoceros beetles (Oryctes species): Rhinoceros beetles are of economic importance in oil palm growing areas. In the Far East, *O. rhinoceros* is the dominant species but in Africa, the most common is *O. boas*. The male adult has the characteristic rhinoceros horn, which is small in the female. It is a large black beetle being 40–60 mm long and 20–30 mm broad. The beetle is nocturnal in habit and feeds on the developing spears in the crown and bores through the petioles into the softer tissues of the unopened leaves. If the rachis is penetrated, leaves may snap off. An attack on young palms is most dangerous because once the bud is affected, bud rot may set in and this can lead to death of the palm. The eggs are laid in decomposing matter such as tree trunks or stumps, refuse heaps or sawdust.

Control by insecticides or trappings have been unsuccessful or too costly and sanitary measures have proved to be the most practical and effective. Breeding sites such as rotting vegetable matter should be eradicated and followed by collection and burning of larvae. This is not always easy as the co-operation of neighbouring growers of other crops may have to be sought.

In South America, the equivalent is the Strategus Beetle. The adults attack nursery or young field palms by entering the ground and bore their way into the growing point and thus killing the plant. The palm can also be consumed by larvae from eggs laid in the palm.

This beetle, like Oryctes, also breeds in rotting vegetation and good field sanitation is important as a preventive measure. In severe outbreaks, drenching the soil around the palm with 0.2% solution of Endrin was found to be effective in Colombia.

(c) Hispid leaf miners: In West Africa, the beetle *Coelaenomenodera* elaidis is of significance. Recently, serious attacks by the pest have occurred in Ivory Coast and West Cameroon. The larvae, about 5 mm long, burrow under the upper epidermis of the leaflets of palms normally above three years in the field and destroy the leaf tissue. In severely attacked palms, the young leaves which are mostly unaffected remain green but the remainder are grey-brown and wither with dessicated rolled-in leaves. Later, the withered laminae shatter, leaving the midribs only. The adult beetle is pale yellow with reddish wing cases. Eggs are laid on the under side of the leaf.

Effective control of the adult insect can be achieved with 25% BHC as a dust. Control of the larval stage is more difficult and expensive.

In Ecuador, the Alurnus beetle is an important pest. This beetle is larger than the leaf miners previously mentioned. Eggs are laid typically in rows of seven to ten in the leaflets or rachis. The larvae are light brown and reach 40 mm before pupating. In a severe attack, the laminae are almost eaten away leaving the midribs. Larvae can also be found in the unopened spear leaves.

The natural predators are mites and wasps but in serious outbreaks, Heptachlor, Toxaphene and Metoxychlor are reported to have given control.

(d) Curculionidae (Weevils): Temnoschoita species. These weevils are found in Africa but appear to be more common in the Congo than in West Africa. The commonest species is *T. quadripustulata.* The adults are 8–10 mm long and dark brown in colour with light brown wings. The eggs are laid on cuts and wounds on the leaf petioles of young palms. The young larvae tunnel their way into the heart of the palm and can cause death. In bearing palms, the eggs are preferably laid in the inflorescences and bring about rotting.

Measures suggested for limiting damage by this pest include (a) avoidance of wounding by excessive pruning, (b) collection and destruction of rotten bunches and scattered fruit, and (c) a general cleaning of the crown followed by dusting twice with BHC at three weekly intervals, the dust applied in the crown from centre to the base.

– *Lepidoptera (moths and butterflies)*

The important pests found in this group include bagworms and various types of caterpillars, and the African spear borer.

Bagworms: These pests are mainly associated with the Far East and the common species are *Metisa plana* and *Cremastopsyche padula.* The larvae are encased in bags, made of pieces of leaf bound with silk. They feed on the upper surface of the leaf and the scraped portion first becomes dried out and forms a hole. Further damage is wrought by the removal of leaf to make the case. The larvae prefer to feed on older leaves and as a result, it is usual to find the younger leaves free from attack.

For control, if attacks are minor, hand picking may be used but for larger outbreaks, lead arsenate or Dipterex can be used.

Caterpillar (Tirathaba mundella): This pest is commonly known as the oil palm bunch moth. The adult moth has black eyes and orange yellow abdomen and hind wings. In the male, the forewings are grey pink and in the female, they are green with red veins. The adult is about 23 mm in length. The caterpillars are light to dark brown in colour and feed on the young inflorescences and fruit bunches, resulting in damage of young kernel. The pest can be controlled by spraying with Dipterex.

Nettle caterpillar (Setora nitens): This pest is found throughout South East Asia. The adult is a robust moth with a wing span of 30–35 mm. The forewings are brown and somewhat glossy. The female lays its eggs on the underside of the leaflet near the tip and the caterpillars usually feed on the under surface and eat away the whole lamina, leaving the midrib. They then drop to the soil and pupate. The larva measures about 35 mm when fully grown, its colour varying from greenish yellow, orange, pale bluish green to almost brick red.

The caterpillar has a number of natural predators and outbreaks have been claimed to be attributed to the use of insecticides. However, where attacks are serious, control can be obtained with lead arsenate.

Other common nettle caterpillars in South East Asia are *Orthocraspe terima* and *Plonetta diducta* which attack the whole leaf surface and in severe cases, only midribs remain. They can be controlled with lead arsenate sprays.

– *Slug caterpillars (Parasa viridissima* and other sp.)

This caterpillar is found mainly in West Africa *[1].* The adult is a green hairy moth, the pupal cocoons being attached to the rachis or old leaf bases. Attacks are mostly on adult palms, the caterpillars feeding from the tip of the leaflets and may result in complete defoliation. Fortunately, fungi and natural predators keep the population in check by attacking the larvae and pupae and general control measures with insecticides are not necessary.

– *The African spear borer (Pimelephila ghasquiery)*
This pest damages leaves of young palms in Africa, especially those of 2–5 years old. The eggs are laid at the base of the upper leaves and the larvae penetrate the rachis and leaflets of the unopened spear. The attack may proceed downwards towards the growing point and the young leaves may later snap near the base. Generally, the caterpillar does not kill the palm but secondary bud rot may. The caterpillars change from dark red to yellowish as it develops while the moth is olive to brown.
In the Congo, it has been found that serious attacks can be checked with sprays of DDT or Endrin.

– *Grasshoppers (Acrididae)*
These are relatively large insects which feed on the pinnae of nursery and young plantings. Generally, the attack is not serious but in some cases, a considerable amount of green tissue can be lost and this can have an effect on yield. In Malaysia, the most common species is *Valanga nigricornis*. The adult is large, being 70–80 mm in length. It is yellowish green in colour with black markings while the hind wings are reddish. The eggs are laid in the soil and on hatching feed on the ground vegetation and later on the palms. They are active during the day.
The grasshopper has natural predators which include small mammals, birds and beetles. Where the population is large, control with insecticide is available. Lead arsenate at 4 kg/ha may be applied or alternatively, aldrin or dieldrin at 150–300 g/ha should give a good kill.

– *Mammals*
Rodents: Porcupine and Cutting grass. Both in South East Asia and Africa, severe damage and often total destruction of newly planted palms are done by rodents. In Malaysia, in recent plantings from jungle, the porcupine is the culprit *[2]* while in Africa, the equivalent is known as cutting grass *(Thryonomus swinderianus)*. In both cases, the animal eats through the leaf base to get at the heart of the plant. As a result, the apical bud is devoured and the young palm dies.
In Malaysia, it has been found that painting the palm collar with a poison paste containing zinc phosphide can be effective. A protective wire collar is of little avail. In Africa, however, the only effective measure of control appears to be the wire collar.
Rats: In West Africa and Malaysia, rats can cause considerable damage to nursery and newly planted palms by eating the young apical tissues or bud resulting in death of such palms.
In mature palms in Malaysia, rats can also become a major problem by attacking fruit bunches and young inflorescence. *Wood [19]* has estimated that rats can consume about 330 kg mesocarp per hectare per annum.
The most effective means of control is the use of stomach poison bait containing products called Warfarin or Tomorin, which can be mixed with bran and applied in

weeded circles or on bunches *[3]*. For young immature palms, a protective wire collar fixed to the palm base can also be effective.
Birds: In very recent years in Malaysia, parakeet damage has been reported *[19]*. No effective measure of control is known at present.

– *Natural biological balance*
An understanding of the biological balance in nature with respect to pest problems can help considerably the judicious use of pesticides. Many insect pests have natural predators and these can be used to advantage. Indiscriminate use of insecticides has been shown to eventually worsen pest problems because natural predators were also eliminated in the process and as a result, a natural check on a particular pest no longer existed. In the case of oil palm, numerous observations in Malaysia have shown that major outbreaks on a big scale of leaf eating caterpillars occurred after the use of certain insecticides initially applied against minor outbreaks *[18]*. Reliance on natural control in such minor cases would probably have avoided this situation.
In view of such reactions, the more modern concept of pest control centres on the integration of techniques involving knowledge on biological balance, cultural methods and insecticides.
The major pests of field palms and their control are summarised in Table 22.

Table 22. Major pests of field palms and their control

1. *Insects*		
a) Night flying beetles (*Apogonia* and *Adoretus*)	Eat green tissue.	Lead arsenate spraying 0.36–0.6% or Dipterex (0.1%).
b) Cockchafer grubs (*Psilopholis vestita*)	Feed on root system, ultimately killing palm.	Rotavate and drench soil with 0.5% a.e. of Aldrin, Heptachlor or Telodrin.
c) Hispid leaf miners (*Coelaenomenodera*)	Destroy leaf tissue.	BHC dust.
d) Rhinoceros beetles (*Oryctes*)	Attack young and spear leaves, leading to bud rot.	Control by eradicating breeding sites and grubs.
e) Bagworms (*Metisa and Cremastopschye spp.*)	Eat leaf tissue.	Spray with Dipterex at 1–1½ kg/ha is preferable to lead arsenate
f) Nettle caterpillars (*Setora and Ploneta spp.*)	Eat laminae, leaving midribs only.	Lead arsenate at 4 kg/ha or Dipterex at 2 kg/ha.
g) Grasshoppers (*Valanga*)	Cut out edges of pinnae.	Lead arsenate at 4 kg/ha or spray with aldrin or dieldrin.
h) Bunch moth (*Tirathaba*)	Feed on mesocarp and kernel.	Spray with Dipterex – 0.5 kg/ha.
2. *Rodents*		
a) Porcupines	Eat out apical bud.	Bait with zinc phosphide/coconut or flour.
b) Rats	As above.	Bait with mixture containing rice bran and Warfarin or Tomorin. Also use protective wire collar.

Appendix 1

Common and chemical names of fungicides

Group	*Common name*	*Chemical name*
Carbamates	Ferbam	Ferric dimethyldithio carbamate
	Thiram (TMTD)	bis (dimethylthiocarbamyl) disulphide
	Zineb	Zinc dimethyldithiocarbamate
	Ziram	Zinc ethylenebisdithiocarbamate
Organo-mercurials	Antimucin WBR	Phenyl mercuric acetate
	Aretan 6	Contains 6% mercury as methoxy ethyl mercury chloride
Other organic compounds	Captan	N-(trichloromethylthio) cyclohex-4-ene-1, 2-dicarboxyamide

Appendix 2

Principal insecticides used in oil palms

Chemical classification	*Common name*	*Main mode of action*	*Insects controlled*
Organo-chlorine	Aldrin (Aldrex)	Contact	Grasshoppers, root feeding cockchafers.
	BHC (Agrocide-lindane, gammexane)	Contact	Caterpillars, cockchafers, leaf hispid miners.
	Dieldrin (Dieldrex)	Contact	Ground dwelling insects, grasshoppers, caterpillars.
	Endrin (Endrex)	Contact	Caterpillars
	Heptachlor	Contact	Ground dwelling insects, cockchafers, rhinoceros beetle.
	Telodrin (Isobenzan)	Contact	Caterpillars, root feeding cockchafers.
Organophosphate	Dimethoate (Rogor)	Contact and systemic	Red spider mites.
	Malathion	Contact	Caterpillars, red spider mites.
	Trichlorphon (Dipterex)	Contact and stomach	Caterpillars and cockchafers.
Carbamate	Sevin (Carbaryl)	Contact	Caterpillars.
Inorganic	Lead arsenate	Stomach	Caterpillars and cockchafers.

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8. Nutrition and Manuring

Like other crops, the oil palm requires both macro- and micro-nutrients for growth and reproduction. Although the ash composition also contains sodium, silica and aluminium, the practically important mineral nutrients are nitrogen, phosphorus, potassium, magnesium, and boron. In the immature period of 2½–3 years in the field, vegetative growth dominates but later and during maturity, production of fruit bunches becomes equally important. Growth and bunch production reach a peak from about 7–10 years in the field and it is evident that if growth and production are to remain satisfactory, adequate nutrition is essential. Thus, in assessing the nutrient requirements of the oil palm, it is necessary to consider rates of vegetative and inflorescence production during the normal life span of the oil palm.

8.1 Dry matter production

The oil palm produces dry matter throughout the year and this comprises vegetative tissues such as leaves, stem and roots, and reproductive organs, i.e. male inflorescence and fruit bunches. While inflorescence production can be measured fairly accurately, with a perennial crop like the oil palm measurement of annual vegetative dry matter production on an experimental level is not only difficult but takes a very long time. The expedient approach of sampling whole palms of various ages is normally chosen by workers in this field and the rates of dry matter production are deduced from the cumulative data. A main limitation of this approach is that the sites used may be biased in terms of environmental factors and the sampling unrepresentative. Be that as it may, within the past ten years, separate growth analysis studies have been carried out in Malaysia and Nigeria.

Rees and Tinker [82] sampled palms of six age groups varying from 7 to 22 years old in *WAIFOR Main Station,* Benin, Nigeria. The data they obtained on dry matter production are shown in Table 23.

In Malaysia, separate estimates of dry matter production by palms from the time of planting to 17½ years planted on marine clays in Banting, Selangor were made and the results are as follows (Table 24).

It is evident that the biggest difference between Nigerian and Malaysian palms lies in the production of fruit bunches, which is about two to four times as great in Malay-

Table 23. Dry matter production of palms in Benin, Nigeria (kg/palm/yr)

Age (yrs)	Leaves	stem	Fruit	Total
7	55	—	25	—
10	62	31	35	128
14	54	19	29	101
17	66	22	48	136
20	86	18	30	132
22	84	17	28	129

Table 24. Dry matter production of palms in West Malaysia (kg/palm/yr). (1) Based on *Ng et al. [55]* (2) Based on *Gray [40]*

Age in field (yrs)	Leaves		Stem		Roots		Fruit*		Male inflorescence	Total	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(1)	(2)
0–1	5.2	n.d.	1.1	n.d.	0.6	n.d.	—	—	n.d.	6.9	n.d.
1–2	35.9	n.d.	14.8	n.d.	4.4	n.d.	—	—	n.d.	55.1	n.d.
2½–4½	63.0	80.0	20.6	14.9	12.3	10.2	42	50	n.d.	137.9	155.1
4½–6½	71.8	92.8	24.2	17.6	16.2	2.1	90	100	n.d.	202.2	212.5
6½–8½	83.0	93.6	25.9	12.4	10.2	1.7	100	100	4	223.1	207.7
8½–10½	83.2	105.0	30.5	20.8	5.2	2.5	100	100	4	222.9	228.3
10½–14½	87.5	105.6	37.5	21.8	3.5	5.0	100	100	4	232.5	232.4
14½–17½	85.9	105.6	37.5	19.4	2.0	2.4	100	100	4	233.4	222.6

* Estimated from yield records

sia. Leaf dry matter production is also somewhat higher in Malaysia. In total dry matter production, Malaysian production is nearly double that of Nigeria.

These differences are not due to a difference in leaf area index which is higher in Nigeria because of lighter pruning, but mainly to lower nett assimilation rate (Table 25). As a result of the lower nett assimilation rate, total dry matter production per hectare per annum is much lower in Nigeria as shown in Table 26. A notable point in the Malaysian data is the very rapid increase in dry matter production from the second year of planting. As a matter of fact, dry matter production in the second year is estimated to be eight times that in the first year and this has an important bearing on nutrition and manuring.

The much lower values obtained in Nigeria are due to climatic factors, the principal limitation being a long dry spell of 4–5 months in the year. Malaysia on the other hand, does not suffer from such a handicap and consequently growth is not retarded.

Table 25. Leaf area index (L.A.I.) and nett assimilation rate (N.A.R.) of Nigerian and Malaysian palms

Age (yrs)	L.A.I.		N.A.R. g/dm²/week	
	Nigeria	Malaysia	Nigeria	Malaysia
7	2.97	3.0	—	0.169
10	3.74	3.9	0.097	0.169
14	3.76	3.7	0.077	0.146
17	4.42	3.6	0.088	0.146

Table 26. Rate of total dry matter production (t/ha/annum)

Age (yrs)	Nigeria	Malaysia
0–1	n.a.	1.01
1–2	n.a.	8.58
2½–4½	n.a.	22.9
4½–8½	n.a.	31.2
8½–17½	18.3	34.0

The results also suggest that assimilates are first channeled towards vegetative tissues and only when these requirements are satisfied is the excess directed to fruit bunch production.

8.1.1 Leaf and inflorescence development

The estimates of total quantities of nutrients necessary for production of vegetative and inflorescence dry matter do not indicate the rates in which these nutrients are needed. The rates are dependent upon the process of morphological development of the tissue concerned and while no estimates of such rates have been made, the study of growth and flowering carried out by *Broekmans [10]* has contributed significant information on the matter. He defined three stages of development as follows:

(a) The stage of initiation of the leaf or inflorescence bud,
(b) the stage of sex differentiation of the inflorescence, and
(c) the critical stage in the development of the leaf or inflorescence when their rapid development makes them particularly susceptible to external influences.

The leaf and the corresponding inflorescence are initiated at about the same time and it has been estimated that a period of about two years may elapse between initiation and the central spear stage. Including anthesis, the whole period of development of the inflorescence from initiation to anthesis, which is about 9–10 months after the central spear stage, is estimated at approximately 33 months.

In leaf development, two phases have been distinguished. In phase one, which is from initiation to about the 7th to 10th leaf younger than the central spear leaf, the growth of the leaf is rather slow. However, in phase two, which is from the end of phase one to the central spear stage, the leaf grows rapidly from about 2 cm to round about 6 m in length in a short period of 4–6 months (Figure 12). This is a critical stage of development because adequate quantities of water and nutrients are necessary for full development. *Broekmans* considered that the growth of leaves in phase one is less affected by unfavourable conditions than that of leaves in phase two.

The development of the inflorescence is also associated with that of the leaf but there are certain distinctly different features. The most important stage is the stage of sex differentiation as at this stage is fixed the proportion of female to total number of inflorescences or sex ratio. Sex ratio varies considerably within seasons and between seasons. *Broekmans* estimated that sex differentiation takes place at about two years before flowering or anthesis and suggested that light and a dry season favour differentiation of female inflorescence as he found significant correlations between dry season

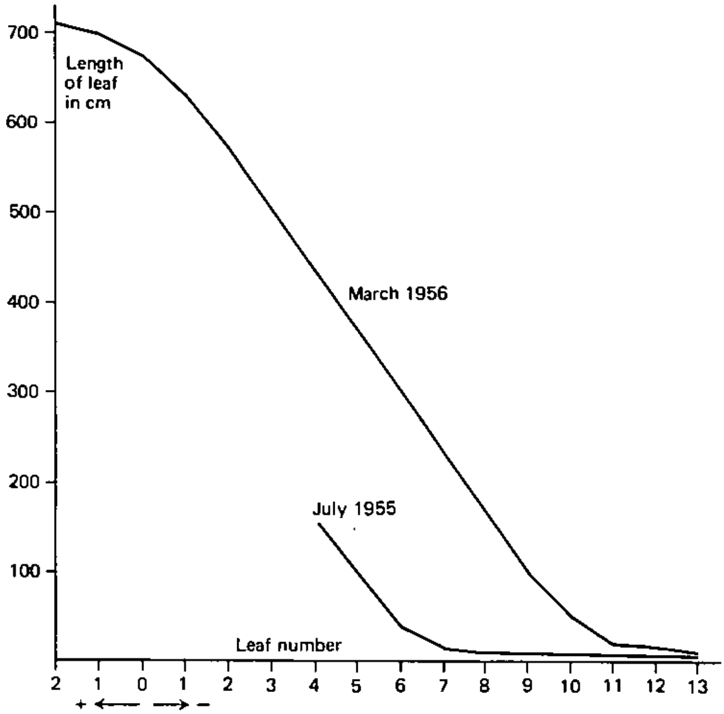

Figure 12. Development curves of the leaf in connection with leaf number obtained from the dissection of six palms in July 1955 and seven palms in March 1958 (leaf 0 is the central spear).
Source: *Broekmans A.F.M.:* J.W.Afr.Inst.Oil Palm Res. *2*, No. 7 (1957)

rainfall and both the average and maximum values of the sex ratio of inflorescences two years later.

The development of the inflorescence also goes through two phases. In phase one, which is from initiation to about leaf No. 7 in the crown, the development is slow. From the end of phase one to about leaf No. 17, i.e. phase two, the inflorescence increases in size rapidly (Figure 13). *Broekmans* found that it is at the beginning of phase two that the inflorescence is most likely to abort. This critical stage corresponds to about half way between the central spear stage and the anthesis stage, i.e. 4–5 months before flowering. Again, adequate supplies of water and nutrient are required during this critical stage to avoid abortion. Further investigations indicate that once this critical stage is passed, abortion is unlikely to occur. Furthermore, floral abortion is likely to have an important influence only in young palms.

Fluctuations in bunch yield of mature palms are largely under the influence of variations in the sex ratio. A close correlation was found by *Broekmans* between dry season rainfall and sex ratio and between dry season rainfall and bunch number two yield cycles later. Subsequently, much higher correlations were found by *Sparnaaij et al. [89]* between measures of «effective sunshine» and yield, effective sunshine being a measure of duration of sunshine in the dry season corrected for severity of drought.

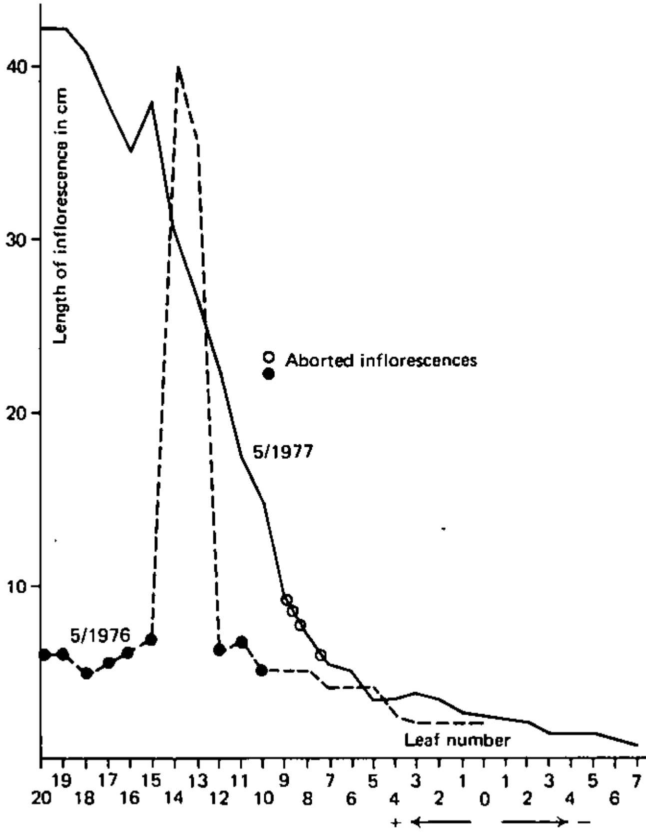

Figure 13. Development of the inflorescences of two Deli Palms in relation to leaf number (leaf 0 is the central spear)

8.2 Nutrient requirement

8.2.1 Major nutrients

The dry matter produced by the palm contains 6–10% mineral elements but the actual quantities of nutrients concerned depend on the amount of vegetative and inflorescence material produced. By chemical analysis of various component tissues, it is feasible to determine amounts of nutrients associated with dry matter production. *Tinker and Smilde [97]* determined nutrient contents in palms of 7–22 years of age in Nigeria while *Ng et al. [65]* analysed palms of 0–15 years in the field. The latter workers showed that Malaysian palms were richer in plant nutrients especially in potassium. Potassium contents in the Nigerian palms were generally rather low.
From their data, *Ng et al.* projected the basic nutrient requirements of palms from the time of field planting to 15 years and these are given in Table 27.

