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The semi-wild oil palm and its industry in Africa

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1 Introduction

1.1 Industry

The oil palm (*Elaeis guineensis* JACQ.) is of great importance to many countries in Africa. The economy of several areas *e.g.* Eastern Nigeria, southern Dahomey, the Kwango district in Congo and several smaller localities depends for a great part, if not completely, on the oil palm. BUCHANAN and PUGH (1958) reported that in the Anang Province of Eastern Nigeria over £ 4 per hectare was obtained from the export of palm produce. Large areas of the land are covered by oil palms, whose exact number is unknown and impossible to calculate, although some attempts have been made. They are based on export figures for the kernels, on the assumption that all the kernels are exported. Other estimates have been made by calculating the density of some sample plots and measuring or assessing the area under palms.

Several authors have estimated the number of palms in a certain country or district; these estimates are listed below:

Country, district	Estimated number of oil palms	Reference
Nigeria	25 million plus palms tapped for wine	FARQUHAR, 1913
Nigeria	1.5 million hectares covered by oil palms (*i.e.* about 200 million oil palms if assuming a density of 135 stemmed palms per hectare *	WATERSTON, 1953 (ZEVEN)
Nigeria: Igala district	100,000 hectares under oil palms (*i.e.* 13.5 million palms if assuming a density of 135 stemmed palms per hectare)	LOMAX, 1962 (ZEVEN)
Dahomey	40 to 60 million	DANIEL, 1902; HENRY, 1922
Ivory Coast	30 to 40 million	JÄGERSCHMIDT, 1953
Former French Cameroons	35 million	ANON., 1951
Congo: Uele district	6 million	LEPLAE, 1922
Tanganyika: Kigoma distr.	170,000	SHEPSTONE, 1951

* figure from table 7.

Using the annual figure of the Nigerian kernel export (see below) and the yield of kernels per stemmed palm as found in the Ikot Okpong Palm Grove (see tables 7 and 21) the total number of stemmed palms in Nigeria would be about 250 million, which is more than calculated with WATERSTON's figure for palm area, but of the same order. FARQUHAR's figure must be too low.

The total number of palms above listed is 325 million to which all the palms growing in the oil palm areas not mentioned have to be added. No estimates are given for the number of stemless palms.

The oil palm provides food (palm oil, kernels, palm wine, palm cabbage), material for building such as leaflets for thatching, and other domestic uses such as for making baskets, nets and ropes; the leaf rachis is used for roofing and walls; ash from the inflorescenses is used for soap making and as salt. As the export market for and internal trade in palm oil and kernels grew so the oil palm became a source of cash.

Exports from Nigeria in 1959 and 1960 averaged 185,000 tons of oil and 440,000 tons of kernels per year, and together accounted for about 24% of the value of the country's total exports. However, since 1960 the quantity of palm produce exported has fallen considerably and it is believed that the price policy of the Nigerian Marketing Boards is one of the main causes of this decline (HARTLEY, 1963). This fall in export does not mean that less oil is being processed, but that more oil is consumed locally; in some areas the local market prices are higher than those of the marketing board's buyers. Such circumstances have stopped the export of palm oil from Ghana, where the local price of oil in 1963 was about £ 120 per ton, considerably above the world price.

1.2 History

The oil palm has grown in Africa from very early times and there is evidence of palm oil being used in 3,000 B.C. in Ancient Egypt (FRIEDEL, 1897).

It could be claimed that the oil palm had been introduced from America into Africa before the end of the fifteenth century and that it had established and spread before the arrival of the early explorers. From studies described in section 6.1.5 it appears that in semi-wild environments it may take from 20 to 30 years before the palm starts fruiting and about 60 years before it reaches a height of 15 m. There is no reason to believe that these periods were shorter in the sixteenth century when the palm was found from Cape Verde to Angola and often in large groves, composed of tall palms. Palm products were well known to the inhabitants of the areas and were recorded by early visitors, such as the Portuguese CA DA MOSTA in 1455–1457, DUARTE PACHECO PEREIRA in 1506–1508 and the German in Portuguese service VALENTIM FERNANDES in 1506–1510 (CRONE, 1937; KUNSTMANN, 1856; MAUNY, 1956; MONOD, TEIXEIRA DA MOTA and MAUNY, 1951), who visited West Africa before and immediately after the discovery of America. Oil palm products were not mentioned by the first botanists PISO and MARCGRAF to visit Brazil separately in the seventeenth century (ZEVEN, 1965a). Further arguments in favour of the African origin of the oil palm were give by ZEVEN (1965a), who compared the vernacular names of the oil palm and of the coconut palm (*Cocos nucifera* L.) introduced by Europeans. The vernacular name of the latter is in most cases descriptive and can often be translated in 'whiteman's nut' or 'Portuguese nut', while the vernacular name of the oil palm can often not be translated.

Furthermore the negro name of the oil palm in Latin America is often identical or a corruption of an African name for this palm or its fruits or nuts. When CLUSIUS named the oil palm in DODONAEUS's *Cruydtboeck* of 1608 he used the specific name *Guineensis* because he thought the palm came from Guinea. In renaming this species in his *Selectarum stirpium americanarum historia*... of 1763 JACQUIN did not hesitate to give the same specific name, *guineensis*, the Guinean oil palm.

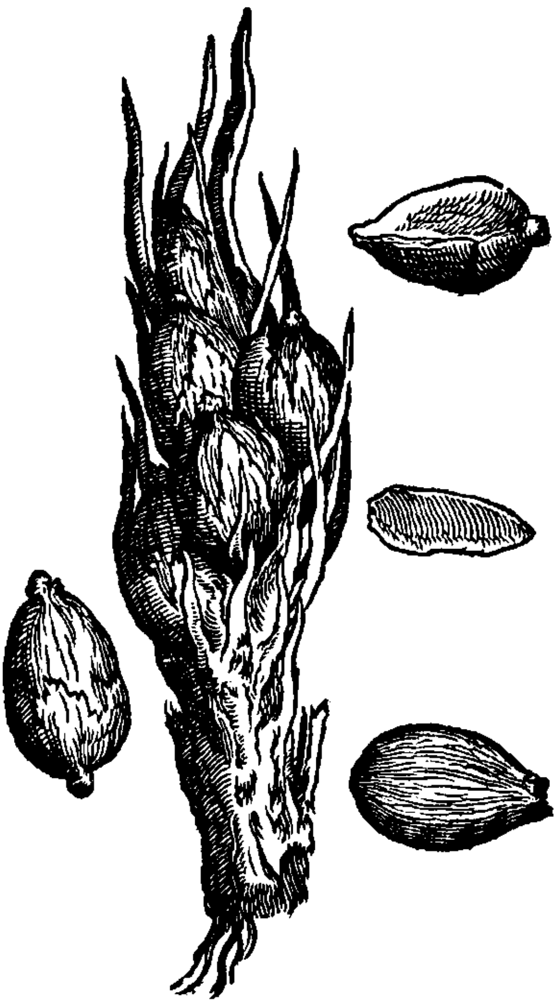

Plate