Table 27. Estimated nutrient uptake for annual vegetative dry matter production (kg/palm/yr)

Year in field	N	K	P	Mg	Ca	S
0–1	0.068	0.095	0.0056	0.017	0.013	0.012
1–2	0.509	0.965	0.0595	0.140	0.151	0.079
2–3	0.586	1.383	0.0673	0.139	0.145	0.170
3–5	0.771	1.533	0.0922	0.131	0.150	0.204
5–7	0.805	1.213	0.0897	0.091	0.118	0.181
7–15	0.809	1.086	0.0930	0.090	0.136	0.205

It can be seen that in the second year of planting, total uptake of all nutrients showed the greatest jump, being about 10 times that of the first year. This is because of the pattern of dry matter production. For the next three years, the additional increments were either considerably less or insignificant. Nitrogen and phosphorus uptake reached a maximum at about the 4th–5th year and this level was maintained up to the 15th year. In the case of potassium, uptake declined after the fifth year, probably indicating the drain due to fruit bunch production. These data show the order of nutrient uptake for vegetative growth of palms from planting to 15 years of age in a high yielding situation in Malaysia. In view of the fact that leaf analysis did not reveal any evidence of excessive or luxuriant uptake of nutrients, it was further assumed that in order to attain an equivalent rate of vegetative dry matter production, the values can be taken to represent basic nutrient requirements. A notable point is that requirements in the 2nd and 3rd year of field planting are high relative to the maximum figures and this has relevance to manurial schedules.
The uptake values for sulphur are notable because they are about double those of phosphorus. As sulphur occurs in the amino-acids, cystine and methionine, and it is also known to be important for some oil bearing crops, the nutritional role of this element in oil palm should not be overlooked. Of course, the presence of sulphur in common fertilisers such as ammonium sulphate, superphosphate and kieserite probably acts as some safeguard against any major occurence of sulphur deficiency.
As a result of the higher dry matter production, palms in Malaysia would be expected to have higher nutrient requirements than those in Nigeria or parts of Africa with climates similar to that of Nigeria. This is also borne out by the greater contents of nutrients in Malaysian palms as shown in Table 28.

8.2.2 Fruit bunch production

For a crop plant which exports such a considerable amount of produce off the land, the quantities of nutrients drained away for fruit bunch production are of major consequence to nutritional considerations. The early work in the Far East *[8, 38]* and the Congo *[107]* on this aspect are quite familiar to researchers on oil palm. However, there is appreciable variation in their values and new estimates have been obtained since. In previous cases, estimates were based on analysis of a limited number of fruit bunches. However, *Ng and Thamboo [64]* analysed bunches of various sizes and found very significant correlation between fresh weight of bunch and content of nutrient in the bunch. From the regressions obtained, they estimated quantities of nu-

Table 28. Total nutrient contents of palms in Nigeria and Malaysia (kg/palm). (a) = Nigeria (b) = Malaysia

Age (yrs)	N		P		K		Mg		Ca	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
7	0.94	2.58	0.11	0.29	0.93	5.58	0.29	0.62	0.40	0.60
10	1.67	3.34	0.15	0.35	1.34	6.62	0.42	0.80	0.58	0.91
14	2.11	4.32	0.25	0.43	1.35	8.25	0.63	1.11	0.72	1.27

trients taken up by various levels of bunch production. These were compared with those obtained previously and are shown in Table 29.

On the whole, there is better agreement amongst post 1960 data for N, P, and K; estimates of *Ferwerda, Tinker and Smilde,* and *Ng and Thamboo* are in reasonable agreement. For Mg and Ca, values of *I. R. H. O.* and *Ng and Thamboo* are higher than those of *Ferwerda* and *Tinker and Smilde.*

From the nutrient data for vegetative growth and fruit bunch production, *Ng and Thamboo* estimated quantities of nutrients taken up annually for growth and reproduction of 8–15 year old palms planted at 148/ha (Table 30).

Table 29. Various estimates of nutrients removed by 1 tonne of fresh fruit bunches (kg)

Source	Country	Fruit form	N	P	K	Mg	Ca
Maas	Sumatra	Dura	4.4	1.1–1.9	7.4–10.4	—	—
Georgi	Malaya	Dura	2.6	0.41	5.9	—	—
Blommendal	Sumatra	Dura	6.0	1.1	7.5	—	1.9
Wilbaux	Congo (Kinshasa)	Dura	4.5	0.68	4.2	0.4	0.54
		Tenera	4.5	0.76	4.5	0.65	0.70
Ferwerda	Congo (Kinshasa)	—	2.9	0.46	3.0	0.38	0.46
Tinker and Smilde	Nigeria	Dura	2.8	0.58	3.3	0.43	0.50
I. R. H. O.	Ivory Coast	—	4.7	0.67	4.7	0.67	0.67
Ng and Thamboo	Malaya	Dura	2.9	0.46	3.7	0.82	0.77

About a third of the N, K, and Mg, and nearly half of the P taken up is removed from the land in fruit bunches. Only about a fifth of the calcium is removed though.

Table 30. Estimates of total nutrients uptake by 148 adult palms per hectare per annum

Component	N		P		K		Mg		Ca	
	kg	%	kg	%	kg	%	kg	%	kg	%
1. Nett cumulative vegetative matter	40.9	21.2	3.1	11.9	55.7	22.2	11.5	18.8	13.8	13.9
2. Pruned fronds	67.2	34.9	8.9	34.2	86.2	34.3	22.4	36.5	61.6	61.9
3. Fruit bunches (25 tonnes)	73.2	38.0	11.6	44.6	93.4	37.1	20.8	33.9	19.5	19.6
4. Male inflorescence	11.2	5.9	2.4	9.3	16.1	6.4	6.6	10.8	4.4	4.6
Total	192.5	100	26.0	100	251.4	100	61.3	100	99.3	100

(26.0 kg P = 59.5 kg P_2O_5, 251.4 kg K = 302.8 kg K_2O)

8.2.3 Trace elements

Data on trace element contents and distribution in oil palms are limited but *Ng et al. [66]* found the following micronutrient contents in whole palms in Malaysia (Table 31).

Table 31. Micronutrient contents in aerial parts of palms (g/palm)

Age in field (months)	B	Cu	Zn	Mn	Fe
14	0.1	0.1	0.3	0.8	1.3
40	1.1	1.4	3.1	19.2	30.0
64	1.6	1.7	6.4	34.9	34.8
104	3.1	3.0	9.5	36.1	61.2
129	3.7	4.6	9.3	30.5	68.6
160	4.5	4.7	18.4	50.9	106.9

Boron and copper contents are the smallest, zinc about 2-3 times as much as the former two, and manganese and iron being the most abundant. For the period of 40–160 months of growth, it is estimated that the average amounts accumulating per annum are given in Table 32.

As can be seen, the quantities are quite small and suggest caution in the use of trace element fertilisers.

With the preceding data as background, it is feasible to plan out field experiments which take into full account the physiology of growth in a particular climatic region. The other major factor to consider is the soil i.e. its morphology and nutrient status.

Table 32. Estimated annual uptake of micronutrients by mature palms (g/palm)

Component	B	Cu	Zn	Mn
1. Cumulative vegetative matter	0.34	0.33	1.53	3.16
2. Pruned leaves	0.85	0.60	1.20	20.00
3. Fruit bunches	0.36	0.79	0.82	2.52
Total	1.55	1.72	3.55	25.68

8.3 Soil fertility conditions

The more modern approach to efficient fertiliser use on crops involves a better understanding of the physical and chemical properties of soils used for cropping. Soils are natural bodies produced as a result of the interaction of parent rocks, relief, climate, organisms and time. The pedological entities are defined in the field by soil surveys and then generally classified according to their profile characteristics of which the physical plays a major role. Thus, soil depth, colour, texture, structure, consistence, mottling and presence of impervious pans or layers, and the order of arrangement of soil horizons are the main criteria used in defining a basic soil unit. The most common unit of classification in the field is the *Series* which encompasses soils of similar profile characteristics derived from the same parent rock material. Further divisions called phases due to variations in depth or texture are also made but on the whole, the Series is probably the most suitable for agronomic purposes. For national mapping and soil correlation purposes, soil series are grouped at higher levels into Families and Great Soil Groups.

With soils thus defined morphologically, the associated chemical and mineralogical properties are also determined and wherever possible, the fertility or nutrient relationships are drawn. In this manner, the physical and chemical properties of classified soil units are known and this information is useful in the planning of field experiments as well as the interpretation of results.

Such information on soils of all oil palm regions is not available but since the Second World War, there has been some fairly extensive studies of soils in countries where oil palm is cultivated *[61, 91, 92, 98]* and these have thrown considerable light on the agronomic potential of soils in the areas concerned. This is particularly true of Malaysia and West Africa. *Hartley [48a]* has given a good account of the major soils in the various oil palm regions and it is not intended to cover the same ground here. However, a brief account of soils in the principal countries such as West Malaysia and Nigeria is attempted.

A. South East Asia

– *Malaysia*

The majority of oil palm plantings of Malaysia are found in West Malaysia or Malaya as it was formerly called although about 30000 ha are found in Sabah in East Malaysia. Soil information available *[62, 72]* has shown that for the oil palm, the following soils are of greater importance.

Gley soils of marine origin: These soils occur exclusively on the West Coast of Malaya and those supporting oil palms are mainly in the northern and central belts. They are essentially gleys of heavy texture with a naturally high water table but with artificial drainage, they are the most productive soils in the country. The most common soils are Selangor and Kangkong Series which are silty clays with organic content in the top soil varying from 2–8%. These soils are characterised by a moderate acid pH of 4.5–5.5, high cation exchange capacity and high magnesium and potassium status and moderate to high phosphate status. Generally, these soils do not respond to phosphate and magnesium application but occasional responses to nitrogen and potassium by adult palms have been obtained *[51]*.

Within these gleys are also found the acid sulphate soils developed under brackish conditions. Intensive drainage aggravates acidity with pH values commonly below 3.0. These soils generally have a mucky surface horizon overlying the cat-clay layer at 30–60 cm which on drying shows a characteristic yellowish encrustation which has been found to contain partly jarosite *[9]*. Yields of palms on normally drained areas are very low compared to the normal marine clays but recently satisfactory methods of amelioration have been devised *[49]*.

Alluvial soils of river flood plains: These soils occur along the lower reaches of the major rivers on the West Coast and have been deposited over marine sediments. These soils are silty clay loams to silty clays in texture with strong orange brown mottles with a low to moderate organic matter status. The nitrogen status is generally low but phosphorus, magnesium and potassium contents are moderate to high. Yield responses to nitrogen and potassium application have been obtained *[63]*.

Red yellow podsolic soils: These soils are the most extensive in the oil palm industry and comprise soils derived from igneous, sedimentary and older alluvial deposits. Parent rocks range from granites, quartzites and sandstones, sandy shales, and older alluvia. In most cases, they are deep (> 1 m), sandy loam to sandy clay loam in texture, friable to loose consistence and free drainage. The more common are Rengam and Jerangau from granitic rocks, Serdang and Kedah from sandstones, Bungor from sandy shales and Harimau and Ulu Tiram from older alluvia. The granitic and older alluvial soils are most extensive in the south of Malaya.

All these soils are characterised by good physical conditions of depth, porosity and satisfactory water holding capacity but chemically are low in organic matter, phosphorus, potassium and magnesium and cation exchange capacity. Their potassium and magnesium reserves are very low *[42, 60]*. These soils are thus deficient in all major nutrients and responses to fertilisers have been obtained *[83]*.

Grey yellow podsolic soils: These soils are derived from iron poor shales and consequently coarsely structured. They are pale yellowish grey clay loam to silty clays with blocky structures of very firm consistence in the subsoil which is impeded in drainage. Cultivation is difficult on these soils. Also, thin bands of lateritic concretions are commonly found within 60 cm of the surface although they are not impenetrable to roots. The most common Series are Batu Anam and Durian, which are marked by extremely low phosphorus and nitrogen status, the latter further aggravated by impeded drainage. The potassium status, however, is greater than that of the Red Yellow Podsolics due to variable amounts of micaceous clays present although it is not adequate to meet the demands of the oil palm. Magnesium contents are also low.

Reddish brown lateritic soils: These soils are clay loam textured derived from diorites and tuffs and moderately iron rich shales. They are well structured and friable and are among the best sedentary soils for oil palm. Chemically, they are also poor in nutrients but in the shale derived soils, potassium status may be moderate to high. Common series are Munchong, Kampong Kolam and Jempol.

Latosols: These are deep dark red or brown clays with crumb structure, derived from basic rocks, mainly basalts and andesite. Because of their good structure, they feel lighter in texture than the mechanical composition reveals. They are rich in iron, the contents of which are 20–30% Fe_2O_3. Phosphate status is moderate to high but potassium status is distinctly low. Nitrogen and magnesium contents are low to moderate but are higher than those of podsolic groups. A physical disadvantage of these soils is that they tend to dry out readily and this is important at planting time. These soils are new to oil palm planting as they have been under forests but so far, growth seems to be good. The common series are Kuantan and Segamat.

Laterites: These soils have a shallow surface horizon overlying a continuous solum of nodular or massive iron rich concretions, which generally constitute a physical barrier to root penetration. Water relations in such soils are poor because of the preponderance of coarse material. Where the surface layer is less than 38 cm, the soil is certainly not suitable for oil palm as there is evidence that yields are relatively low *[62].*

Peats: These organic soils occur on swampy conditions and on the West Coast, a limited acreage has been planted with oil palms. The raw and woody nature of the peat, poor drainage and high acidity (pH 3–4) are major characteristics. Where the peat is less than 1 m thick and overlies a non-acid sulphate clay, satisfactory yields can be obtained but where the peat is deep or overlies acid sulphate clay, yields are variable and low. Potassium, phosphorus and copper deficiencies are the more common factors in nutrition.
Chemical properties of Great Soil Groups found under oil palms are presented in Table 33.

– *East Malaysia (Sabah)*

Most of the oil palm plantings are located in the Tawau area in the south eastern seaboard but sizeable plantations are also found in the Labuk Valley in the north-central part of the state. In the Tawau area, soils are mainly latosols derived from recent basic volcanic ashes some of which have a high base saturation of over 80% and a pH near neutrality. These soils also have a high phosphate status and are therefore the most fertile in Sabah. Other latosols are more leached, not unlike the Kuantan and Segamat series found in West Malaysia. Associated with these soils are red yellow podsolics derived from sedimentary rocks. In the Labuk Valley, soils are mainly hydromorphic derived from recent alluvium of the river flood plain and the lower lying areas are subjected to seasonal flooding.

– *Indonesia (Sumatra)*

Oil palms in Indonesia are planted mainly on the eastern seaboard of Sumatra. There have been no recent systematic studies of the soils of this region but previous accounts of *Hall and Koppel [46], Dell and Arens [28] and Venema [102]* indicate that soils of oil palm areas are derived from acid and basic volcanic materials, sedimentary rocks and recent alluvial deposits. Venema called the soils of sedimentary origin latosols, which might be equivalent to the podsolic soils of West Malaysia. They are clayey sand to clay in texture and yellow to grey in colour and are usually low in nutrients, especially phosphorus. The rhyolitic, basaltic and andesitic soils also appear to be somewhat similar to those in West Malaysia but the recent liparitic soils are

Table 33. Properties of Major Soil Groups found in oil palms plantings in West Malaysia

Property		Great Soil Group: Latosols	Reddish Brown Lateritic	Red Yellow Podsolic	Yellow Grey Podsolic	Marine Gley
(i) pH	T	3.5–5.3	3.7–5.6	4.3–5.0	4.0–5.0	3.9–5.3
	S	4.1–5.0	4.3–4.6	4.3–5.2	4.0–4.8	3.7–5.4
(ii) C%	T	1.20–5.81	1.10–4.37	1.08–4.74	0.56–3.90	1.26–7.25
	S	0.61–3.34	0.30–1.14	0.23–0.71	0.31–0.89	0.36–5.34
(iii) N%	T	0.10–0.38	0.07–0.41	0.05–0.25	0.05–0.31	0.15–0.48
	S	0.04–0.22	0.04–0.14	0.02–0.14	0.03–0.12	0.07–0.31
(iv) Inorganic P (NaOH) ppm	T	65–406	26–95	20–75	17–86	65–158
	S	49–389	12–80	15–65	13–64	32–135
(v) Exch. K m.e. %	T	0.06–0.60	0.05–0.40	0.07–0.32	0.04–0.29	0.23–1.57
	S	0.03–0.34	0.02–0.49	0.03–0.13	0.03–0.16	0.34–0.97
(vi) Exch. Mg m.e %	T	0.31–0.93	0.21–0.83	0.16–0.59	0.10–0.73	1.27–12.6
	S	0.10–0.59	0.05–0.30	0.05–0.42	0.05–0.58	0.42–10.0
(vii) Exch. Ca m.e. %	T	0.10–0.78	0.10–0.45	0.05–0.32	0.21–0.42	1.16–6.90
	S	0.03–0.20	0.05–0.21	0.02–0.20	0.05–0.21	0.58–5.20
(viii) 6N HCl Sol. P ppm	T	220–1320	90–260	52–190	46–187	209–580
	S	214–1110	26–231	46–142	28–160	90–500
(ix) 6N HCl Sol. K m.e. %	T	0.37–1.97	0.57–9.83	0.32–4.73	0.96–14.1	0.50–12.5
	S	0.32–1.69	0.81–10.8	0.30–5.93	2.52–18.1	6.36–13.6
(x) 6N HCl Sol. Mg m.e. %	T	1.68–6.91	1.08–9.48	2.48–4.66	2.36–6.51	2.38–10.6
	S	1.60–5.28	1.28–15.4	0.80–4.68	2.34–5.95	2.67–17.8

T = 0–15 cm
S = 15–30 cm

said to be richer in potash minerals. On the coastal flats, recent accounts indicate that clay soils of marine and riverine origin as well as peat exist. It is possible that these coastal soils are somewhat similar to those found on the West Coast of West Malaysia.

B. Africa

– Zaire

The oil palm region lies in the north of the country between latitudes 1° S and 3° N, as well as the south in Kinshasa and Kasai provinces between 4–7° S. In the north, the climate is more even whereas in the south there is a dry season of 3-4 months.
Sys [91] has made a study of the soils in the Congo. In the northern region, important soils are latosols which are also called hygro-kaolinitic ferrasols, free draining but low in mineral reserves. The most common is the Yangambi type which has a pH of 4.4–4.6, a cation exchange capacity of 3–5 m.e.%, a sand fraction of 60–70% and organic carbon of about 1.2% in the top soil. They are mainly brown to reddish yellow in colour. The major parent material is wind blown sandy deposit but granites and sedimentary rocks are found in some cases.
The other major soil group in the north comprises Gleys which are formed on recent alluvial deposits. These soils have a high cation exchange capacity and are richer in nutrients. They are thus the better soils for oil palms.
In the southern region, very poor sand Latosols prevail. They are derived from wind blown sands and contain only 6–8% clay and are thus very low in nutrient status. Slightly better soils are found to a limited extent on sedimentary rocks and are called the Karoo latosols. They are better in nutrient status and good groves are associated with these soils.

– Cameroons

Podsolic and hydromorphic soils are amongst the major soils of the Cameroons *[17]*. Soils of oil palm areas are derived from ancient basaltic flows which are fairly leached because of high rainfall. On the coastal flats, marine alluvial soils occur but they are lighter in texture than those in West Malaysia. On the west, plantations have been established on latosols derived from basement complex rocks of granite, mica and quartzose schists which have been affected by gravelly drift. The topography of the formations is generally steep and consequently soils are shallow. On less steep terrain, soils are deeper and more favourable for oil palm growth. These soils are low in nitrogen, phosphorus and magnesium but potassium can be in moderate supply according to Nigerian data for similar soils.

– *Nigeria*

Soils of oil palm areas in Nigeria have been studied by *Vine [103]*, *Tinker and Ziboh [98]* and *Tinker [92]*.
The basement complex soils of Eastern Nigeria are similar to those of Cameroons but the greater portion of oil palm groves in Nigeria is established on Cretaceous and Eocene unconsolidated beds of coarse sandstone interspersed with varying layers of clay. These soils are very extensive, surrounding the Niger delta and running some 500 km from west of Benin to Calabar. These soils have been studied by *Vine* and *Tinker and Ziboh*. The sandy parent materials are referred to as Benin Sands from which two major latosols developed. They are:

(a) Benin fasc, which are generally reddish clayey sands to sandy clays with reddish brown topsoil. This soil is developed in areas of high rainfall of about 1780 mm with a severe dry season. The sand content is commonly 80-90%.
(b) Calabar fasc, which is similar in texture and depth to the Benin fasc but yellow to yellowish brown in colour, occuring in areas with a slightly higher rainfall but a less severe dry season (2000 mm). Sand content is about 90%.

Both these soils are low in organic matter content but the Calabar fasc is relatively more leached. Thus, while the Benin fasc soils are markedly deficient in potassium with magnesium contents being moderate, the Calabar fasc soils are markedly deficient in both potassium and magnesium. The main problem with these soils is their poor water holding capacity and retention of added nutrients; water stress is particularly prominent during the long dry season.
Intergrades of these soils are also known to occur while lateritic soils occur in places and are even poorer than the Acid Sands. Chemical analysis of the major soils in Nigeria are shown as follows in Table 34.

– *Dahomey*

The climate in Dahomey is even drier than Nigeria although it is still an important producer of oil palm products. However, yields are low generally. Accounts of soils of the oil palm areas have been given by *Furon [37]* and *Surre and Ziller [90]*. The most common soil appears to be a sandy clay soil derived from sedimentary rocks. The surface horizon of 30–40 cm is a greyish brown sandy loam overlying a deep red sandy clay subsoil. This soil bakes hard during the dry season. Exchangeable potassium content is low being about 0.1 m.e. % on average but magnesium content is higher.

– *Ivory Coast*

According to *Leneuf and Riou [55]*, the greater part of the oil palm plantings is on soils derived from Tertiary sandstone which are not too different from the Acid Sands

Table 34. Chemical composition of Nigerian soils planted to oil palms

Property		Soil series or derivation				
		Benin fasc	Calabar fasc	Benin/Calabar Intergrade	Basement complex	
					Granitic	Schistic
(i) pH	T	4.9–6.0	4.4–5.2	4.7–5.8	3.6–4.9	4.0–4.6
	S	4.5–6.4	4.0–4.9	4.5–5.3	5.2–5.3	4.9–5.3
(ii) C%	T	0.72–1.33	0.88–1.46	0.79–1.61	1.42–2.00	3.00–4.68
	S	0.34–0.95	0.45–0.81	0.56–1.33	0.38–0.90	0.60–0.78
(iii) N %	T	0.060–0.103	0.059–0.086	0.071–0.108	0.065–0.102	0.090–0.309
	S	0.030–0.062	0.038–0.051	0.047–0.086	0.037–0.053	0.038–0.085
(iv) Exch. K m.e. %	T	0.06–0.25	0.06–0.10	0.06–0.08	0.12–0.20	0.17–0.25
	S	0.03–0.21	0.03–0.12	0.03–0.06	0.05–0.10	0.08–0.12
(v) Exch. Mg m.e. %	T	0.26–0.34	0.10–0.14	0.18–0.35	0.15–0.48	0.44–0.74
	S	0.01–0.36	0.03–0.07	0.01–0.20	0.08–0.16	0.18–0.26
(iv) Exch. Ca m.e. %	T	0.50–1.60	0.06–0.25	0.63–0.66	0.16–0.96	0.44–5.86
	S	0.41–1.48	0.03–0.19	0.13–0.25	0.08–0.20	0.14–0.20
(vii) 6N HCl Sol. P ppm	T	130–180	130–390	115–170	127–160	230–300
	S	—	—	—	127–190	270–440
(viii) 6N HCl Sol K m.e. %	T	0.26–0.40	0.27–0.75	0.47–0.54	0.90–1.85	2.85–5.80
	S	—	—	—	1.35–2.35	4.00–6.90
(ix) 6N HCl Sol. Mg m.e. %	T	0.50–1.10	0.76–0.80	0.35–2.50	2.80–6.00	3.90–6.20
	S	—	—	—	1.70–7.30	3.80–5.30

T = 0–7.6 cm
S = 15–30 cm

of Nigeria. They are considered to be yellow latosols with a deep and uniform profile. The topsoil is a brown clayey sand and the subsoil is more clayey, reaching a clay content of about 20% at about 100 cm. The sand content of the first 50 cm is about 80%. As may be expected, these soils are very low in exchangeable nutrients particularly potassium, values in the top 20 cm being 0.05–0.07 m.e. % for potassium and 0.30–0.60 m.e. % for magnesium.
Latosols derived from older rocks also occur to a limited extent.

– *Sierra Leone*

Soils of the oil palm areas were studied by *Tinker [93]*.
Two major soils occur and they are:

(a) latosols derived from the recent sandy sediments of the coastal areas, rather similar to the fasc soils of Nigeria and
(b) ground water laterite soils, mostly overlying basement complex rocks among which are granites and gneiss. According to the analysis of *Tinker*, the laterite gravels appear at about 15 cm and constitute over 60% of total earth. The fine fraction is mainly sandy. The soils are distinctly low in all nutrients particularly potassium and magnesium.

Although total rainfall is high (> 2500 mm) its distribution is uneven with a dry period of 3–4 months. Thus, both soils and climate do not appear favourable for oil palms.

C. South America

Oil palm development in this continent is fairly recent and information on soils planted to oil palms is limited. However, from general accounts *[52]* it seems that the lowland alluvial flats of tropical America contain the best soils because they are periodically refilled by nutrient rich deposits of recent volcanic origin from the Andes ranges. On undulating land, a wide variety of soils can be found but the common appear to be leached latosols of sandy clay texture derived from sedimentary rocks.

From the preceding accounts, it is evident that except for the recent marine alluvial clays, the majority of relatively free draining sedentary soils of all oil palm growing countries are rather leached and potassium status is particularly low. In view of the importance of potassium in the nutrition of the oil palm, this deficiency assumes major significance in fertiliser use.

8.4 Fertiliser experiments

The exact fertiliser requirements of oil palms growing on a specific soil type in a certain environment can only be determined finally by statistically designed field experiments.

With a perennial crop like the oil palm, yield recording for 3–5 years is necessary before any definite conclusions can be drawn and if the immature period is also included, the time of experimentation is extended to 6–8 years. This is a long period to wait and therefore, it is of considerable importance that such experiments are soundly planned. Ideally, as much information as possible on the growth physiology, nutrient uptake, soil morphology and nutrient status and climatic conditions ought to be integrated into experiments. To a large extent, this has not been possible in past experiments because it is only lately that relevant data on the various factors concerned have become available. Be that as it may, there is no doubt that past experiments coupled with leaf analysis have provided information of major practical importance.

8.4.1 Early experiments

Few experiments were carried out prior to 1940 and extensive trials were only laid down at the close or after the Second World War. Up to 1955, these experiments were reviewed by *May [57, 58]*. In Africa, the experiments were conducted by *Unilever, WAIFOR* and *I.R.H.O.*

– *Malaya (West Malaysia)*

The earlier experiments were reviewed by *May [57]*. The early experiments laid down in the twenties and thirties tested N, P, K and Mg in combinations but unfortunately, treatments changed during the course of experimentations and yield recordings were not long enough and consequently long term conclusions were not possible. Nevertheless, certain guidelines in manuring were apparent. On 8 year old palms planted in 1922 on a sandy soil derived from quartzite, 7 treatments of various combinations of 0.45 kg sulphate of ammonia, 1.4 kg of superphosphate (changed to Christmas Island rock phosphate in 1935), 0.45 kg muriate of potash and 0.7 kg magnesium sulphate were applied. Four years yield records up to 1934 showed that phosphate alone was as efficient as in combination with other fertilisers, the response being 35–55% *[108]*.

In a second experiment on a similar planting, 7 years' yield recording indicated that the main response was to phosphate at 2.7 kg rock phosphate or basic slag but there was a suggestion that nitrogen was also necessary at 0.9 kg calcium cyanamide. It was learnt that a time lag of 18 months was necessary before response was noted.

For 5 year old palms planted from virgin forest, *Guest [41]* reported there was no response to phosphate or phosphate with nitrogen in the two years of yield recorded.

With regards to potassium, the only response was reported by *Hartley [41]* who obtained a significant response to Patentkali with a composition of 29.6% K_2O and 9.8% MgO on 9 year old palms planted in 1930. The rate of application was 2.7 kg per palm per annum. From 1940 onwards, bunch number and bunch weight in the treated plots were much greater than control and leaves were much greener.

No response to Mg was recorded although the Patentkali experiment could have been an indication.

West Africa (I. R. H. O.)

The I. R. H. O. was responsible for experiments in Ivory Coast, Dahomey, French Cameroon and French Congo since about 1946–50. *Bachy [6]* has presented results of these early trials. The major finding on mature palms was the outstanding effect of potassium in preventing drops in yield. Magnesium was also shown to be required to avoid K-induced deficiency.

– *Ivory Coast*

In La Mé, 1 kg muriate of potash increased yield of 21 year old palms by about 28% in the presence of nitrogen but nitrogen alone had no effect.
At Grand Drewin, natural groves thinned to 140/ha responded to application of 1 kg muriate of potash, the increase in yield from 1949–52 being 24%. The increase was mainly due to a greater number of bunches.
At Dabou, a fertiliser trial on 16 year old palms planted on a laterite soil was started in 1946 *[29]* (Figure 14). Only muriate of potash at 1 kg per palm had a significant effect, increasing yield by more than 100% in the first three years after treatment and this difference enlarged further in later years as shown below:

	kg/palm/annum		
Period	K after 1946	K after 1950	K after 1956
1947–49	32	17	18
1950–55	64	59	17

A second experiment at Dabou on 19 year old palms showed that 1.5 kg of muriate of potash in the presence of 3 kg of superphosphate applied in 1951 only increased yield to 233% of control over 1953–54 but there was no residual effect after this as yellowing was said to set in during 1954 *[2]*.
In another experiment on 21 year old palms at Dabou, 1.5 kg of muriate of potash increased yield by about 200%, through an increase in number of bunches and in bunch weight (Figure 15).
The relative efficiency of uraform and sulphate of ammonia was tested on 20 year old palms in Dabou in 1950, the rates being 1 and 2 kg respectively. Results showed that sulphate of ammonia gave higher yield.

– *Dahomey*

The early experiments were conducted at Pobé and the important finding was the need for potassium, 1 kg of potassium chloride increasing bunch yields by about 40% *[80]*.

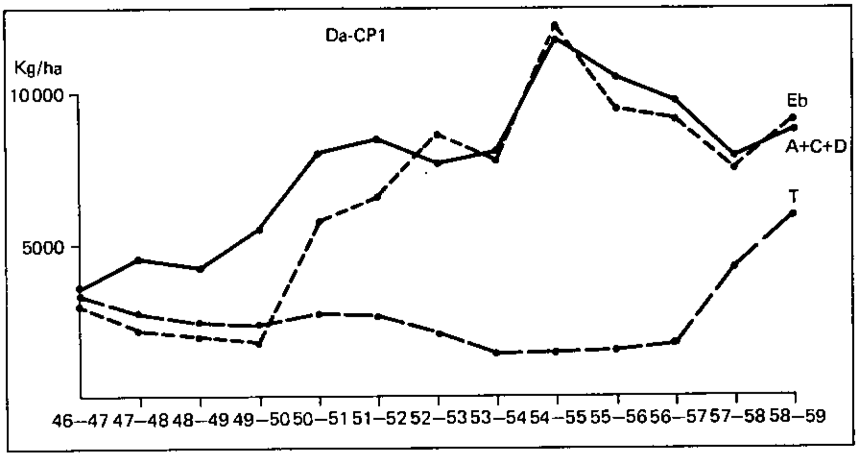

Figure 14. Effect of muriate of potash on course of yield of palms in Dabou, Ivory Coast
Eb – 1 kg KCl/palm/annum applied since 1949
A + C + D – 1 kg KCl/palm/annum applied since 1946
T – 1 kg KCl/palm/annum applied since 1956.
Source: *Surre Ch. and Ziller R.* (1963)

Evolution of number and average weight of bunches DA–CP–3

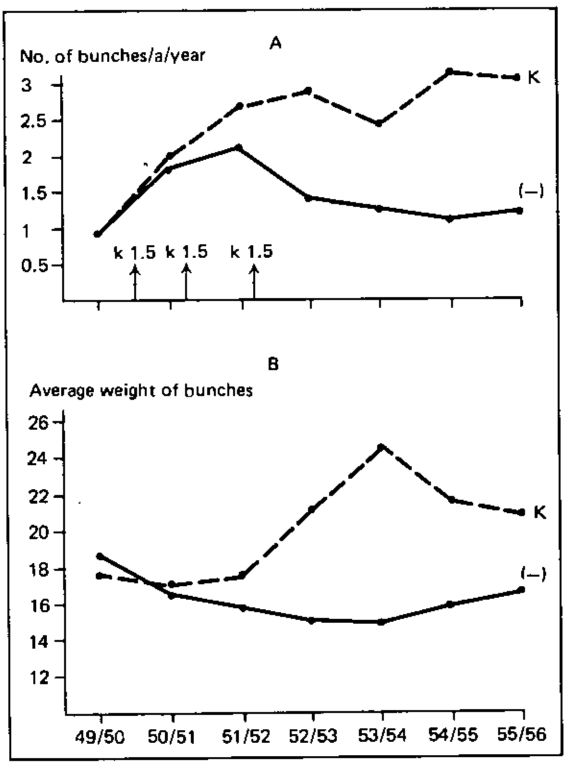

Figure 15. Effect of KCl on bunch number (A) and bunch weight (B) in Dabou.
Source: *Surre Ch. and Ziller R.* (1963)

In an experiment on 19 year old palms in 1948, treatments consisted of KP, NK, and NPK, the rates being 1 kg of muriate of potash, 3 kg of rock phosphate and 3 kg of sulphate of ammonia annually. As treatments were altered during the trial, interpretation was difficult but on average, K increased yield by about 40% and good correlation between bunch yield and leaf K was established *[81]*. *Prévot [75]* recommended 1 kg of muriate of potash yearly or every two years to palm groves in Dahomey as well as Togoland as being economic.
In an experiment on young palms in 1948 testing single application of N (0.5 kg ammonium nitrate), P (1 kg rock phosphate), K (0.2 kg muriate of potash), organic manure (5 kg) and castor seed waste (5 kg), growth measurements over 1950–51 showed no difference in number and length of leaves. However, leaf analysis showed that K increased leaf K level and potassium deficiency was stated to appear rapidly in the third year of planting and an application of 0.5 kg KCl was proposed.
An experiment on 23 year old palms tested different forms of phosphate in 1949 and it was found that there were no differences between ammonium phosphate, triple superphosphate and kourifos.

– *Cameroons (formerly French)*

The only experiment on 30 year old palms at Edea showed a 15% yield increase due to nitrogen but no response to potassium, which is distinct from results for other parts of West Africa.

– *Congo (Brazzaville)*

At Etoumbi in 1948, an experiment on palms of unknown age was laid down to investigate the effects of major fertilisers in combination with one of the micronutrients. This stemmed from the common problem of 'little leaf' encountered in the area. The NPK + trace element treatment consisted of 2 kg sulphate of ammonia, 3 kg rock phosphate, 1 kg of muriate of potash plus 250 g of the salt of a trace element. *Ferrand, Bachy and Ollagnier [30]* concluded that Mg and Mn showed the greatest improvements, yields being 48% and 49% higher than control respectively in the second year and 41% and 57% higher in the third year. Increases were also found to be effected by zinc, copper and boron.
However, in a second experiment with a 2^5 design testing NPKMg and trace element on 11 year old palms, no significant effects were found although leaf analysis showed that K increased leaf potassium, and decreased Ca while Mg increased leaf magnesium.

– *Summary*

N – Generally, no positive effect was found except at Edea in the former French Cameroons.

P – No favourable effect was found.

K – Positive responses were registered in Ivory Coast, Dahomey but not in Cameroons or Congo (Brazzaville). The rate of application was about 1 kg muriate of potash and it was found that both bunch size and bunch number were increased. The response was discerned after about 12 months after application and 1 kg could last for about two years.

8.4.2 Unilever experiments

These were also known as *Crowther Experiments*, which were 3^3 NPK factorial in design and were laid down in 1940 and as a result the fertilisers were not regularly made because of difficulties over supplies during the War. There were 10 experiments altogether, five in the former British Cameroons, 4 in Nigeria and 1 in Congo (Kinshasa). In the Cameroons and Congo, the palms were planted in 1933 while in Nigeria, they were 1936 plantings but in one experiment, the palms were planted in 1942. As stated earlier, the quantities of fertilisers applied in each treatment were not consistent but approximate amounts applied every three years for the periods concerned are as follows.

Fertiliser	Period					
	1940–1946 kg/palm			1947–1952 kg/palm		
	I	II	III	I	II	III
Sulphate of ammonia	0	1.5	3.0	0	4.5	9.0
Rock phosphate	0	1.5	3.0	0	4.5	9.0
Muriate of potash	0	0.5–1.0	1.0–2.0	0	3.0	6.0

The soils were either very sandy or gravelly.

Fertiliser effect

Detailed results of these trials have been reported by *Haines and Benzian [44]*. Briefly, it was shown that palms on sands responded significantly to both P and K, and on gravels, there was response only to K, but the response was greater than twice that on sands. The general yield level improved slowly on gravel but markedly on sands. There was a small but fairly consistent improvement from N. The Nigerian type of palms responded moderately well to N on all three kinds of soil, fairly well to P on Ndian sands and Cowan sand, very well to K on Ndian gravels and Cowan sands, much less on Ndian sands. The Deli palms were more responsive to K than the Nigerian variety.

These experiments also revealed the importance of poaching and the need for adequate guard rows. It was also observed that there was a long term cycle of responses. The fluctuations of N effect were closely followed one year later by similar trends in K effect.

8.4.3 Zaire

In addition to the Crowther Experiments just described, experiments in Congo (Kinshasa) were also conducted by *I.N.E.A.C.* (Institut National pour l'Etude Agronomique du Congo Belge) and the *Research Department of Huilever S.A.* The *I.N.E.A.C.* experiments have been discussed by *Focan [33]* and *Vanderweyen [101]* while those by H.S.A. were reported upon by *Broeshart [11]* and *Ferwerda [31, 32]*.

– *H.S.A.*

In a replanting experiment on riverine soil in southern Kasai bank, *Ferwerda [31]* found that the treatment of felling plus NPK manuring produced the greatest number of leaves as well as longer leaves up to the sixth year of growth. On the whole, manuring increased female inflorescence and bunch production. On this soil, K, Mg, B and to a lesser extent P were required.
In an experiment on young palms of 2 years, *Ferwerda [32]* tested sulphate of ammonia and rock phosphate at rates of 1.2 and 2.4 kg and 0.9 and 1.8 kg respectively. He found that P decreased '*Little Leaf*' while N increased it. Male inflorescence production was increased by both N and P 18 months after application and fruit bunch production was also increased by N and P.
In a further 2^7 factorial experiment testing K, Mg, lime, Cu, Mn, B, and other trace metals on 3 year old palms, *Ferwerda* found that there was no effect on leaf length or number but B reduced 'Little Leaf'.
On 14 year old palms, *Broeshart [11]* showed that 0.2–0.3 kg K_2O increased bunch production by about 100% and in the case of young palms, potash increased leaf length.

– *I.N.E.A.C. Experiments*

The majority of the experiments showed no responses to N, P or K. *Vanderweyen* reported on four experiments in Yangambi on 9–12 year old palms where nil responses to the major nutrients were recorded. However, in one experiment on a 1939 planting on unburnt land, NPK with Mg added significantly increased yield by 22% and 24% in 1948 and 1949.

– *Summary*

N – No outstandingly beneficial effect was demonstrated. On the contrary, it was suggested that it enhanced 'Little Leaf'.
P – The I.N.E.A.C. experiments showed no response but the H.S.A. trials gave positive responses in young replants and adult palms.

K – Again, the H.S.A. experiments obtained responses in fruit bunch production to K although the I.N.E.A.C. experiments showed no effects.

Mg– Yield responses of 22–30% were attributed to Mg.

Ca – In one experiment, it reduced leaf length of young palms while in another, female inflorescence and bunches were said to have been reduced.

Trace elements – Little Leaf was shown to be related to B shortage and this could be aggravated by application of N and K. In one experiment, B decreased female inflorescence and fruit bunches.

8.4.4 Nigeria

The older experiments tested farm yard manure and wood ash during the War years because of the absence of fertiliser supplies. In the *Moore Plantations* in the Western Province, 32 t/ha of farmyard manure applied to 1931 plantings in 1941 increased yield in 1943–45 only. At Umudike in Owerri Province, 55 t farmyard manure per ha applied to 1925 plantings in 1941 increased yields by 40–45% in 1942 to 1944 but thereafter, the difference was not significant. At the lower rate of 16 t farmyard manure, yield increases were 16–30% for the same three year period.

At *Moore Plantations*, no response to 620 kg/ha of bean ash rich in phosphorus and potash was obtained in 1941–45 after its application in 1940 to 1931 palms on a reddish yellow sand. However, in Onitsha Province, an immediate and dramatic response to a total application of 42 t incinerated ash over 1940–42 on 1931 plantings was obtained. The yield jumped in 1941 and increased by about 900% in 1943 and 1944, being equivalent to 8800 kg of fruit bunches/ha. The ash contained 4.43% K_2O and 0.50% P_2O_5, indicating the effect of potassium.

At Nkwele, different rates of wood ash were tested, the treatments being 13.5, 27, 40.5 kg incinerated ash per palm. The experiment was on 1931 plantings on gravelly sand and the ash applied in 1943. The yield records up to 1952 showed that only the highest rate gave significant responses two years after application.

The above indications of potassium shortage were supported by results of experiments using potash fertilisers. In an experiment on mature palms showing severe Confluent Orange Spotting at Nkwelle the effects of potassium were tested. The rates of application of sulphate of potash were 3.4 and 9 kg per palm. These applications were put down for two years in 1944 and 1945. A large yield increase to the higher rate of potash was obtained; for 1945–48 and 1949–52 periods, these yields of the higher K plot were 413% and 222% of control. Bunch yield was increased from 13.5 to 26–50 kg per palm in 1946–52 (Figure 16).

At Akwete, a 3^3 factorial experiment was laid down to test three rates of potash and three intervals of application, i.e. annual, biennial or triennial, and three numbers of dosages as shown below:

Rates of sulphate of potash	0	2.7	5.4 kg/yr
Doses per year	1	3	6
Frequency	Annual	Biennial	Triennial

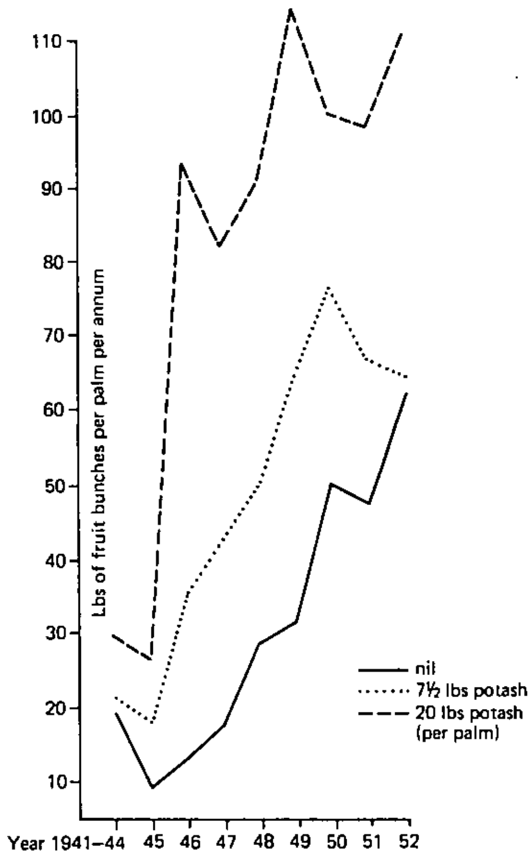

Figure 16. Experiment 703–4, NKwelle Yield of fruit bunches per palm for the period 1941–52 for the potash treatments
K_1 = 3.4 kg of K_2SO_4 per palm
K_2 = 9.1 kg of K_2SO_4 per palm.
Source: *May E.G.:* J.W.Afr.Inst. Oil Palm Res.*2*, No.5 (1956)

The palms were planted in 1929 and the experiment was started in 1949. The soil was a leached sand. Results of this experiment were presented by *May [58]*.
The highest rate of potash significantly increased yield, as indicated below:

Bunch yield in 1949–55	0 Potash	18.6 kg/palm/yr
	5.5 kg Potash	27.7 kg/palm/yr

However, this 5.5 kg needed to be applied only over 7 years and higher quantities produced no further positive effects. Also, no extra benefit was gained from applying the potash in frequent doses during the rainy season.
At Umidike in 1948, a 3^4 experiment on 23 year old palms on an intergrade acid sand soil tested large doses of N, P, K and lime, the rates being 616 kg and 1232 kg/ha each of sulphate of ammonia, superphosphate and potassium chloride and 1232 kg and 2464 kg/ha of lime applied in 1948. Only potassium was found to increase yields which were about double those of control in 1950–55 except for the 1952 figure and the highest rate gave no added advantage (Figure 17) *[23]*.

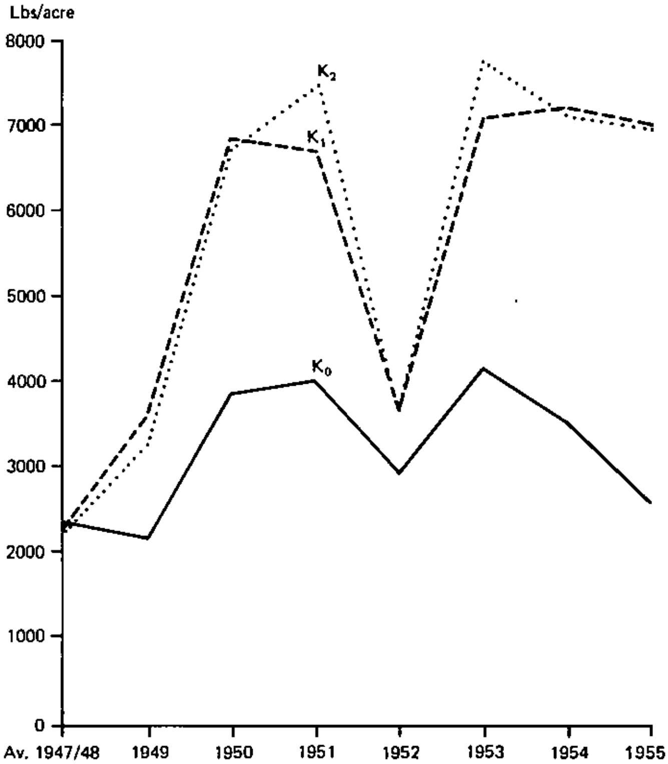

Figure 17. The effect of a single application of 616 kg (K_1) and 1232 kg (K_2) of KCl per ha on the yield of fruit bunches at Umudike.
Source: *Chapas L.C. and Bull R.A.:* J.W.Afr.Inst.Oil Palm Res.*2*, No.5 (1958)

Summary

N – No significant response was observed; rapid leaching was thought to be partly responsible.
P – No response was obtained, fixation was thought to be responsible.
K – Positive responses were obtained within a year of application. Both bunch number and bunch weight were increased and the effect of a large dose of 5.5 kg could last 6 years.
Mg – Some suggestion of it limiting production was apparent.

8.4.5 Recent fertiliser experiments

Indonesia

Post war experiments have confirmed the need for nitrogen and phosphorus on rhyolitic soils. On a replant, yield in the 7th year was increased by 21% by the application of 1.5 kg sulphate of ammonia per palm, the N plot and control yields being 23.5 and 19.5 t/ha respectively. On 20 year old palms, NP was the best combination, the rates being 150 kg/ha sulphate of ammonia and 200 kg/ha Christmas Island rock phosphate. The yields are shown below *[106]:*

N_0P_0	14.6 t/ha
N_1	15.8 t/ha
P_1	16.5 t/ha
N_1P_1	18.1 t/ha

Malaysia

After the War, sizable yield responses to fertilisers were reported by *Rosenquist [83, 84].*

Four experiments on mature palms were laid down in the fifties, two on a granitic soil and two on a sedimentary soil. However, fertilisers were not applied consistently throughout and results of one site of each soil only can be presented. On the granitic soil, fertilisers were applied yearly from 1949–56 while on the sedimentary soil, fertilisers were put down in 1949–53. Consequently, yield data are for periods 1956–59 and 1950–53 respectively. The experiments were of either the 3^3 or $3^3 \times 2$ type and rates of fertilisers are as follows:

N	0	0.9	1.8	kg/palm/yr of sulphate of ammonia
P	0	1.36	2.72	kg/palm/yr of rock phosphate
K	0	0.9	1.8	kg/palm/yr of muriate of potash
Mg	0	0.9	–	kg/palm/yr of kieserite

On the granitic soil, the main response was to potassium, the increase in yield being about 82% at the highest K level as shown below:

	K_0	K_1	K_2
kg/palm/yr	66	89	94

Further, in the presence of potassium, significant secondary responses to N and P were obtained, increases being 42% and 29% respectively. A small increase due to Mg was also indicated.

On the shale derived soil, the main responses were to P and N, the increases being 80% and 42% respectively.

	kg/palm		
	P_0	P_1	P_2
N_0	45	54.5	57
N_1	48	55	57
N_2	35	63	64

The experiment on granitic soil also showd the inter-dependence of nutrients. Responses to N were dependent on an adequate supply of K. Where K was sufficient, N responses were positive at all levels of P and the highest yields were obtained from N_2P_1 and N_1P_2 with K_1, and N_2P_2 with K_2. There was a slight response to phosphate at the P_2 level with N_2 and K_2. These results are shown in Table 35.

Table 35. Interactions between N and P at different rates of K on Rengam Series Soil (kg)

		P_0	P_1	P_2
K_0	N_0	50	75	73
	N_1	71	73	65
	N_2	66	66	58
K_1 (0.9 kg KCl/palm)	N_0	85	99	92
	N_1	72	97	107
	N_2	96	109	100
K_2 (1.8 kg KCl/palm)	N_0	86	76	96
	N_1	90	99	103
	N_2	99	101	113

N_2 = 1.8 kg sulphate of ammonia
P_1 = 1.8 kg Christmas Island rock phosphate

The yields of these experiments are not high, the highest yields being about 15 t/ha/yr. This is because the palms were neglected during the War years of 1942–45 and also they were more than fifteen years old. Nevertheless, substantial yield increases could be obtained provided a balanced supply of nutrients was maintained.

In a follow up experiment on mature palms, also on granitic soil, a fertiliser mixture with a composition of 6.6% N, 3.0% P_2O_5, 21% K_2O and 7.8% MgO was applied at the following rates:

0 kg per palm per year
2.7 kg per palm per year
5.4 kg per palm per year

Substantial increases were obtained and the highest yields were given by the highest fertiliser treatment as shown below:

Fertiliser	% yield increase	
	Site A	Site B
2.7 kg	17.9	12.7
5.4 kg	33.0	25.4

Further evidence of the fairly large nutrient requirements of old palms on inland soils was also given by *Martineau et al. [56]*. A 2^3 NPK experiment was laid down on 15 year old palms which were established on a pale, coarse structured shale derived soil (Batu Anam Series) just before the Second World War. At the start of the experiment, the palms were already deficient as they received little or no fertilisers during the period 1942–45. The rates of fertilisers are as follows:

N, 1.36 kg Sulphate of Ammonia
P, 2.7 kg Christmas Island Rock Phosphate
K, 1.8 kg Muriate of Potash

The highest yield obtained during the 1953–60 period was given by the full treatment.

Average yields of most effective treatments for 1953–60	f.f.b.t/ha/yr
Control	10.6
NK	13.7
PK	14.4
NPK	15.9
Main effects	
N	1.27
P	1.72
K	2.52
m.s.d. at 5%	0.77

Thus, main effects accounted for almost all the increase and potassium gave the largest effect. Bunch number was increased more than bunch weight.

By 1959, magnesium deficiency had become widespread in the trial and a blanket application of 1.36 kg kieserite/palm/year was given to correct the deficiency and by 1965, the deficiency was well taken care of. Yields during the 1961–65 period were comparable to those previously obtained.

Later in 1965, the experiment was converted to an observation in which high doses of fertilisers were applied to all the treatments; the rates before and after 1965 are as follows:

1960–65	2.3 kg NPK (13:13:20) + 1.36 kg KCl + 0.45 kg Urea
1966 and 1967	4.5 kg NPK (13:13:20) + 4.5 kg sulphate of ammonia + 4.5 kg KCl + 7 kg magnesium limestone

There was a 40% increase in yield as shown by the yields for the years concerned.

1960–65	11.1 t f.f.b./ha/yr
1966	19.2 t f.f.b./ha/yr
1967	18.1 t f.f.b./ha/yr

It is noteworthy that these relatively high yields were obtained by palms about 30 years old and the response was apparent within one year.

The above experiments refer to rather old plantings which were neglected for some time. However, there is evidence that younger mature palms also have large fertiliser requirements. *Piggott [74]* showed that 10 year old palms planted on a sedimentary soil responded linearly to nitrogen up to 0.8 kg N/palm/yr. Yield was increased from 11.2 to 17.5 t f.f.b./ha/yr. In a second experiment on a rather infertile soil, responses to large dressings of N, P and K were obtained, the greatest response being given by nitrogen at 4.5 kg sulphate of ammonia. The yield was almost doubled from about 10 to 20 t f.f.b./ha/yr. However, this was only achieved when adequate K and P were supplied at 4.5 kg muriate of potash and 4.5 kg superphosphate. Similarly, responses to K and P were maximum when N was at 4.5 kg sulphate of ammonia.

In contrast, responses to fertilisers on the more fertile coastal alluvial soils are not so prominent or widespread. On the marine clays which are non-acid sulphate, the main response is to potassium and this usually does not become evident till after the 10th year of planting (*Hew*, priv. comm.), the rate of application being 2.7 kg muriate of potash per palm per year. On the very fertile members of the marine clays, nil responses have also been obtained with 10 year old palms *[59]*. On riverine clays deposited over marine sediments, responses to both potassium and nitrogen have been obtained but there again this does not become evident till about the 4th or 5th year of harvesting.

The preceding data have indicated a fairly definite trend to respond earlier to fertilisers by the oil palm in Malaya, particularly on the leached inland soils. In the light of

Table 36. Results of 3^4 NPK Mg Experiment on shale derived soil in West Malaysia

Treatment	kg/ha*	Yield data t/ha		Foliar analysis. Leaf No. 17. Dec. 1969			
		2nd yr	1st and 2nd	N	P	K	Mg
				%			
N_0		28.51	45.00				
N_1	94 N	29.32	45.28				
N_2	188 N	29.82	45.32				
P_0		26.70	42.16	2.60	.146	1.28	.35
P_1	91 P_2O_5	30.38	46.88	2.67	.164	1.20	.35
P_2	182 P_2O_5	30.58	46.71	2.70	.168	1.18	.35
K_0		27.46	42.46	2.64	.159	1.19	.36
K_1	210 K_2O	30.09	46.63	2.66	.159	1.22	.34
K_2	420 K_2O	30.11	46.66	2.66	.159	1.26	.34
Mg_0		29.03	45.13				
Mg_1	59 MgO	28.45	44.31				
Mg_2	117 MgO	30.16	46.29				
Mean		29.22	45.25				
S.E. ±		0.62		0.02	0.002	0.02	0.006

* At 140 palms/ha

Table 37. Results of 4^2 NK Experiment on a sandstone derived soil in West Malaysia

Treatment	kg/ha*	Yield t/ha	Foliar analysis. Leaf No. 17. July 1969			
		1st yr	N	K	P	Mg
			%			
N_0		19.61	2.64	1.05	.190	0.37
N_1	66 N	19.36	2.66	1.00	.196	0.37
N_2	132 N	20.13	2.68	1.04	.194	0.36
N_3	196 N	20.53	2.71	1.08	.196	0.36
K_0		16.82	2.65	0.85	.196	0.39
K_1	227 K_2O	20.77	2.64	1.06	.192	0.37
K_2	454 K_2O	21.22	2.73	1.11	.195	0.35
K_3	689 K_2O	20.82	2.67	1.15	.194	0.34
S.E. ±		1.01	0.02	0.04	0.002	0.01

* At 140 palms/ha; P = 70 kg/ha P_2O_5, Mg = 50 kg/ha MgO

the more recent data on rate of dry matter production and nutrient uptake by the oil palm, this is not altogether surprising and *Ng [63]* has shown that most recent fertiliser experiments designed on the basis of recent data on growth, nutrient uptake and soil nutrient status have borne out his earlier conclusions that the nutrient requirements of the oil palm are large right from the second year of planting in the field. In three such experiments, there was evidence of response to potassium and phosphate in the first two years of fruit bunch production and a definite need of magnesium from foliar analysis data. The presence of a vigorous legume cover masked any effect due to nitrogen but later response to N is well anticipated. Relevant data from these trials are shown in Tables 36, 37, 38 and 39.

Table 38. Results of 3^4 NPK Mg Experiment on marine clay in West Malaysia

Treatment	kg/ha*	Yield t/ha		Foliar analysis. Leaf No. 17. Dec. 1969			
		1969	Cumulative	N	K	P	Mg
		4½–5½ yrs	(5½ yrs)	%			
N_0		26.39	120.2				
N_1	53 N	26.97	121.9				
N_2	106 N	26.18	120.9				
P_0		27.17	122.0				
P_1	91 P_2O_5	26.33	120.4				
P_2	182 P_2O_5	26.06	120.5				
K_0		25.14	116.9	2.54	0.93	.174	.26
K_1	227 K_2O	27.22	123.8	2.56	0.94	.173	.25
K_2	454 K_2O	27.17	122.3	2.56	0.99	.173	.24
Mg_0		26.68	119.7				
Mg_1	66 Mg O	26.60	121.7				
Mg_2	132 MgO	26.28	121.7				
S.E. ±		0.69		0.02	0.01	0.002	0.01

* At 140 palms/ha

Table 39. Results of 3^4 NPK Mg Experiment on riverine clay in West Malaysia

Treatment	kg/ha	Yield t/ha		Foliar analysis. Leaf No. 17. Aug. 1969			
			Cumulative	N	K	P	Mg
		4½–5½ yrs	5½ yrs	%			
N_0		23.74	108.0	2.53	0.96	.170	0.33
N_1	27 N	25.07	112.9	2.59	0.95	.175	0.33
N_2	53 N	24.26	111.6	2.62	0.95	.173	0.33
P_0		24.48	109.9				
P_1	70 P_2O_5	24.63	110.9				
P_2	140 P_2O_5	23.96	111.7				
K_0		23.00	103.8	2.57	0.95	.174	0.33
K_1	118 K_2O	25.32	115.4	2.59	0.96	.172	0.32
K_2	235 K_2O	24.75	113.2	2.58	0.97	.173	0.33
Mg_0		24.28	110.3				
Mg_1	33 MgO	24.72	112.6				
Mg_2	66 MgO	24.06	109.7				
S.E. ±		0.74		0.03	0.02	0.002	0.01

In West Malaysia, oil palms are also planted on acid sulphate soils which occur along with the marine clays and it has been found that the hyperacidity produced on drainage causes a severe reduction in pH to below 3.0 and dessication of leaves *[9, 100]*. More intense drainage aggravates the acidity and a reversal of the process by keeping the water table as high as feasible seemed to arrest the acidification. *Bloomfield et al.* also noted that natural leaching could not improve the situation either. Yields of such areas are generally very low, i.e. less than 5 t f.f.b./ha/yr. A practical method of ameliorating such soils has been worked out by *Hew and Khoo [49]*, who combine blocking up of drains to arrest excessive oxidation of sulphides to acid sulphates with application of 9 kg of bunch ash, and increased yields substantially (Table 40). Limestone had very little effect on yield but potassium and magnesium enhanced the response to bunch ash.

Table 40. Effects of various treatments on yields of oil palms on acid sulphate soils in Malaysia

Treatment	Fruit bunch production over 21 months t/ha	
	No Kieserite	9 kg Kieserite
Control	12.4	12.4
68 kg limestone/palm/yr	14.8	14.8
68 kg bunch ash/palm/yr	24.0	26.0
34 kg bunch ash/palm/yr	14.9	13.9
68 kg dolomite/palm/yr	16.1	15.7
23 kg refuse/compost mulch/palm/yr	15.6	19.5

Africa

Experiments since 1959 designed to determine the fertiliser needs for the first 8–9 years of the life span of the palm were of the 4^n type.

– *Nigeria*

On the Acid Sands, there is evidence of requirements for nitrogen and potassium by immature palms of modern pedigree. For nitrogen, yield for the first six months indicated a response.

New Area Treatment	Rate/palm g	kg/ha fruit bunch
Control	0	2479
Sodium nitrate	290	2399
Sulphate of ammonia	227	2792
Ammonium phosphate	422	2895
Urea	109	2686
	L.S.D.	365

On a replant, potassium increased growth as indicated by height at the K_1 level as given below.

Treatment	kg	Palm height at 2 years cm
K_0	0	274
K_1	0.34	294
K_2	0.68	298
K_3	0.98	300
		L.S.D. 9.6

Thus, it is recommended that urea and sulphate of potash be applied at 0.1 kg per palm in the initial year, rising to 0.45–0.9 kg during the non-bearing period. As N and K application can induce magnesium deficiency on sandy soils, it is also recommended to apply magnesium sulphate in a rising order of 0.1–0.7 kg during immaturity. The requirement for phosphate appears less definite.
For adult palms, the outstanding response is to potassium. In a trial near Benin, an NK interaction was also obtained.

Yield at 2 years after first fertiliser application, kg/ha/yr:

	K_0	K_1	K_2	K_2–K_0
N_0	10 978	10 551	10 400	— 567
N_1	10 395	11 496	12 466	+ 2 071

N_1 = 1.8 kg sulphate of ammonia
K_1 = 2.3 kg potassium sulphate
K_2 = 4.5 kg potassium sulphate

In the absence of nitrogen, there was no early response to potassium.
In the case of magnesium, on Benin fasc, there was no yield response to Mg despite the appearance of deficiency symptoms on young palms. However, on the Calabar fasc, palms with Orange Frond symptoms responded strikingly to magnesium *[22]*.
C.O.P.E. Ex 522

Treatment	Years of application	Yield 1954–57	kg/ha/yr 1960–61
Control		3535	2488
Mag. sulphate 2.3 kg/palm	1953, 1954, 1961	5206	5428
Mag. sulphate 3.1, 1.1, 1.1 (kg/palm)	1953, 1954, 1961	6303	5599
Mag. sulphate 4.5 kg/palm	1953 only	4467	3542

A rate of 2.3 kg per palm per year appears minimal and usually potassium is also required on such soils.
On basement complex soils, there is limited experimental data but recent evidence indicates that fertilisers are required in the early years. On soils derived from granitic gneiss and granites, there is indication of P and Mg requirements, the rates in the first four years are 0.1, 0.23, 0.45 and 1.7 kg superphosphate and 0.23, 0.45, 1.36 and 4.1 kg magnesium sulphate. On granitic soils, *Tinker [92]* has also shown a need for potassium. On soil derived from mica schist, there was a growth response to potassium followed by early

yield response to phosphate. On soils derived from basalts, growth and early yield responses to both nitrogen and potassium were recorded, the rates of application being 0.45–0.7 kg in the first year rising to 1.36–1.8 kg of fertiliser in the third year. For adult palms on these soils, responses have not been very clear. On soils derived from mica and quartzose schists, highest yields were obtained from applying 2.3 kg per palm every three years of each of ammonium phosphate and potassium sulphate.

– Ghana

On soils overlying Tertiary sandstone, a marked response to phosphate was obtained at Aiyinasi with suggestions of possible nitrogen and potassium responses in later years as shown below *[48b]*. The palms were planted in 1954 and for each fertiliser, the rates were 0.23 kg at planting, then 0.45 kg for each age in the field, making a total 9.8 kg up to 1960. There was suggestion of a response to magnesium at Bunsu.

Treatment	Yield kg/ha/yr			
	Aiyinasi 1958–61	1961	Bunsu 1958–61	1961
N_0	9 153	12 679	10 147	13 696
N_1	9 263	12 389	10 817	13 912
P_0	7 644	10 594	10 388	13 842
P_1	10 772	15 574	10 576	13 765
K_0	9 223	12 760	9 958	13 137
K_1	9 193	13 408	11 005	14 470

At Bunsu, there was a K/Mg interaction

	Mg_0	Mg_1
K_0	10 515	9 403
K_1	10 326	11 686

West Africa (formerly French)

Principal results have been reported by *Bachy [6]*.

– Ivory Coast

Young palms

At La Mé, on a 1959 planting, growth in immaturity was improved by nitrogen application and the N_1 treatment was as good as the higher levels. The area was previously under forest.

At Dabou in the savannah area, different sources and rates of nitrogen were tested on a 1962 planting. Foliar analysis data for 1965 indicated that urea was as effective as sulphate of ammonia. At the N_1 and N_2 levels, there was no difference between single and split applications and between sulphate of ammonia and urea but at the N_3 level, urea was better and split doses seemed better than single application. The general recommendations at Dabou are as follows:

N_1 250 g sulphate of ammonia in 1st year
350 g sulphate of ammonia in 2nd year
500 g sulphate of ammonia in 3rd year

Potassium: Potassium manuring depends on the previous cultural history. In the savannah zone, it is necessary to apply K to palms on tertiary sands but in the forest zone, the effect on growth and early production is slight.

Magnesium: In the tertiary sands, magnesium deficiency is commonly induced by application of potassium on young palms and a growth response to magnesium application has been obtained where potassium is applied on a 1964 planting. Growth measurements at June 1967 are as follows:

	No Mg	With Mg
Girth at collar cm	167	179
Frond length cm	263	284
Number of inflorescence	15.9	17.2

Adult palms

The principal deficiency of palms is potassium, but some response to phosphate was indicated. However, no response to nitrogen or magnesium has been obtained.
At La Mé in the forest zone, an application of 2 kg/KCl/palm on 1946 plantings increased yield by over 60% as shown below.

Period	kg bunches/palm/yr	
	No K	K
1957–60	60	96**
1961–65	63	99**

On older palms at Dabou, planted in 1930, yield was increased from about 2.5 tonnes to 12.5 tonnes/ha/yr with a sustained application of 1 kg muriate of potash since 1946.

	kg bunches/palm/yr		
	K after 1946	K after 1950	K after 1956
1947–49	32	17	18
1950–55	64	59	17
1956–60	83	82	44

The response became ostensible after four years, due to the fact that the palms were rather deficient.

At Grand Drewin, an experiment on eight year old palms planted in 1948 also showed that the largest yields were obtained with the highest level of potash application.

	kg bunches/palm/yr			
	No K	0.8 kg KCl	1.2 kg KCl	1.6 kg KCl
1957–60	69	67	76	83
1961–65	50	55	57	64

In the same experiment, it was also shown that the response to potassium was augmented by phosphate.

	kg bunches/palm/yr			
	K_0	K_1	K_2	K_3
P_0	62.6	71.7	62.8	72.7
P_1	60.1	62.6	90.0	92.2

P_1 = 3 kg superphosphate.

Phosphate: In La Mé, no response to 2 kg superphosphate applied to 1946 plantings was obtained. However, in the region of Sassandra, there was a positive effect.

	kg bunches/palm/yr	
	No P	P
1957–60	68	80
1961–65	54	59

At Grand Drewin, there was a interaction effect of potassium with phosphate.

	kg bunches/palm/yr			
		K_0	K_2	K_3
1957–60	P_0	65	64	75
	P_1	73	87	91
1961–65	P_0	51	49	59
	P_1	49	65	69

– *Dahomey*

The main response is to potassium but nitrogen is also important.

Young palms

Although the potassium status of soils is relatively better than that of soils in the Ivory Coast, response to K application to young palms has been shown. At Pobé, growth of 1959 plantings was enhanced by potash.

	Index of growth	
	June 1961	June 1962
No K	130	448
Small dose of K	165	593
Medium dose	156	563
Large	176	629

Mature palms

On 1929 plantings on alluvial soil, a yield increase of about 50% was achieved by application of potash in 1948. There was also a suggestion of response to nitrogen.

	Yield kg bunches/palm/yr				
	No K	K	NK	PK	NPK
1953–64	50	73	81	86	83

It was found that on heavy soils, potash could be applied round the palm but on sandy soils, broadcast was thought to be preferable. There was no difference between sulphate of potash and muriate of potash.

– *Cameroons (La Dibamba)*

Young palms

The soils are similar to those in the Ivory Coast and on the ferrallitic sands and gravels, nitrogen is indispensable to young palms although relatively small doses are adequate. Urea was found to be comparable to sulphate of ammonia.
There has been no response to potash application.
Magnesium deficiency has been found to be important in young plantings as shown by the following foliar analysis data on palms planted in 1960.

	Leaf analysis % Mg		
	1961 Fd.1	1963 Fd.17	1965 Fd.17
$MgSO_4$	0.282	0.324	0.280
MgO	0.259	0.334	0.282
Dolomite	0.230	0.296	0.256
Control	0.206	0.249	0.215

Mature palms

A response to nitrogen has not been evident as indicated by the following data on a 1951 planting.

	kg bunches/palm/yr	
	No N	N
1957–60	57	58
1961–65	88	86

No positive effect of potassium was obtained on six year old plantings over the period 1957–65. However, a suggestion of a response to magnesium at 1 kg magnesium sulphate per palm after the 10th year of planting has been obtained.

	kg bunches/palm/yr	
	No Mg	Mg
1957–60	57	59
1963–67	82	92

A significant response to phosphate in the presence of potassium has been given by a 1951 planting.

		kg bunches/palm/yr	
		K_0	K_1
1961–65	P_0	66	61
	P_1	63	79

P_1 = 2 kg superphosphate.

– *Sierra Leone*

Magnesium deficiency symptoms are widespread on inland alluvial and laterite soils. On the latter, there is an early need for nitrogen, and phosphate and potassium had been shown to increase leaf production.

– *Zaire*

The history is one of lack of response to fertilisers and part of the reason could be due to the over emphasis on phosphate in the experiments because of the fear of phosphate fixation. Liberal doses of phosphate were generally given and there was little or no provision of potassium. As shown elsewhere, where potassium is the primary requirement, phosphate can have a depressing effect on yield.
In northern Congo, an experiment at Bingo on a 1951 planting strongly indicated the need of manuring. Different rates of a fertiliser mixture with the following composition were applied.

Ammonium nitrate	18.9%
Triple superphosphate	19.1%
Potassium nitrate	41.9%
Potassium sulphate	20.1%

The fertiliser was applied yearly in 1958, 1959, 1960 and 1961 at the rates of 1, 3, 4 and 4 kg per palm and the yields are given below:

	kg bunches/palm	
Year	Control	With fertiliser
1956–57	15.4	20.0
1957–58	31.2	46.7
1958–59	37.8	55.6
1959–60	37.1	46.3
1960–61	64.9	81.7 *[3]*

The *Unilever Experiments* gave more positive results; responses to potassium and phosphate had been obtained as well as suggestions of magnesium requirement.

– *Congo (Brazzaville)*

Young palms

A growth response to nitrogen applied to 1959 palms was obtained on a heavy soil. Urea and sulphate of ammonia were better than ammonium nitrate.

		Index of vigour		
Fertiliser	Rate/Palm	1962	1963	1964
Sulphate of ammonia	2 kg	568^{++}	1410^{++}	2.17^{++}
Sulphate of ammonia	0.5 kg	491^{++}	1440^{++}	2.29^{++}
Urea	0.25 kg	453^{++}	1250^{++}	2.15^{++}
Ammonium nitrate	0.5 kg	291	710	1.46
Control	0	273	540	1.47

Adult palms

The limited information available indicates that magnesium deficiency is a major problem in old palms as shown by the following leaf analysis data for palms in Etoumbi.

	% Mg in leaf 17	
Year of planting	No chlorosis	With chlorosis
1930	0.267	0.040
1941	0.280	0.005
1947	0.251	0.030

In an experiment on 11 year old palms, 1 kg of muriate of potash increased bunch yield from 76 to 83 kg/palm/yr over the period 1953–61 but this was not significant. It is possible that the amount applied was too low to produce a significant effect.

8.5 Leaf analysis

The technique of leaf analysis can be said to have contributed considerably to better nutrition and yield of oil palms in all oil palm growing regions. Early information on leaf levels were mainly based on comparative analysis of leaves of healthy palms and those with symptoms such as Confluent Orange Spotting and Orange Frond (Mbawsi disease) *[18, 27, 45]*. As experiments were laid down to eliminate such deficiency symptoms, more precise knowledge of nutrient levels associated with healthy conditions and better yields was obtained. As time went by, these guidelines were further refined by results of experiments on fertiliser rates. Thus, there is considerable information on leaf analysis data but yet, the exact relationship between specific nutrient values and yield is still not fully understood. Firstly, nutrient inter-relationship or balance may be more important than individual nutrient values and although this has come to be realised in more recent years, its effect on yield is not precisely known. Then, nutrition is only one of the factors that affect growth and production and it may be necessary to take into account in interpretation of leaf analysis data factors such as solar radiation, rainfall data for possible influence on flowering, rate of dry matter production, soil moisture and soil nutrients. It appears that an exercise such as crop-logging is worthwhile for the oil palm and the more recent work of *Ng et al. [65]* and *Corley et al. [25]*, on rates of dry matter production of palms since field planting is a major step in the right direction.

However, at present, the main point still lies in determining the so-called critical limits above which no yield response would be obtained. Experience with the use of leaf analysis has tended to indicate that it is probably more realistic to speak of a critical range than an absolute value. In West Malaysia, experience has shown that critical levels are not standard; in the case of potassium and to a lesser extent nitrogen, those for inland soils tend to be 0.1–0.2% higher than those for the coastal clays. Whether this phenomenon is due to better water relations in the alluvial soils needs to be verified experimentally. The crux of the difficulty may be due to the fact that in many plantings, the nutritional status is or has been brought to a sufficient region where the relationship between yield and nutrition is less discernible. Be that as it may, leaf analysis remains a valuable aid in assessing nutrient needs of the oil palm but wherever possible, it should be used with all relevant data on growth and yield, soil conditions particularly nutrients and water and climatic conditions.

The application of leaf analysis more or less pursued parallel courses in Malaysia and Africa. In West Malaysia, *Chapman and Gray [24]* showed in conjunction with fertiliser experiments on adult, deficient palms that nutrient contents in lamina tissue varied with the portion of the pinna and age of leaves. These workers came to the conclusion that the middle section of the pinnae taken from the middle part of leaf or frond No. 17 showed the least variation and was most sensitive to fertiliser application. They found significant correlations between leaf P and K and yield of bunches and considered that the K_2O/P_2O_5 ratio in the leaf ash was important in depicting potassium needs and potassium-phosphorus balance and optimum ratios were proposed.

Yield response	P_0	P_1	K_0	K_1
%	100	193	100	168
Leaf level %	0.128	0.153	0.56	1.09

Coulter [26] studied variation in leaf 17 of healthy young and old palms on inland and coastal soils in West Malaysia as well as the effect of time of day of sampling on nutrient levels. He found no significant variation from 7.00 a.m. to 11.00 a.m. and recommended that field sampling be confined to this period. From his survey, he suggested tentative critical levels for leaf 17 as follows:

	% of dry matter					
	N	P	K	Mg	Ca	ppm Mn
Young palms (6 years) coastal clay	2.70	0.17	1.20	0.29	0.45	250–350
Old palms (30 years) coastal clay	2.60	0.17	1.10	0.26	0.30	200–300
Young palms (6 years) upland soils	2.60	0.17	1.10	0.25	0.70	200–300
Old palms (20 years) upland soils	2.60	0.17	1.10	0.25	0.70	250–350

The Ca levels are somewhat arbitrary as they are not related to definite deficiency symptoms or responses. In any case, even the limits for the other nutrients are mere deductions as they were not derived from fertiliser experiments but they were useful guidelines in the absence of adequate experimentation.

These limits have not been altered substantially in later years although *Rosenquist [84]* has proposed higher critical levels as follows:

	N	P	K	Mg	Ca
%	2.70–2.80	0.18–0.19	1.30	0.30–0.35	0.60

These levels for leaf No. 17 were largely for palms planted on inland soils in Malaysia. For leaf No. 3, *Rosenquist* proposed the following tentative critical levels:

	%
N	2.8–3.0
P	0.19–0.21
K	1.50–1.80
Mg	0.30–0.35
Ca	0.30–0.50

In addition to the above, *Rosenquist* also suggested the following values for micronutrients for leaf No. 17:

	Mn	B	Cu	Zn	Mo
ppm	150–200	10–20	5–8	15–20	0.5–1.0

As very little is known about the effects of micronutrients on yield, these values should be treated as rough approximations only.

In Africa, French workers are the ones who have used leaf analysis most extensively in association with deficiency symptoms and fertiliser experiments with major emphasis on potassium. *Prévot and Ollagnier* are amongst the early workers in this field *[76, 77]* and they proposed the following critical limits for leaf 17.

	N	P	K	Mg	Ca
%	2.5	0.15	1.00	0.24	0.60

The nitrogen and phosphorus values are slightly lower than those of *Coulter and Rosenquist*. Later, these workers stressed that the critical level was only a first approximation and should not be applied mechanically and they showed the importance of the concept of nutrient balance and inter-dependence in their effects. Furthermore, environmental factors and husbandry conditions could also affect critical levels. The significance of nutrient balance was demonstrated by the influence of the N level on the response to K application and vice versa as shown below *[78]*.

Yield correlation between leaf N and K levels

$N < 2.70\%$ K: Yield correlation $r = 0.239$ N.S.
$N > 2.70\%$ K: Yield correlation $r = 0.643^{+++}$
$K < 1.10\%$ N: Yield correlation $r = 0.042$ N.S.
$K > 1.10\%$ N: Yield correlation $r = 0.655^{+++}$

Similarly, *Ochs [69]* showed such interdependence between K and P.

$P < 0.15\%$ K: Yield correlation Insig.
$P > 0.15\%$ K: Yield correlation $r = 0.739^{+++}$
$K < 1.0\%$ P: Yield correlation Insig.
$K > 1.0\%$ P: Yield correlation $r = 0.832^{+++}$

To illustrate the nutritional inter-relationship of palms, *I.R.H.O.* uses a pentagonal diagramme as shown in Figure 18. The critical levels are shown on a circle which cuts through five axies for N, P, K, Mg and Ca.

As for environmental effects, *Ruer [85]* found in the Ivory Coast an association between critical K levels and effective sunshine hours. Critical levels were lower where effective sunshine hours were low and he suggested that for regions of lower sunshine as the Ivory Coast, the critical level was 1.0% but for areas with more solar radiation as Malaysia, the critical level was probably 1.2%.

A similar relationship has not been noted in Malaysia but it is noteworthy that palms yielding about 25 t/ha/yr on marine clays on the West Coast usually had K levels in leaf 17 of 0.90–1.00% whereas comparable yielding palms planted on inland soils had values of 1.10–1.20%. *Ng [63]* suggested that different soil moisture regimes could probably be responsible for this difference in healthy leaf levels.

In Nigeria *[4]*, tentative critical levels are more in line with those of *I.R.H.O.*, indicative of similar climatic conditions. The levels are:

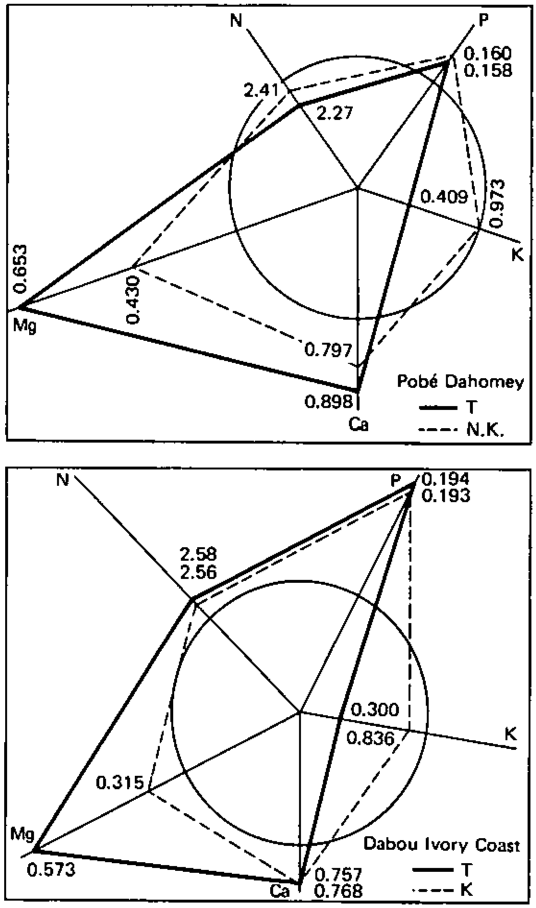

Figure 18. Diagrammatic representation of leaf analysis data for plots of palms with K (---) and without K(—) in Pobé and Dabov. Critical levels are shown as intersections between the circle and the five axes.
Source: *Surre Ch. and Ziller R.* (1963)

	N	P	K	Mg
%	2.5	0.145–0.155	1.00–1.10	0.28–0.30

For the Congo (Kinshasa), *Broeshart [12, 13, 14]* studied leaf analysis and the nutrition of young palms in sand culture and proposed the following critical levels for leaf No. 3.

	P	K	Mg	Ca
%......................	0.21–0.23	1.7–1.9	0.25–0.35	0.55–0.65

These values are reasonably comparable to those of *Rosenquist.*
For young palms, *Bachy [5]* also proposed critical levels for leaf 9: N 2.70%, P 0.160%, K 1.25%, Ca 0.500% and Mg 0.230%.
In terms of nutrient balance, the effect of a particular nutrient fertiliser on other elements is also of considerable importance. The antagonistic effect between K and Mg

or Ca is well known but interpretation for other nutrients is not often easy because a particular fertiliser also contains another anion or cation which may also have an effect. Thus, application of rock phosphate not only raises P level but can suppress K uptake because of the presence of Ca in the rock phosphate. Also, a nitrate or chloride salt tends to leach out more exchangeable K and Mg than a sulphate salt, and this may lower the uptake of these cations. Thus, the effect of a fertiliser on leaf nutrient levels should not be attributed to the nutrient element alone. Nevertheless, *Hartley [48c]* has presented the effects of major elements of leaf composition as follows.

	Leaf nutrient				
Fertiliser nutrient	N	P	K	Mg	Ca
N	+	0^+	–	–	0
P	0^+	+	–	0	+
K	0^{++}	0	+	–	–
Mg	0	–	–	+	–
Ca	0	0	–	0	+

+ increase. – decrease. 0 = no marked effect.
0^+ both increases and decreases have been recorded.
0^{++} small increases have been reported.

Thus, urea might possibly have a lesser depressive effect on K and Mg than ammonium sulphate or nitrate which tends to accentuate leaching of these cations. The depressive effect of phosphate on potassium is most probably due to the calcium in the phosphate fertiliser. The antagonisms between K and Mg and K and Ca have relevance for balanced manuring in sandy soils where both natural potassium and magnesium are in short supply.

It has become apparent in Malaysia at least that leaf analysis alone is inadequate in assessing fertiliser needs. Data relating to rainfall, sunshine, vegetative growth, soil moisture and nutrients and the results of fertiliser experiments are necessary to make the whole business more objective and precise.

Recently, *I.R.H.O.* workers (*Ollagnier M.* and *Ochs R.*, Oléagineux *26*, 1–15 [1971]) have claimed chlorine to be an essential element for oil palm. As this claim is based solely on leaf analysis data, its verification by experimentation would be necessary.

8.5.1 Field sampling errors

While foliar analysis from experiments may be entirely representative of the plots because all the palms are sampled, the same cannot be said of commercial fields which can vary from 10 to 100 ha in size. In practice, a sub-sample of the population is taken and most commonly, a 1% random sample of palms is practised *[7]*. This has stemmed mainly from the work on leaf No. 1 of palms in Nigeria *[104]*. How precise such a sampling device is in different conditions has not been as extensively studied as the diagnostic aspect. The few studies that have been made are largely confined to Nigeria and Malaysia.

In Nigeria, sampling studies were carried out by *Smilde and Chapas [86]* and *Smilde and Leyritz [87]*, who investigated individual palm nutrient variation of 15 year old palms. For leaf No. 17, they found that N and P were the least variable, followed by Ca and Mg and last by K which was quite variable. They concluded that in a 2 ha homogeneous block, 30 random palms had to be sampled to give results accurate to within 20% of mean values for K, 10%–20% for Mg and Ca and about 5% for N and P. These authors were of the opinion that sampling only 30 palms from a field of 20 ha would not achieve the precision desired.

Ward [104] carried out a larger sampling investigation on leaf No. 1 which allegedly is equivalent to leaf No. 3 in Malaysia, also in Nigeria. 512 single palms were sampled and analysed and he found that N, P and K were less variable than Mg, and Ca was extremely variable and proposed that a 1% sampling would achieve the precision required except for calcium. It was based on this finding that the 10th palm every 10th row technique was evolved.

More recently, *Ng and Walters [68]* studied nutrient variation of leaf No. 17 of individual palms in three 10 ha sites with a uniform soil type in each site. In the three instances, the numbers of palms sampled were 312, 750 and 1250. They found that on the whole, N and P were less variable than K and the most variable were Mg and Ca. Similar to the finding of *Ward*, they also found that in one site, there was a large and systematic variation in Ca. These results point to the need to have a prior assessment of variation in a particular field and the dangers of blindly applying one sampling scheme to all areas.

Correcting the Nigerian data to the same formula as used in Malaysia, the sample sizes in term of individual palms for estimating average nutrient contents in leaf No. 17 within 5% and 10% of the mean values for the major nutrients are summarised in Table 41.

Table 41. Oil palm sample sizes (number of palms) for each nutrient and set precision limits (a) = *Smilde* and *Leyritz* (b) = *Ward* (c) = *Ng and Walters*

	(a)		(b)		(c)					
					Site 1		Site 2		Site 3	
	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%
N	5	1	12	3	22	4	6	1	3	1
P	5	1	17	4	16	4	87	3	22	1
K	106	27	15	4	125	21	51	13	21	5
Mg	65	16	47	12	141	45	158	50	59	17
Ca	58	15	1231	307	56	11	75	31	173	123

Broadly speaking, the results of Nigeria and Malaysia are in reasonable agreement and indicate that if a 1% sampling intensity is followed such as the 10th palm every 10th row method, for N and P, the precision should be better than 5%, for K about 10% and for Mg 10–20%. For more rapid sampling on rolling to hilly terrain, Ng and Walters proposed an alternative scheme involving five random points and nine palms at each point.

Seasonal effects on leaf nutrient levels have not been extensively investigated. In Nigeria *[87]*, seasonal variation was found to be small and it was suggested that sampling could be carried out at any time of the year except during the April-June period of nitrogen flush at the beginning of the wet season. Published data are not available in Malaysia but work conducted (*Hew*, unpublished) has shown that differences between single months could be appreciable but over a yearly period, coefficients of variation were of the order of 6–10%.

As far as size of sampling unit is concerned, it seems 10 ha would be optimal from considerations of practicality and palm variation.

8.5.2 Choice of leaf

The common use of leaf No. 17 for diagnostic purpose may not be the best indicator as alone it may not be sufficiently sensitive in showing more rapid or short term changes in nutrient supply. Because of this, it has been suggested that use of a nutrient gradient analysis involving leaves Nos. 1, 9 and 17 may be more appropriate. Certainly, this proposal is worthy of further examination. *Ng et al. [67]* suggested that for boron and manganese, leaf No. 3 may be more sensitive.

8.6 Soil analysis

Soil analysis for assessing fertiliser requirements of oil palms has lagged behind leaf analysis, principally due to the following limitations: (a) there is a large volume of soil for the oil palm roots to extract nutrients and this cannot all be accounted for by soil analysis, (b) the oil palm, being a perennial, can take up nutrients released by slowly weathering minerals and (c) nutrient availability is affected by other factors such as moisture regime, soil structure which are not measured in chemical analysis. These difficulties had contributed to the generally poor correlations obtained and therefore the lack of interest in soil analysis by oil palm research workers. Yet, in retrospect, it is to be wondered whether many of the fertiliser experiments conducted would not have had an enhanced value if primary information on profile characteristics and chemical properties had been provided in complement to leaf analysis.

At least, the extrapolation of experimental findings to other soils or localities would have a better base. Also, the effect of past manurial applications on soil nutrient status might have been better known.

The use of soil analysis in oil palm nutritional work has been mainly confined to Nigeria and Malaysia. In Malaysia, soil analysis specifically for oil palms had been limited and information on nutrient status and physical properties has been drawn from more general analysis performed on soil units defined by soil surveys. However, the analytical work done *[42, 60]* has given a fairly clear pattern of nutrient status as briefly described as follows.

1. The generally higher nutrient status of the marine clays on the west coast of West Malaysia, particularly in P, K and Mg and occasionally N.
2. The very low K and Mg reserves in soils derived from granites, sandstones and quartzites, older and sub-recent alluvial sediments.

3. The very low K status of soils derived from basalts and andesites.
4. The variable but higher status of K of soils derived from shales.
5. The very low N and P status of soils derived from pale coloured shales.
6. The extreme acidity of acid sulphate soils and low K and Mg status.
7. The generally low N and P status of most inland soils derived from acid igneous and sedimentary rocks, and the higher P status of soils derived from basic rocks.

Admittedly, such information is not precise enough for making exact fertiliser recommendations but it is at least an aid in planning fertiliser experiments and interpretation of results. This dual approach of soil morphology and nutrient characteristics is in line with international advances in Soil Science. In a broad sense, there has been reasonable agreement between this macro-differentiation and main results of fertiliser trials for both oil palm and rubber in Malaysia. Thus, on the granitic soils, *Rosenquist [83]* and *Pushparajah [80]* found potassium to be the major limiting factor in yield performance during maturity. On soils derived from sandstone, *Ng [63]* reported a yield response of young palms to potassium and this is in agreement with a similar finding for rubber.

In Nigeria, soil analysis had been carried to a more advanced stage at the *Nigerian Institute for Oil Palm Research*. In earlier work, *Tinker and Ziboh [99]* found a significant relationship between K mole fraction (Exch. K/cation exchange capacity) and yield of fruit bunch in most areas. Later, *Tinker [95]* obtained a better relationship by using thermodynamic parameters of activity ratio (AR), which also took aluminium into account. For an Acid Sand soil, correlations were found between exchangeable K, mole fraction and AR without aluminium and leaf potassium as well as individual palm yield *[36]*. If the mole fraction was 0.015–0.020, K status was probably marginal and when it was less than 0.015, a likely response was expected. An activity ratio of 0.006 was considered critical.

In Dahomey, *Ochs [70]* also found relationships between exchangeable K in the top 20 cm and leaf K. When K in leaf No. 17 was 0.9%, soil K was about 0.2 m.e., but when it was 0.1 m.e., leaf K was around 0.3–0.5%.

In Congo (Brazzaville), *Prévot and Ziller [79]* showed a relationship between water soluble Mg and deficiency symptoms. *Tinker and Ziboh [99]*, working on 26 Nigerian and 10 Congolese soils found that symptoms were usually related to exchangeable Mg. However, exchangeable K also had an effect. In 1963 *Tinker and Smilde [96]* found a correlation between exchangeable Mg/K ratio and Orange Frond score of palms near Benin. Where the Mg/K ratio was greater than 4, a score of less than 10% was found but where the ratio was 4–2, the score went up to 30%.

No clear correlationships between soil N and P indices and leaf N and P or yield have been recorded.

8.6.1 Changes in soil nutrients during life of plantation

This aspect has only been studied in Nigeria *[54, 94]*. The most serious loss is in K but Mg and Ca losses from Benin fasc were also substantial.

	K		Mg		Ca	
Depth cm	0–15	15–45	0–15	15–45	0–15	15–45
Loss kg/ha over 1945–61	97	113	71	147	632	539

The type of treatment of vegetation can also affect soil nutrients. In burnt areas, there was a large initial build-up of K due to the ash of the vegetation but this lasts only about 5 years and a gradual decline then ensues. In areas which were not burnt, it was found that there was a rapid release of K from the vegetation followed by Mg and Ca in the top soil.

8.7 Deficiency symptoms

Certain nutrient shortages in plants are reflected in well defined symptoms. Generally, when such symptoms become visually distinct, the deficiency is already in a fairly advanced stage. Symptoms of known and suspected nutrient deficiencies of the oil palm have been elaborately described by *Bull [19, 20]*, *Broeshart et al. [16]* and *Turner and Bull [100]*.

8.7.1 Nitrogen deficiency (Plate No. 1)

N deficiency is mostly found in young immature palms in situations where the soil is inherently poor such as very sandy soils, ill drained or very shallow as found in laterite soils. A general chlorosis of the leaflets is the main symptom. The fronds first become pale green, then pale or bright yellow as the deficiency advances. Both the upper and lower rank leaflets are equally affected. Finally, purple or brown discolorations appear, usually towards the tip of an affected pinna. Pinnae of newly emerging leaves may become progressively narrow.

8.7.2 Potassium deficiency (Plate No. 2 + 3)

This disorder is characterised by three major symptoms, i.e. *Confluent Orange Spotting*, which is common in Malaysia and Africa, *Orange Blotch* and *Mid-Crown Yellowing* which are found more commonly in Africa. Potassium deficiency is most common on light sandy soils.

(a) *Confluent Orange Spotting*. Initially, this disorder is shown by the appearance of small, rectangular-like pale green spots on the pinnae of older leaves. The spots are best seen against light. As the deficiency advances, the spots increase in size and change to olive green and then bright orange. These spots or lesions may fuse to form compound orange spots, hence the name Confluent Orange Spotting. The lesions are usually less than 5 mm in length and may be partly necrotic. Finally, the spotting ends in terminal and marginal necrosis of affected leaflets in older leaves.

Orange Spotting may also be of genetic origin *[34]* which can be distinguished by its occurrence on isolated palms only.

(b) Orange Blotch: In Nigeria, this was known as Mbawsi symptom but orange blotch is probably more precise. Large, somewhat elongated, diffuse olive green blotches on pinnae of older fronds constitute the first symptom. These blotches usually appear about halfway along the length of the pinna. As leaves become older, the blotches become bright yellow and later orange with little necrosis. Ultimately, the tissues are invaded by weak parasites and become brown or purple in colour. This symptom is rare in the Far East, being reported only in sands and some peat soils *[100]*.

(c) Mid-Crown Yellowing. This disorder is marked by a dull brown or ochre chlorosis on young fronds on the upper part of the crown and the discoloration is strikingly uniform. The chlorosis first appears at some point in the leaflet, expands until the entire leaf is uniformly yellow in colour. Later, a clear band of necrotic tissue develops around the margin of the yellow pinnae. Often, affected palms also show Orange Blotch symptoms.

8.7.3 Magnesium deficiency (Plate No. 4)

This deficiency is generally termed as *Orange Frond* in view of the vivid chlorosis seen in severely deficient palms. The disorder first appears as olive green or ochre-coloured areas at some point on the leaflet and these merge gradually into the healthy green tissue. The discoloration begins as a narrow ochre patch or strip lying between two adjacent lateral veins and the yellow colour spreads along the leaflet towards the base of the leaflet as the deficiency advances. The colour changes from ochre to bright chrome yellow and finally to a deep orange. A characteristic is that areas of the leaflet protected from direct sunlight by shading are not chlorotic. Thus, lower rank leaflets remain greener than those of the upper rank. Usually, these affected leaflets are attacked by fungi. The symptom characteristically appears first in the older fronds.

8.7.4 Boron deficiency (Plate No. 6)

Various symptoms thought to be attributed to boron deficiency have been described in Africa *[16, 32]* and Malaysia *[100]*. Boron deficiency has been reported to have affected large areas of palms in Colombia in South America *[Ollagnier,* priv. comm.*]*. In Malaysia it was considered that the various symptoms represent different facets of the same syndrome. In Malaysia, the most common symptom is *Hook Leaf* but other symptoms such as *Leaflet Shatter, Blind Leaf, Bristle Tip and Hook Leaf–Little Leaf* are said to be associated with boron deficiency. It should be emphasised that there is little experimental evidence that boron deficiency is really responsible for all these symptoms and the following statements are therefore largely tentative.

Hook Leaf gives a rounded outline to the tip of the youngest frond. The pinnae in the terminal section of the leaf are shortened and the leaflets are abnormally rigid and more closely packed. A distinctive terminal hook then appears at the apex of one or more pinnae on an affected leaf. The hook may itself be corrugated and is normally fragile. In severe cases, the midrib may show one or more acute bends which give the lamina a zig-zag outline. However, Hook Leaf may also be associated with abnormal palms.

Leaflet Shatter tends to be associated with palms less than 10 years old. Affected leaflets droop very abruptly from one particular point along their length and bending is usually more severe on one side of the leaf than the other. Complete fracture at the midrib occurs at the point of bending. Whether wind has any influence on this is not known.

Bristle Tip is usually associated with Hook Leaf but at the apex of the leaf, the normal pinnae are replaced by a tuft of long fibrous bristles arising from the tip of the rachis of the truncated leaf.

Hook Leaf–Little Leaf. This is different from the Little Leaf of pathogenic origin. Advanced symptoms of this disorder are uncommon in Malaysia. In affected palms, the newly emerging leaves are reduced in size and show extensive deformation of the pinnae. The pinnae normally show extensive hooking or folding. The apical leaflets remain laterally fused to produce a large compound mass of laminar tissue.

To correct the deficiency, an application of about 110 g (4 ounces) per palm is generally used in Malaysia.

8.7.5 White Stripe (Plate No. 5)

This disorder is commonly encountered in oil palm plantings in Malaysia and is most prominent in palms of 3–6 years old. Less severe symptoms can be observed in palms up to 20 years old. The symptoms pass through different stages of severity in growing palms. Typically, light symptoms are seen in palms of 2–3 years in age, then they turn severe at 3–5 years as crop builds up and finally a phase of less obvious White Stripe from 5–6 years. Observations indicate that it is strongly associated with ground cover conditions. A vigorous legume cover on a light soil or inadequate potassium manuring, generally provides the most severe symptoms.

The first symptom is indicated by the youngest leaves becoming abnormally dark green in colour, and erect in habit and the rachis does not bend downwards away from the spear. The leaflets show narrow bands or stripes of chlorotic tissue as the disorder develops. Initially, the chlorosis produces a clear white or very pale yellow longitudinal stripe which is very sharply defined from the adjacent green tissue. As symptoms become more severe, the chlorotic stripe widens and the margin becomes more diffuse but usually one stripe is found on one side of the leaflet. *Rajaratnam [private communication]* found that the white tissue is devoid of mesophyll cells. The rachis and leaflets become abnormally slender and the latter fragile and finally the entire leaf becomes fore-shortened.

There is no direct evidence of the actual cause of White Stripe but foliar analysis has indicated high nitrogen and low potassium are mostly associated with it. *Turner and Bull* suggested that White Stripe begins to appear when the N/K ratios in leaf No. 17 exceeds 2.5 but this does not always apply to all situations. Boron shortage has not been entirely ruled out as a possible cause as it has been reported in South America that borax application alleviated White Stripe symptoms. More recent opinion is that

Plate 1. Young palm showing nitrogen deficiency

Plate 2. Orange spotting due to K deficiency; common in Africa and the Far East (by courtesy: I.R.H.O., Paris)

Plate 3. Orange blotch due to K deficiency; common in Africa (by courtesy: I.R.H.O., Paris)

Plate 4. Orange frond due to Mg deficiency

Plate 5. White Stripe symptoms

Plate 6. Hook Leaf said to be due to B deficiency

Plate 7. Severe desiccation of leaves due to extreme acidity in acid sulphate soils in Malaysia

the disorder, like some type of Confluent Orange Spotting, may also be of genetic origin.

8.7.6 Peat Yellows

This disorder has been observed in palms on peat soils in West Malaysia and it has a marked effect on yield.

The malady is indicated by the appearance of pale green to whitish interveinal chlorotic streaks of leaflets on the youngest expanded leaf. The chlorosis extends from the pinna tip to within 5–7 cm of the base. As the disorder advances, a diffuse uniform yellow speckling develops within the chlorotic streaks which become more pronounced yellow in colour. The lesions coalesce and large areas of the pinna become uniformly pale orange in colour. In older palms of 8–10 years of age, young fronds and leaflets are considerably shortened and except for the very new and spear leaves, the rest of the crown is chlorotic.

The cause is still uncertain but micronutrient deficiencies may be involved as copper levels are commonly very low, i.e. 1–4 ppm; potassium is also low although magnesium is high. Lately, *Ng and Hew [unpublished]* found that zinc levels in leaf No. 17 were also very low at 5–8 ppm as against 15 ppm in normal palms. Experiments with trace elements have been laid down to correct the disorder but in view of the common finding that responses to trace elements are inconsistent *[35]*, other factors may also be involved.

8.7.7 Hyperacidity disorders (Plate No. 7)

The disorder is found on palms planted on acid sulphate clays or cat clays which had developed by the draining of former brackish and sulphurous swamps. Such soils are found in the coastal areas of Malaysia and yields are very low. The pH of the surface horizon is generally less than 3.5 in water and this drops to below 3.0 in the subsoil. Intensive drainage accentuates the disorder rather than improves it. Undoubtedly this very low pH has a strong influence on nutrient availability.

Apart from soil characteristics, the extremely acid condition is indicated by very sparse or bear ground cover. Legumes hardly establish on this land and grasses are sparse, the common vegetation being a sedge, *Fimbristylis spp*. The typical symptom is the gradual necrosis of leaflets and as it progresses, more and more leaves become dessicated except for the spear and young leaves. At this stage, there are hardly any fruit bunches on the palm.

Until recently, there were no profitable means of ameliorating these soils. Heavy liming is neither successful nor economic but *Hew and Khoo* have shown that a combination of blocking up the drains during dry spells, application of bunch ash, potassium and magnesium could bring such palms back to economic production.

8.8 Fertiliser recommendations

The preceding data have indicated that through the years, the requirements of the oil palm for fertilisers have been on the increase steadily especially with the newer planting materials. However, there is considerable variation in fertiliser needs, depending on climate, soil type and nutrient status, age of palms and level of fruit production. As a result, general fertiliser recommendations may not be as valuable in practice and very few recommendations have been published prior to the sixties but since then, *Jacob and von Uexkull [53], Werkhoven [106]* and *Geus [39]* have assembled useful information on manuring oil palms. Although not specific, such data serve as general guides and refinement can be made after evaluation of soil and leaf analysis data and yield records. More recently, more elaborate fertiliser recommendations have been made for the Far East, Africa and South America and these are presented in Appendices 1–7.

8.9 Other aspects of fertiliser use

8.9.1 Placement

In principle, nutrients should be applied at sites with the highest concentration of feeder (tertiary and quaternary) roots in order to achieve maximum uptake. For the oil palm, it can be surmised that the feeder roots expand outwards with palm age after establishment in the field. The distribution of tertiary and quaternary roots of immature and mature palms has been studied in the Ivory Coast by *Ruer* and in Malaysia by *Gray*. Both these workers found that in palms of up to 2 years in the field, most of the feeder roots were located within 2 m of the palm base. In palms of 3–5 years, the feeder roots were mainly found within 4 m of the base although the higher density was still within the 2 m radius. For older palms, the feeder roots were more evenly distributed and in 9 year old palms, *Ruer* found that the majority were within 3–5 m of the base and this is more or less the finding of *Gray*.
As a result, *Ruer* recommended that for palms of 1–2 years in the field, fertilisers should be placed in a circle band between 1.5–2.5 m of the base and for palms of 3–5 years, application should be restricted to 1.5–4.0 m. For palms of such age, these recommendations are also practical because of the existence of either legume or natural covers in the inter-rows. Thus, during this period, applying fertilisers at the periphery of the weeded circle is quite sound. Placement studies using radioactive tracers carried out by *Broeshart [15]* have also shown that for immature palms, placement near the palm base is most effective but for mature palms, no optimal position was established. It appears that for mature areas, two options are open to choice. On terraced land or areas with appreciable growing vegetation, fertilisers can be applied near the edge of the weeded circle, and on flat land with little ground cover, inter-row broadcast may be practised and there is also the possibility of mechanisation.

8.9.2 Frequency

Work in Africa, mainly with potassium on mature palms has indicated that annual application is not necessary and one large application can last for three years. In the Far East, similar experimentation has not been conducted and comparison is not meaningful. Generally, for mature areas in Malaysia, potassium, phosphate and magnesium are usually applied once a year while nitrogen may be applied twice. For palms in the first two years, 4–8 rounds a year are common. Clearly, there is a need to examine current practices in the Far East because of the large rates of application and the occurrence of rainfall in heavy thunderstorms when more than 250 mm of rain can fall in a few hours. Under such conditions, leaching losses may well be substantial should heavy rain follow fertiliser application. This is particularly pertinent for nitrogenous fertilisers.

8.9.3 Form of nutrient

This mainly concerns nitrogen because of the developments of alternate sources of nitrogen. With the advent of more concentrated and cheaper sources of nitrogen, the efficiency of urea against sulphate of ammonia or ammonium nitrate for oil palms needs to be thoroughly evaluated. Results of investigations in Africa seem to show that urea is as efficient as sulphate of ammonia or ammonium nitrate. Unfortunately similar work has not been carried out in Malaysia. However, it has been shown *[105]* that on inland soils, as much as 28% of the N in surface applied urea can be lost but on the coastal clay soil, the loss was only 6%. Also *Acquaye and Cunningham [1]* showed that losses were considerably reduced by raking urea into the soil. In view of the prospects of considerable savings, investigations on the use of urea should be actively encouraged.

A problem with nitrate fertilisers is that not only is it more easily leached out but also it accelerates leaching of basic cations. On the other hand, ammonium sulphate increases soil acidity and eventually leads to greater leaching of nutrients.

As far as phosphatic fertilisers are concerned, rock phosphate has been found to be effective because soils planted with oil palms are generally strongly acid with a pH of less than 5.5. Where the soil is only weakly acid as some of the volcanic soils with pH of above 6.0, it is likely that soluble phosphates are more effective.

8.10 Economics of manuring

Fertiliser cost is a major input factor in palm oil production and the prospect of getting profitable returns from such expenditure is constantly in the mind of plantation management. Few studies on the economics of manuring oil palms have been carried out but those that have been undertaken have shown that economic responses depend on yield levels as well as market prices but on the whole, profitable returns are not difficult to achieve. In one of the earliest studies, *Gunn [43]*, in Nigeria estimated that for palms yielding in the region of 12000 kg/ha/yr, a response of 7.5% to a total application of 6.4 kg/palm of complete fertiliser comprising sulphate of ammonia, rock phosphate, muriate of potash and magnesium sulphate would be profitable. The prices of fertilisers used for the calculations are given as follows:

Fertiliser	£/t	Plant nutrient	£/t
Sulphate of ammonia	24	N	114
Rock phosphate	19	P_2O_5	53
Muriate of potash	26	K_2O	43
Magnesium sulphate	19	MgO	

For palms which are more productive as those in the Far East, it can be predicted that break even responses are lower and this was shown by *Paterson [73]* in Malaysia. The various increases in yield required to show a profit in Malaysia are presented in Table 42. Thus, it can be said that for palms yielding in the region of 25 t/ha/yr, a significant response obtained in a fertiliser experiment strongly suggests that such a level of response is also economic.

Table 42. Percentage increases in yield required to show a profit

Fertiliser	kg/palm	Nutrient kg/ha	Yield t/ha	7.4	12.4	17.3	22.2	27.2
				%				
Nitro-26	1.8	66 N		21.7	13.0	9.3	7.2	5.9
CIRP	1.8	91 P_2O_5		10.3	6.2	4.4	3.4	2.8
Muriate of potash	1.8	151 K_2O		16.3	9.8	7.0	5.4	4.4
Kieserite	1.8	66 MgO		13.3	8.0	5.7	4.4	3.6

Fertiliser cost:		per tonne material	per kg nutrient
	Nitro-26	M$275 N	M$1.06
	CIRP	M$120 P_2O_5	M$0.33
	Muriate of potash	M$205 K_2O	M$0.34
	Kieserite	M$165 MgO	M$0.63

Table 43. Economic analysis of responses obtained in experiments on young mature palms in Malaysia

Expt.	Yield						Net income at palm oil* f.o.b.		
	Response	Response	Duration	Costs/ha $M			Prices ($/t) of		
	level	t/ha	yrs	F	H&P	total	400	500	600
No. 1	K_1	4.17	2	195	126	321	351	450	546
	P_1	4.74	2	82	143	225	383	489	635
No. 2	K_1	3.95	1	242	118	360	339	427	504
No. 4	K_1	6.84	5½	395	205	600	590	736	867
No. 5	N_1	4.92	5½	143	148	291	440	553	679
	K_1	11.58	5½	198	348	546	1188	1252	1509

F = Fertiliser H&P = Harvesting & Processing
* After deduction of duty

Using responses actually obtained from very recent fertiliser experiments on young palms in West Malaysia, *Ng [63]* showed that the small to moderate early responses during the 3rd to 8th year of planting were very profitable at palm oil prices of M$500/t but even at a low f.o.b. price of M$400/t, most of the responses were profitable (Table 43).

Therefore, the preceding findings clearly indicate that fertiliser use, if effectively applied, can be a very sound investment and enables planting of oil palms to be more profitable.

8.11 Yield projections of fruit bunch

The productivity of the oil palm is dependent upon the type of genetic material, climate, soil conditions, husbandry practices and incidence of pests and diseases. As discussed earlier, climate, primarily rainfall, exerts an overriding effect on the level of expression of full genetic potential. This is evident in the vast difference in yield levels of comparable planting materials in Malaysia which has a favourable climate and in Nigeria which has a pronounced dry season. Such differences in yield levels can be expected to have an appreciable influence on the intensity of fertiliser use on oil palms in a given environment. Thus, yield data of plantations of various oil palm regions serve a very useful guide to the projections of probable fertiliser needs.

Table 44. Bunch yields of post war Dura plantings on inland and coastal soils in West Malaysia t f.f.b./ha/annum *[2]*

Years from planting	(a) Inland soils		(b) Coastal soils		
	Average	Best	Good	Average	Poor
4	2.3	4.5	9.9	7.4	6.1
5	5.8	9.5	19.8	11.1	8.6
6	8.9	13.4	18.6	14.4	12.4
7	11.3	18.3	21.0	17.3	14.9
8	13.7	20.8	23.6	19.8	16.0
9	15.5	22.3	24.8	21.0	18.6
10	16.7	21.8	23.6	22.3	19.3
11	17.6	21.3	22.8	21.8	19.8
12	18.1	21.0	22.3	21.0	18.6
13	18.2	20.8			
14	18.3	20.6	21.0	19.8	18.6
15	18.2	20.3			
16	18.0	20.0			
17	17.7	19.7			
18	17.5	19.3	19.3	18.6	16.0
19	17.2	19.0			
20	16.8	18.6			
21	16.4	18.2			
22	16.1	17.8			
23	15.7	17.4	16.0	14.9	13.6
24	15.3	17.0			
25	14.9	16.7			

Table 45. Bunch yield of D × T and D × P material on inland soils in West Malaysia t f.f.b./ha/annum *[21]*

Years from planting	D×T		D×P	
	Range	Mean	Range	Mean
3	0–6.2	2.7	0–8.6	1.2
4	1.2–18.6	8.9	0–17.3	6.0
5	6.2–26.0	15.8	6.2–23.5	12.1
6	9.9–22.0	16.5	5.0–28.2	18.1
7	15.0–25.0	20.2	16.0–25.0	21.2
8	—	—	17.3–23.6	21.1

Table 46. Yield estimates for D × T material on coastal clays in West Malaysia t f.f.b./ha/annum *[7]*

Years after planting	Class A areas	Class B areas
3–4	12.5	11.2
4–5	21.2	17.5
5–6	23.7	21.2
6–7	26.2	23.7
7–8	27.0	24.5
8–9	27.2	24.7
9–10	27.2	25.0

For West Malaysia, such projections of yield of various planting materials have been made by *Bull [21]* and *Bevan et al. [7]*, and these are presented in Tables 44 to 46. It can be seen that major soil differences have an influence on yield levels in West Malaysia. Yield projections for West Africa are not available but from miscellaneous published records, yield levels are probably within 40–60% of those in Malaysia. More recent observations indicate that the expected declines in yield after the tenth year of planting are likely to be appreciably smaller due to advances in husbandry methods including sound manuring programmes.

Appendix 1 (A)

Rates of Sulphate of Ammonia (N) and Muriate of Potash (K) recommended for young plantings on four major soil groups in West Malaysia (kg/palm)

Years in field	I. Sandy loams to sandy clays from granite, sandstone, older alluvium		II. Clays from basic igneous rocks		III. Silty clay from shales		IV. Marine clays	
	N	K	N	K	N	K	N	K
1	0.68	0.45–0.90	0.45	0.68	0.45–0.68	0.45	0–0.23	0
2	0.90–1.36	1.36–2.50	0.68–0.90	1.36–1.60	0.68–1.36	1.14	0–0.23	0.45–0.68
3	0.90–1.36	2.27–3.41	0.68–0.90	2.04	0.68–1.36	1.60–2.04	0–0.23	1.14–1.60
4	0.90–1.60	2.73–3.86	0.90–1.14	2.04–2.73	0.90–1.60	2.04–2.73	0–0.23	1.14–1.60
5	1.14–1.81	2.73–3.86	0.90–1.14	2.73	1.14–1.81	2.04–2.73	0–0.23	1.81–2.04
6	1.14–1.81	2.73–3.86	1.14–1.60	2.73	1.14–1.81	2.04–2.86	0.90–1.14	1.81–2.04
7	1.81–2.04	2.73–3.86	1.60	3.41–3.64	1.60–2.04	2.73–2.86	0.90–1.60	1.81–2.73
8	1.81–2.73	2.73–3.86	1.60	3.41–3.64	1.60–2.73	2.73–2.86	0.90–1.60	1.81–2.73

Source: *Hew and Ng [50]*

Appendix 1 (B)

Rates of Christmas Island Rock Phosphate (P) and Kieserite (Mg) recommended for West Malaysia (kg/palm)

Years in field	I. Sandy loams – sandy clay loams from granites, sandstone and older alluvium		II. Clays from basic rocks		III. Silty clay loams – silty clays from shales		IV. Marine clays	
	P	Mg	P	Mg	P	Mg	P	Mg
1	0.45–0.90	0.23–0.45	0.23–0.45	0.23	0.45–0.90	0.23	0	0
2	0.68–1.14	0.45–1.14	0.23–0.45	0.45	0.68–1.14	0.45	0	0
3	0.68–1.60	0.90–1.14	0.45–0.68	0.45–0.68	0.68–1.60	0.68–0.90	0	0
4	0.90–1.60	0.90–1.60	0.90–1.14	0.68–0.90	0.90–1.60	0.90–1.14	0.23–0.45	0–0.23
5	1.14–1.60	1.14–1.60	0.90–1.14	0.68–0.90	0.90–1.60	0.90–1.36	0.23–0.45	0–0.23
6	1.14–2.04	1.14–1.81	0.90–1.14	0.90	1.14–2.04	1.14–1.36	0.23–0.45	0–0.23
7	1.60–2.04	1.36–1.81	1.14–1.36	0.90	1.14–2.04	1.14–1.60	0.45–0.90	0–0.45
8	1.60–2.04	1.36–1.81	1.14–1.36	0.90	1.36–2.04	1.14–1.60	0.45–0.90	0–0.45

Source: *Hew and Ng [50]*

Appendix 2

A schedule of manuring polybag nursery palms in West Malaysia, using a compound 12/12/17/2 (NPK Mg) fertiliser [7]

Age (months)	Amount/palm (g)
5	7
6	14
7	14
8	14
9	21
10	21
11	28
12	28
13	28
14	42

Appendix 3

Rates of fertilisers recommended for oil palms in Indonesia (kg/palm). Ollagnier et al. [71]

Year in field	*Sulphate of Ammonia*	*Rock Phosphate*	*Muriate of Potash*
Nursery	—	—	—
1	0.50	1.0	0.5
2	0.75	1.25	1.0
3	1.0	1.5	1.25
4	1.0	2.0	1.5
>4	Not stated	2.0	2.0

Appendix 4

Rates of fertilisers recommended for oil palm plantings in West Africa (kg/palm)

Country	*Source*	*Year in field*	*Sulphate of Ammonia*	*Urea*	*Phosphate*	*Muriate of Potash*	*Kieserite*
Dahomey	*Surre & Ziller [90]*	0–1	0.50			0.20	
		1–2	0.75			0.20	
		2–3	1.00			0.50	
		3–4	1.00			0.75	
		4–5	n.a.			1.00	
		>5	n.a.			1.0–1.5	
Dahomey	*Ollagnier et al. [71]*	0–1		0.175		0.20	
		1–2		0.250		0.50	
		2–3		0.300		0.75	
		3–4		0.300		1.00	
		> 4		n.a.		1.25	
Ivory Coast	*Ollagnier et al.*			*Forest*	*Savannah*	*Savannah*	*Savannah*
		0–1		0.25	0.375	0.75	0.125
		1–2		n.a.	0.50	1.00	n.a.
		2–3		n.a.	n.a.	1.25	n.a.
		3–4		n.a.	n.a.	1.50	n.a.
		>4		n.a.	n.a.	1.50	n.a.

Country	*Source*	*Year in field*	*Sulphate of Ammonia*	*Urea*	*Phosphate*	*Muriate of Potash*	*Kieserite*
Liberia	*Ollagnier et al.*	0–1	0.50			—	
		1–2	0.75			0.50	
		2–3	n. a.			0.50	
		3–4	n. a.			0.75	
		>4	n. a.			0.75	
Nigeria	*Werkhoven [106]*	0–1	0.225			n. a.	
		1–2	0.450			n. a.	
		2–3	0.900			n. a.	
		3–4	n. a.			n. a.	
		>4	n. a.			2.27 every 3 yrs	
Nigeria, NIFOR	*Ollagnier et al. [71]*	0–1	0.45			0.23	
		1–2	0.94			0.45	
		2–3	1.40			0.94	
		3–4	n. a.			1.40	
		>4	n. a.			2.30	
Sierra Leone	*Ollagnier et al.*				(super)		
		0–1		0.20	0.25	n. a.	0.15
		1–2		0.30	0.375	n. a.	0.15
		2–3		n. a.	0.50	n. a.	0.60
		3–4		n. a.	n. a.	0.50	n a.
		4–5		n. a.	n. a.	1.00	n. a.
		>5		n. a.	n. a.	1.50	n. a.
Togo	*Ollagnier et al.*	0–1	0.35			0.20	
		1–2	0.50			0.50	
		2–3	0.60			0.75	
		3–4	0.60			1.00	
		>4	n. a.			1.25	

n. a. = data not available

Appendix 5

Rates of fertilisers recommended for oil palm plantings in Central Africa (kg/palm)

Country		*Year in field*	*Sulphate of Ammonia*	*Urea*	*Phosphate*	*Muriate of Potash*	*Kieserite*
Cameroon	*Ollognier et al. [71]*	0–1		0.15		n. a.	n. a.
		1–2		0.25		n. a.	n. a.
		2–3		n. a.		n. a.	n. a.
		3–4		n. a.		n. a.	0.40
		4–5		n. a.		n. a.	0.40
		5–6		n. a.		0.50	0.50
		>6		n. a.		1.00–1.50	0.50
					(double super)		
Congo (Kinshasa)	*Ferwerda [32]*	0–1	0.25–0.50		0.15–0.30	0.20	0.12
		1–2	0.50		0.30–0.60	0.40	0.25
		2–3	0.75		0.45–0.90	0.60	0.36
		3–4	1.00		0.60–1.20	0.80	0.50
		>4	0.50–1.00		0.50–1.00	0.80–1.00	0.80–1.00

Continuation

Country		*Year in field*	*Sulphate of Ammonia*	*Urea*	*Phosphate*	*Muriate of Potash*	*Kieserite*
					(triple super)		
Congo (Kinshasa)	*Ollognier et al. [71]*	0–1	0.10		0.23	0.25	0.10
		1–2	0.15		0.34	0.35	0.15
		2–3	0.20		0.46	0.50	0.20
		3–4	0.50		0.50	0.75	n.a.
		4–5	0.50		0.70	0.85	n.a.
		>5	n.a.		1.00	1.00	n.a.
Congo (Brazzaville)	*Ollagnier et ol.*	0–1	0.30			n.a.	0.15
		1–2	0.40			n.a.	0.20
		2–3	n.a.			n.a.	0.30
		3–4	n.a.			n.a.	0.40
		4–5	n.a.			0.50	0.40
		>5	n.a.			1.00–1.50	0.50

Appendix 6

Rates of fertilisers recommended for oil palm plantings in South America (kg/palm). Ollagnier et al. [71]

	Year in field		*Sulphate of Ammonia*	*Urea*	*Phosphate*	*Muriate of Potash*		*Kieserite*	
Brazil S. Bahia	0–1		0.50			0.30			
	1–2		0.75			0.75			
	2–3		n.a.			1.00			
	3–4		n.a.			1.20			
	>4		n.a.			1.20			
N. Bahia	0–1		0.50			n.a.			
	1–2		0.75			n.a.			
	2–3		1.00			0.50			
	3–4		1.25			0.75			
	>4		1.50			1.00–1.20			
Para	0–1			0.50	1.00 (super)	0.75		0.125	
	1–2					1.00		n.a.	
	2–3					1.00		n.a.	
		Savannah	Forest		(super)	Savannah	Forest		
Amapa	0–1	0.50	0.50		0.65 Savannah	0.35	0.50		
	1–2	0.50	0.75		1.00 and forest	0.50	0.75		
					(slag)				*Borax*
Colombia	0–1			0.25	1.00	0.50		0.50	n.a.
	1–2			n.a.	n.a.	0.75		0.50	0.05
	2–3			n.a.	n.a.	1.25		0.65	0.075
	>3			n.a.	n.a.	1.25		0.65	0.075
Peru	0–1			0.20		n.a.		0.10	
	1–2			0.20		n.a.		0.10	
	2–3			n.a.		0.50		n.a.	

Appendix 7

Rates of fertilisers used in the nurseries in Africa and South America (g/palm). Ollagnier et al. [71]

Country	Sulphate of Ammonia	Urea	Phosphate	Muriate of Potash	Kieserite
Dahomey	—	125	—	200	—
Ivory Coast (Forest)	—	125	—	—	—
(Savannah)	—	250	—	250	50
Liberia	400	—	—	—	—
Nigeria	450	—	—	—	—
Sierra Leone	—	200	125 (super)	—	100
Togo	250	—	—	200	—
Cameroon	—	100	—	—	—
Congo (Brazzaville)	200	—	—	—	100
Congo (Kinshasa)	100	—	120 (triple super)	125	50
Brazil S. Bahia	250	—	—	250	—
N. Bahia	250	—	—	—	—
Para	—	250	500 (super)	250	60
Amapa (Savannah)	250	—	650 (super)	250	—
(Forest)	250	—	650 (super)	250	—
Colombia	—	125	500 (slag)	250	—
Peru	—	100	—	—	50

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9. Harvesting and Processing

Although the quality of palm oil is affected by several field factors *[8]*, harvesting forms a most critical part of oil palm production because all preceding operations can be largely negated if harvesting is not carried out efficiently. The principal products of the oil palm are palm oil and palm kernels; palm kernel oil is later extracted from the kernels leaving palm kernel cake as a by-product. The objective of harvesting is to obtain as high a quantity and quality of oil as feasible. Hitherto, consumer requirements of palm oil reaching ports of destination are that it should have low amounts of dirt and moisture, and a free fatty acid (f.f.a.) content of less than 5%. Since a margin must be allowed for a slight increase in f.f.a. during shipment, it is desirable that palm oil leaving producing countries should have an f.f.a. content of less than 3.5%. A discount is levied if f.f.a. exceeds 5% while a small premium may be awarded if it is below this level.

The harvesting of oil palm fruit bunches has to contend with three factors. Firstly, fruit ripening does not take place evenly on all palms and secondly ripening within a fruit bunch is also uneven. These two conditions make it impossible to harvest all fruit bunches which have a maximum oil content of high quality. Bunches varying in ripeness are therefore harvested and the pragmatic approach is to obtain an optimal amount of oil of good quality. The third factor is that fruit bunch production is also not even throughout the year, the peak month having about 12 ½% of the total annual crop while the lowest month may have only 4% of the total. This means that a flexible system of labour and transport organisation should be available to ensure that ripe fruit does not deteriorate in quality.

As the fruit in the bunch ripens, the colour changes from deep purple to reddish orange and the oil content increases in the process. When the oil content reaches a maximum, the fruit becomes loose and falls on the ground. As a result of uneven ripening, it takes about 16–20 days for all fruitlets in a bunch to ripen; hence the impossibility of getting all fruitlets of the same ripening stage. When the fruitlet falls on the ground, the f.f.a. content rises rapidly because the enzyme lipase present in the fruitlet brings about the splitting of fatty acids from the glycerides.

Thus, the fruit bunch has to be harvested neither in an under-ripe nor over-ripe stage. However, there is no exact criterion for optimal ripeness and it is common practice bred from experience to harvest when there are two loose fruitlets on the ground per estimated kilogramme of bunch weight, e.g. 40 loose fruitlets for a 40 lb or 18 kg bunch [3,7]. As fruit ripening is not even, it is not economic to harvest daily and the usual interval between harvesting is 7–10 days as a practical compromise between quantity and quality of oil.

9.1 Harvesting techniques

9.1.1 Cutting of bunches

The implements used comprise chisels, axes and knives on bamboo poles, depending on the accessibility of bunches as determined by the height of the palm. Generally, chisels are used from first harvesting until the ripe bunches are produced at about 3–4 m high, after which knives on bamboo poles are used.

9.1.2 Collection of bunches and loose fruit

There are a number of ways to collect cut bunches and loose fruit but the most acceptable appears to have adult male workers performing the cutting and carrying of bunches while the women and young workers gather loose fruit. The bunches and loose fruit are carried to a collecting point or platform near the roadside or rail in rattan baskets and a kanda stick. On level terrain, wheelbarrows may be used. From the collecting points, fruit is transported by tractor-trailer or lorry to the factory. Where a railway system exists, fruit is loaded directly onto tipping trunks or steriliser cages. In Malaysia recently, there have been developments in transportation of fruit from the field to factory. In one [5] a container system of transportation was followed while in the other, fruit is placed in a large net instead of a container, spread out at a collecting point and the net with fruit is then lifted into a lorry by a crane system built into the lorry [10]. This latter method of loading is not only quicker and cheaper but involves less handling than the conventional manual lifting method. In the container system, fruit bunches are transferred directly into ½ t capacity containers which are then lifted onto trailers. It is likely that these systems or modifications will become increasingly popular because of the following advantages:

(a) there is less handling of fruit and thus oil quality is not lowered,
(b) labour requirement is less as containers or nets are lifted into a lorry or trailer in one operation, and
(c) crop weights of individual harvesting teams and individual fields can be easily and more accurately obtained.

The harvested fruit should be transported on the same day to the factory where the fruit should be processed within 24 hours in order to avoid oil deterioration. This means that field harvesting and factory operations ought to be co-ordinated to ensure that processing of fruit is not unduly delayed. In general, it must be the aim to process all fruit not more than 48 hours after harvesting.

At the factory, fruit from lorries or trailers are tipped into specially constructed ramps *[4]* and thence into steriliser cages.

9.2 Processing at the mill

In parts of Africa where oil palms are planted by smallholders, traditionally crude and inefficient methods have been used and generally, oil of poor quality is produced. Since World War II, there have been significant improvements such as the development of the curb press and later the hydraulic hand press *[9]*. Improved methods of sterilisation and the use of the hydraulic press have helped to enhance the quantity and quality of smallholder palm oil from Africa.

However, for most efficient processing of fruits and production of good quality palm oil on a large scale, the use of a palm oil mill is essential. First used in Africa before World War I, such mills are now exclusively used in the oil palm plantations in the Far East as well as in plantations in Africa and South America.

Palm oil mills can vary in capacity according to the size of the plantation. For plantations of up to 2000 ha, a 10 t/hr throughput is sufficient to handle crops at peak periods. A 20 t/hr mill should be adequate for plantations around 4000 ha. For very large plantations of about 8000 ha or more, it has been estimated that a central large mill of 40 t/hr capacity is preferable to two smaller 20 t/hr mills because of economy of scale *[4]*.

The milling process (Figure 19)

The major stages of fruit processing are as follows.

(a) Sterilisation: Most sterilisers are of the horizontal cylinder type and sterilisation is carried out by steam under pressure. Steriliser cages charged with fruit bunches are entered into the steriliser and steam is gradually introduced until the pressure and temperature are at 2 kg/cm² and 130° C respectively and these conditions are maintained for about 40–55 mins. The total time of sterilisation is 60–75 mins. Usually, a steriliser can hold 2 or 4 cages each of which has a capacity of 2 ½ t of fruit. The primary objective of sterilisation is to loosen fruitlets on the bunch to facilitate subsequent stripping but at the same time, the fat splitting enzyme, lipase is destroyed.

(b) Stripping of fruitlets from bunches. The fruitlets are separated from the bunch stalk and spikelets in a rotary drum or beater arm stripper, the latter being used only in small mills of less than 10 t/hr capacity. The rotary drum is made of horizontal metal bars with adequate space between them to permit the stripped fruitlets to fall through onto a conveyor which takes them to the digester. The empty bunch waste is carried out at the other end of the drum.

(c) Digestion: The purpose of digestion is to press out the oil from the mesocarp of the fruit and this process is therefore most important. Heat is provided in order to assist in the loosening of oil containing cells from the fibre in the mesocarp. Digestors of present day are steam jacketed cylindrical vessels with a central rotating shaft. The fruitlet is mashed by pairs of stirring arms attached to the shaft. Steam pressure is

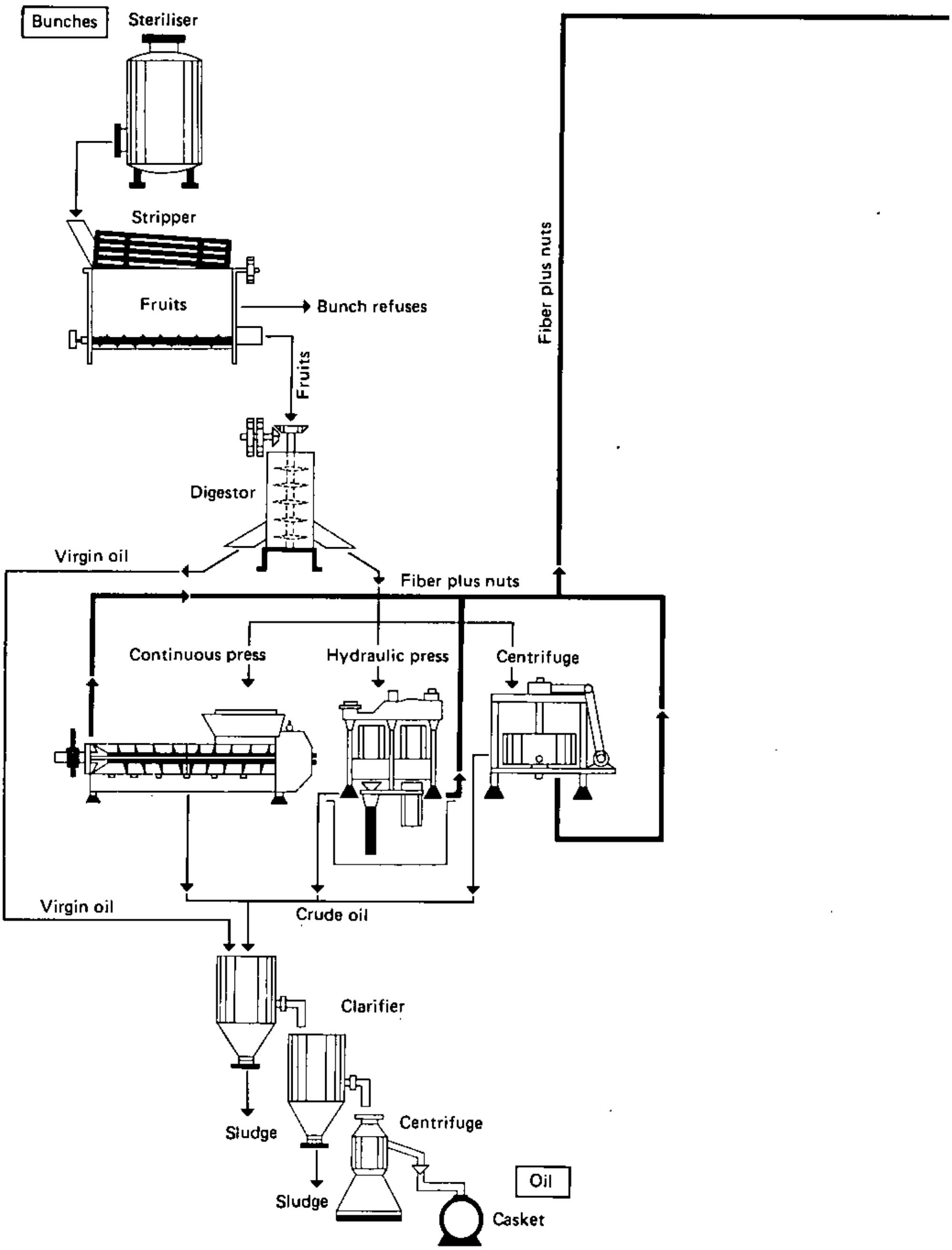
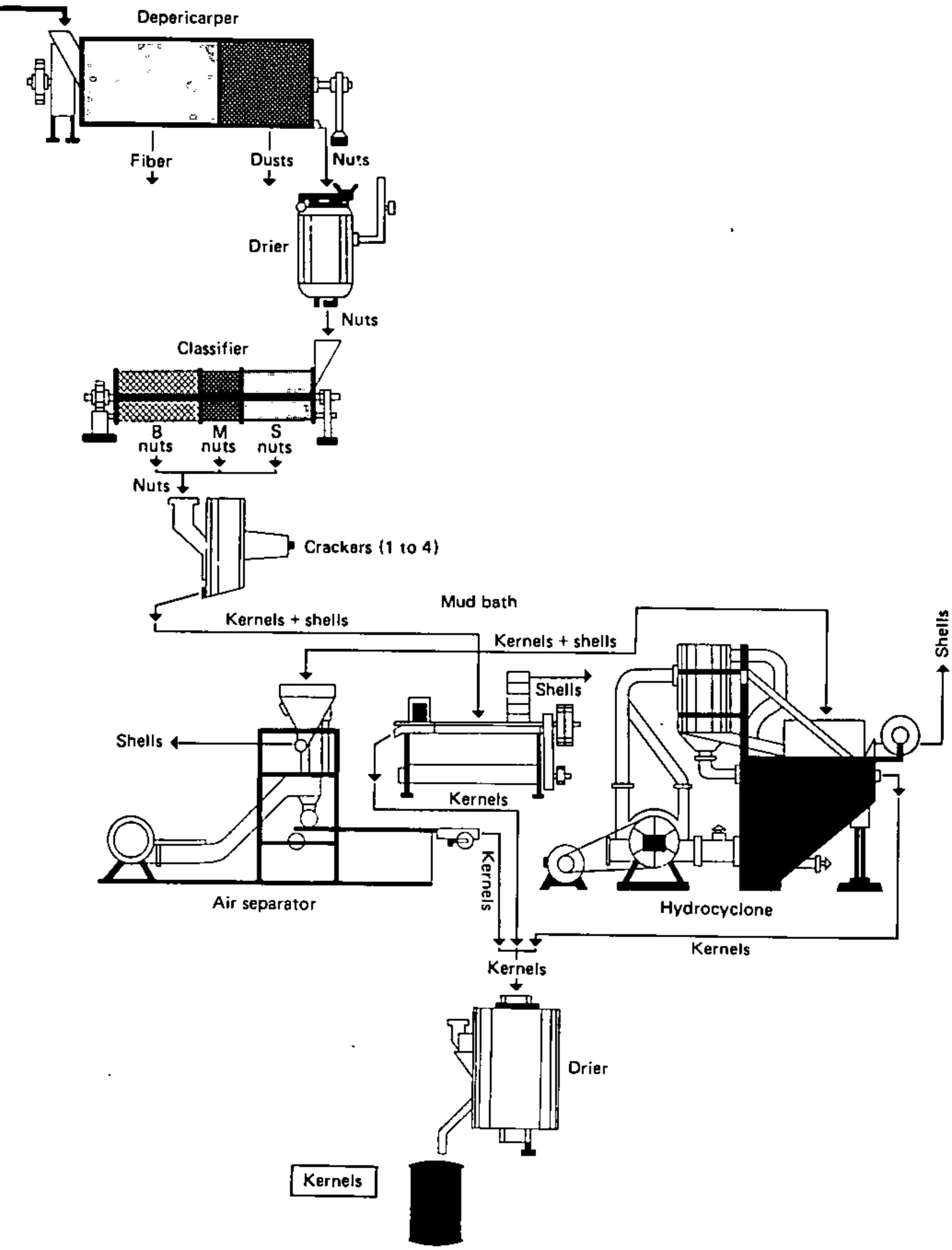


Figure 19. Schematic diagramme of various and alternative stages in processing fruit bunches. Source: *Surre Ch. and Ziller R.* (1963)


Depericarper
Fiber
Dusts
Nuts
Drier
Nuts
Classifier
B nuts
M nuts
S nuts
Nuts
Crackers (1 to 4)
Mud bath
Kernels + shells
Kernels + shells
Shells
Shells
Shells
Kernels
Kernels
Air separator
Hydrocyclone
Kernels
Kernels
Drier
Kernels

maintained so that the mash leaves the digestor at about 90°C. About half of the oil in the mash can seep through the perforations at the bottom to the crude oil tank.

(d) Oil extraction: Centrifuges were widely used in the past and are still being used although it is likely that they will gradually disappear from the scene. The digested mash is charged into a basket of 1.0–1.3 m in diameter and centrifuged at a speed of 950–1250 r.p.m. The load is equivalent to 1–2 t fruit bunches per hour. The operation from filling to discharging takes about 20–25 mins and the oil is discharged through the mass via the perforations of the basket into the clarification section. Centrifuges give an oil which is generally sludge free and clarification losses are small. On the other hand maintenance is more difficult and the outlay is higher. The throughput is also lower.

Hydraulic presses have generally replaced centrifuges. Two types have been developed; the standard with a capacity of about 3 t fruit bunches per hour, and the automatic press with a higher capacity of 4.5–6.5 t/hr. The standard press seems to be more advantageous for Dura than Tenera fruit. The mash is introduced into the perforated press cage from the digestor through a hole in a sliding door, and a ram moves upwards to press the mash and then returns by its own weight. It has been shown that there is an increased loss of oil in the fibre when the proportion of nuts to fruit exceeds or falls short of a certain percentage but no explanation for this has been advanced. According to *Bek-Niesen [2]*, the wear and tear of the standard press is greater than that of the automatic press in terms of throughput but the latter has a higher maintenance cost.

Very few comparisons of centrifuges and hydraulic presses have been made but the one study by *Georgi [6]* in Malaysia showed that there was no difference in efficiency between the two types of machine but centrifuges gave a clearer crude oil, lower losses in sludge but a higher oil content in residual cake. However, in view of higher throughput and lower labour requirement, hydraulic presses have a slight advantage although this point can be strongly contended.

Screw presses appeared on the scene since the 1950's but developed slowly because of their higher wear and tear and feared effects of metals on oil quality. However, more recent tests with screw presses indicated that they were as efficient as the hydraulic presses and oil was of equal quality and losses were even less *[2]*. One countervailing consideration is that screw presses are more suitable for D × P materials because with Duras, a high proportion of nuts is cracked. Major advantages of the screw presses are (a) high throughput of 9–15 t/hr and (b) lower capital outlay and power consumption. The maintenance cost is about comparable to those of hydraulic presses.

9.2.2 Clarification

The crude oil from the presses also contains water, dirt and cellular matter. At the crude oil tank, the oil passes through vibrating screens to remove larger impurities and whatever material that does not pass through is automatically returned to the digestor. The screened crude oil is pumped to clarification tanks and nowadays, a continuous system of separation is usually followed. In these clarifying tanks, the crude oil is passed to near the bottom of the tank and the oil rises as a thick layer until it reaches the top where it is discharged through an outlet pipe. The intermediate sludge-water layer which has a higher gravity than the oil is syphoned off at a slightly lower level and the oil in it is further recovered in special sludge separators. The sludge, being the heaviest, collects at the bottom and can be discharged to the sludge tank. In order to reduce oxidation of the clear oil in the tank, floats can be used.

9.2.3 Kernel extraction

The matter from the press or centrifuge consists of nuts and moist fibre and the first step is the separation of the nuts from the fibre. Pneumatic fibre separators are most commonly used. The mixture passes into a large rotating drum which has baffles mounted on the inside and these carry the mixture upward and allow it to drop. A current of air passing through the drum carries the partially dried fibre to the exit tube and blows it out. The nuts fall into smaller lower rotating drum where they are polished by friction. Recently, stationary direct air separation columns have been introduced in place of the rotating drum and they occupy less space.
The nuts are generally dried in a silo before being screened and graded into size prior to cracking. Silo drying is not absolutely necessary but for Tenera material, it is of greater importance. The nuts are then fed into nut crackers where they are hurled against a cracking ring. Usually, a 90–95% cracking success is achieved. The kernel and shell are separated in a water-clay mixture of 1.17 specific gravity. The shells sink to the bottom while the kernels float and are skimmed off, washed and dried.
More recently, hydrocyclones have reduced the use of clay baths as they use water only. The mixture is introduced into a tank of water and forced with the water to a cyclone *[2]*. Due to a combination of centrifugal and non-tangential forces, the kernels are discharged at the vortex and the shell at the apex of the cyclone. The kernels are subsequently dried in a silo.

9.2.4 Mill efficiency

In a commercial mill, there is no direct method of measuring efficiency and this is estimated by determining oil losses in various components, i.e. steriliser condensate, bunch refuse, dry fibre, nuts and sludge. Generally, the biggest loss is in the fibre. The efficiency of present day mills is round about 92–95%.

9.2.5 Quality control at the mill

In every mill, there is a quality control laboratory to carry out certain specified tests on the oil *[1]*. These are: moisture content, dirt and free fatty acid content. On the kernels, amount of foreign material and moisture are normally determined. Discoloration is also assessed by eye.

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10. Composition, Processability and Uses of Palm Oil and Kernels

10.1 Composition

Palm oil is a semi-solid fat which varies in colour from orange yellow to deep orange. Oil of low acidity will separate on standing into a yellow solid fraction and a deep red liquid fraction. It is well known that the oil consists mainly of triglycerides of palmitic, oleic and linoleic acids. *Eckey [4]* and *Loncin and Jacobsberg [11]* have given ranges of fatty acid composition of 21 samples of commercial oil from the Far East, and Africa as follows.

Fatty acid	*Eckey* Far East and Africa %	*Loncin and Jacobsberg* Congo %
Myristic	0.6–5.9	1.2–2.4
Palmitic	32.3–45.1	41.0–43.0
Stearic	2.2–6.4	4.4–6.3
Oleic	38.6–52.4	38.0–40.2
Linoleic	5.0–11.3	9.9–11.2

It can be seen that *Eckey's* figures are more variable than those of *Loncin and Jacobsberg*. More recently, *Jacobsberg [6]* has given mean values of fatty acid composition of palm oils of three countries, sampled over a period of six months in 1968 and these indicate a fairly stable composition (Table 47).

Table 47. Average fatty acid composition of palm oils *[6]*

Fatty acid	Malaysian plantation oil %	Cameroon plantation oil %	Congo S.P.B. plantation oil %
Saturated Lauric C_{12}	0.07	0.12	0.12
Saturated Myristic C_{14}	1.27	1.14	1.02
Saturated Palmitic C_{16}	39.60	38.90	45.50
Saturated Stearic C_{18}	6.17	6.51	5.90
Mono-unsaturated Oleic C_{18}	39.30	40.80	34.60
Di-unsaturated Linolenic C_{18}	12.18	10.74	11.81
Tri-unsaturated Linolenic C_{18}	0.37	0.51	0.29
Iodine value	58.60	57.70	53.50

Thus, there is a slightly higher proportion of unsaturated acids in Malaysian palm oil and *Loncin and Jacobsberg* established the following estimates.

Triglycerides S–S–S	approximately	6%
Triglycerides S–S–U	approximately	48%
Triglycerides S–U–U	approximately	43%
Triglycerides U–U–U	approximately	3%

S = saturated acid, U = unsaturated acid

Palm oil also contains unsaponifiable matter amounting to about 0.3% of the total. The principal components are phosphatides, carotenoids which give the oil its colour, tocopherols and sterols. An average composition of such constituents is presented in Table 48 as given by *Jacobsberg*.

Table 48. Average composition of unsaponifiable matter in palm oil *[6]*

Constituents	Abundance ppm	Composition %
Carotenoids	500–700	α Carotene 36.2 β Carotene 54.4 γ Carotene 3.3 Others 6.0
Tocopherols	500–800	
Sterols	300	
Phosphatides	500–1000	
Alcohols	800	

Carotene content can vary considerably in the mesocarp of the fruit as *Purvis (12)* found that oil from red and orange fruits contained 2560 and 1100 ppm carotene respectively.

Palm kernel oil: Unlike palm oil, palm kernel oil is colourless and resembles coconut oil and the composition range of fatty acids is shown in Table 49.

Table 49. Composition of palm kernel oil

Fatty acid		%
Caprylic	C_8	3–4
Caproic	C_{10}	3–7
Lauric	C_{12}	46–52
Myristic	C_{14}	14–17
Palmitic	C_{16}	6–9
Oleic	C_{18}	13–19
Stearic	C_{18}	1–2.5
Linoleic	C_{18}	0.5–2

Properties. The common properties of palm oil and palm kernel oil are given by *Gehlsen [5]* as in Table 50.

Table 50. Common properties of palm oil and kernel oil

Property	Palm oil	Kernel oil
Melting point ° C	27–42.5	23–26
Solidification value ° C	31–41	20–23
Specific gravity at 15° C	0.920	0.952
Specific gravity at 40° C	0.896	0.912
Saponification value	199–202	241–255
Iodine number	53.6–57.9	10–23.4

Free fatty acid (f.f.a.). Free fatty acids are formed by the splitting of the long chain fatty acids from the triglycerides and the f.f.a. content has been the principal criterion of palm oil quality. An upper limit of 5% f.f.a. at port is imposed by consumers and oil with f.f.a. higher than 5% is considered inferior and a discount is levied because of greater loss of oil during refining. However, as can be seen later, refining of palm oil also depends on other factors besides f.f.a.

Free fatty acids are formed by two processes, both of which involve hydrolysis. These are (a) enzymatic hydrolysis and (b) acid catalysed hydrolysis.

Enzymatic hydrolysis is due to the action of the fat splitting enzyme *lipase* which occurs naturally in the mesocarp of the fruit. Normally, the oil is protected from the enzyme by the membranes of the vacuoles but these can be mechanically ruptured when the fruit is bruised or crushed during harvesting or transportation. Thus, f.f.a. content can increase very rapidly although the original content in intact fresh fruit has less than 0.5% f.f.a. *Desassis [3]* found that within 15–20 mins, f.f.a. content in mesocarp increased from about 5% to nearly 40% following crushing. This indicates, that handling the fruit is relatively more important than getting the fruit to the mill quickly. Lypolitic degradation can also be brought about by the invasion of fungi and other microorganisms into the mesocarp, particularly in over-ripe fruit as well as bruised fruit contaminated by soil during harvesting *[14]*.The enzyme can be completely inactivated by heating at 55° C and this is achieved during sterilisation. *Turner* also found that in Malaysia, further f.f.a. build-up was unlikely during processing at the mill.

Where water is present, spontaneous autocatalytic hydrolysis can be brought about by the f.f.a. already in the oil and sufficiently high temperatures around 70° C *[9]*. *Loncin and Jacobsberg [10]* studied spontaneous autocatalytic hydrolysis of palm oil at 70° C and found that over a period of 120 days, the content of triglycerides decreased by more than 50% and the f.f.a. increased from about 5% to 40%, and there were smaller increases in diglycerides and monoglycerides. Moisture is thus the most critical factor in this form of hydrolysis. At a moisture content of 0.1%, the splitting rate becomes negligible. Thus, in well dried oils, no f.f.a. increase should occur during storage.

10.2 Refining (Figure 20)

Palm oil has to be refined before it is used for the manufacture of edible fats, and this consists of three steps, (a) neutralisation (b) bleaching and (c) deodorisation. Of the three, bleaching is the most important. The alternative systems of refining are outlined in Figure 20 *[7]*.

Three bleaching processes are used depending upon the oil concerned. These are as follows:

(a) bleaching with *Fuller's* earth at low temperature of up to 100° C,
(b) heat bleaching at about 240° C, and
(c) earth catalysed heat bleaching at 180° C.

With higher temperatures of bleaching, a subsequent neutralisation is necessary because of the increase in f.f.a. Generally, heat bleaching with *Fuller's* earth is most common.

In the bleaching process, the carotenes are destroyed and/or absorbed by the *Fuller's* earth. Formerly, it was thought that Malaysian palm oil was better in bleachability than Nigerian oil merely because it contained less carotene i.e. less than 500 ppm against 700–1300 ppm. However, later investigations showed that this was not entirely correct; oxidation products probably played a greater role as shown by two groups of workers. *Ames, Raymond and Ward [1]* suggested that the inferior bleachability of Nigerian crude palm oil was due to the formation of yellow degradation pigments which were less readily absorbed by the bleaching earth. These resistant pigments were said to be formed from the coupled oxidation of carotenoids and the oil, the latter being attacked by the enzyme lipoxidase. It was also mentioned that atmospheric oxidation, catalysed by iron could cause a further deterioration of the oil.

Similarly, *Loncin and Jacobsberg [10]* thought that autoxidation of the unsaturated fatty acid bonds led to the formation of hydroperoxides and this action was strongly catalysed by copper and iron. Copper was found to be about 10 times more active than iron and amounts as low as 0.3 ppm could cause irreversible damage over very short periods. Oxidation also destroys the carotene and tocopherols. However, the peroxide value itself gives no reliable indication of the degree of spoilage since the hydroperoxides are highly unstable products. In Sweden, *Johannson [8]* claimed that Benzidine value gave a better indication of the state of autoxidation. It is evident that more research is needed to elucidate the mechanism leading to poor bleachability.

Palm kernel oil: Like palm oil, kernel oil should also have a low f.f.a. content and a light yellow colour which is easily bleached. The major cause of high f.f.a. is lypolitic microorganisms and rapid drying is required to prevent such deterioration *[14]*. A moisture content of 6–7% in kernels is said to be near the border line of the safe moisture limit. *Turner* has also shown that aflatoxin producing moulds such as *Aspergillus flavus* may be found in kernels and a low moisture content is desirable to avoid such development. There are about six methods of refining kernel oil depending on the quality of the crude oil.

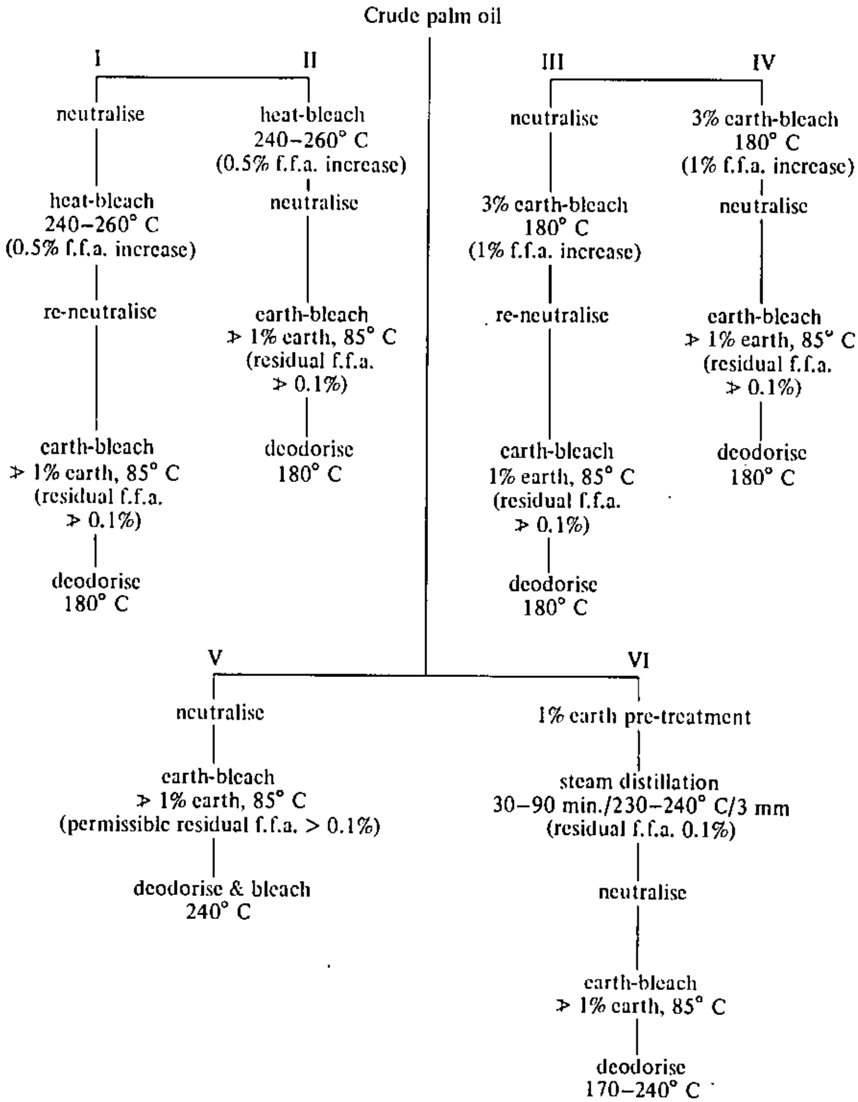

Figure 20. Methods of processing crude palm oil.
Source: *Jasperson H. and Pritchard J. L. R.:* Trop. Sci. 7 (1965)

10.3 Uses of oil palm products

Palm oil: The principal end uses are as follows:

(a) edible fats
(b) manufacture of soap
(c) manufacture of candles
(d) tin-plating of iron sheets
(e) fuel for internal combustion engines
(f) greases and lubricants

Of the above, edible fats form the dominant outlet for palm oil. The main edible products are margarine, bakery and table, and shortenings. Palm oil is particularly suited to the manufacture of margarine because of its low tendency to turn rancid and therefore longer shelf life. It has been estimated that world margarine and shortening consumption in 1969 totalled about 6 million t *[2]* and it can be assumed that palm oil would have had an important portion of this consumption.
For the manufacture of solid edible fats, soaps and candles, hydrogenation of palm oil is necessary and this is carried out with a catalyst, usually nickel. The hydrogenation also renders the fat more stable.
The industrial uses of palm oil are very limited.

Palm kernel oil: This oil is also used for the manufacture of edible fats, soaps and detergents. Refined kernel oil has a limited application in pharmaceutical and toilet preparations.
Palm kernel cake: This by-product is principally used for the preparation of compound animal feeds. It is mixed with more palatable feedstuffs because it has little flavour. Pressed kernel meal has about 6–9% oil while solvent extracted meal has a lower oil content of 2%. The press cake tends to turn rancid. Some analytical data for German and Malaysian kernel cake are presented in Table 51.

Table 51. Malaysian and German chemical analysis of some kernel cakes

	Malaysian analysis*	German analysis**
Moisture %	11	9.9
Fat	8	7.1
Crude Protein	15	15.6
Crude fibre	10	19.2
N-free extractable substances	53	44
Ash	3	3.9

* The Oil Palm in Malaya. Min. Agric. Co-op. Malaysia p. 232, 1966.
** The Oil Palm, its Culture, Manuring and Utilisation, Inter. Potash Inst. Berne p. 101, 1957.

Palm wine: In West Africa, mainly Nigeria, smallholders obtain palm wine by cutting the budding inflorescence and collecting the exudates in a vessel. This is very similar to the juice called «toddy» collected from the coconut palm. The wine is consumed locally and apparently, there is good profit in the limited business *[13]*.

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11. The Future

Through increasing world population and rising standards of living, the overall demand for edible fats and oils will continue to expand but whether palm oil can capture much of this expansion depends largely on its competitive position. Although palm oil production at present constitutes only about 5% of the total edible oils and fats, it has to compete keenly with vegetable oils like soyabean and sunflower as weil as fish oil. As statistics indicate, prices of palm oil in the sixties have trended downwards and this also being the long term prospect, it is vital that the oil palm industry undertakes to modernise itself in production and consumer requirements, and become as highly efficient as feasible. To achieve this, the following considerations need to be taken into account:

(a) selection of favourable climatic and soil conditions for new plantings,
(b) replanting with high yielding Tenera materials,
(c) expand research on all aspects of production, particularly in breeding, physiology, nutrition and processing,
(d) initiate consumption research to improve oil quality and meet consumer requirements, and enlarge end uses,
(e) secure economy of scale in developing land with oil palm, and
(f) provision of effective and extensive advisory services to growers.

The first point on environment has been adequately dealt with earlier and needs no further elaboration.
Since existing oil palm stands greater than 10 years of age are largely Duras, replanting of old stands with Tenera materials which have an average oil content of 21–23% in the bunch compared with only 17–18% in Duras, should give about 20–25% more oil on the same production of bunches per hectare. However, current experience in Malaysia indicates that bunch production of Tenera plantings in early maturity is also higher, probably because of heterosis or hybrid vigour.
Research on oil palm production in the past 15 years has already brought considerable benefits such as improved planting materials, polybag techniques, assisted pollination, better nutrition and plant protection. To reduce cost of production, still higher yields of oil are necessary and for this purpose, work on genetics and plant breeding has to be sustained. *Hardon [4]* has provided evidence to indicate that the potential of oil content

in bunch is as high as 30%; so there is still good prospect of using superior planting materials in future. Coupled to this, a better understanding of the physiological basis of flowering, fruit set and development may help to achieve an optimum sex ratio and even bunch production throughout the year.

Only rudimentary research on oil quality and end use has been carried out thus far and there is an urgent need to launch investigations in this important field. Markets for palm oil can only be assured if palm oil is of the right quality and meets consumer requirements. The development of S.P. oil from the Congo is a step in the right direction. Production of palm oil to technical specifications from producing countries as in the case of natural rubber will go a long way to satisfy consumer demands. To expand markets or outlets for palm oil, it is necessary to promote research into existing and potential areas where palm oil is used or can be substituted. In addition, technical advisory services to major consumers should also be provided.

Finally, from the point of view of producer countries to achieve maximum efficiency in production, there should be economy of scale in development of new oil palm plantations. In Malaysia, it is generally considered that a unit should be at least 2000 ha in view of the heavy capitalisation for establishment and factory construction. *Bevan and Goering [2]* estimated that to establish an estate of approximately 2400 ha from jungle into bearing at the end of three years, a total outlay of about M$8.3 million would be required, inclusive of a factory. They further computed that for such development on a good inland soil in West Malaysia, the internal rate of return to investment was 16.9% per annum, using a declining price projection for palm oil of M$600 to M$450 in the seventies. For a plantation of 8000 ha, *Cooper and Bevan [3]* in a separate exercise showed that a large central factory with a capacity of 40 t/hr was more economical in the long run than two 20 t/hr mills, provided the mill was suitably sited from the point of transportation. Thus, if such advantages in large scale development are taken and with prospects of better planting materials, the return to investment in the oil palm industry should be reasonably attractive to potential investors.

However, the preceding remarks do not imply that oil palm plantings can only be successful if they are large plantations. Economy of scale and maximum returns from investment are not the only criteria; social and political considerations may also be very important. Thus, other forms of development which invariably involve smallholders are feasible but to ensure economic viability, the small plantings should be organised as

(a) large land settlement schemes but run along plantation lines,
(b) blocks closely associated or contiguous to a nucleus plantation with processing facilities and
(c) co-operatives of existing cultivators.

Hartley [5] has described such forms of development in the Far East and West Africa. The first type of smallholder development has been the normal practice in Malaysia where the *Federal Land Development Authority* develops large parcels of forest land of more than 2000 ha on behalf of settler families each of which gets a share of 4 ha although the land is not subdivided into such basic units. The scheme is run almost like a plantation with central management and supervision and over the past decade, this development can be considered to be successful. In the Ivory Coast, the second form is found and this comprises a nucleus industrial area of 1000–9800 ha surrounded by individual plantings averaging 3.7 ha per owner *[1]*. In Dahomey, the co-operative schemes are found involving original land owners and peasant proprietors. In Colombia and Ecuador *[Hartley, priv. comm.]* smallholder schemes of medium size are also being developed with fair success. With the preponderance of small cultivators in most developing countries, these types of oil palm development are likely to gain ascendance over private plantations.

Finally to bridge the gap between research and husbandry practices, the provision of extensive and effective advisory services to oil palm growers in the first instance is most necessary. This service is particularly critical for smallholders and some form of group organisations such as small growers associations are desirable to facilitate dessemination of technical information. In addition, a technical advisory service to consumers on the use and technological properties of palm oil and kernel needs to be developed.

If all the above measures are undertaken by the oil palm industry, the future can be faced with reasonable confidence and so will the wellbeing of any developing country be better secured.

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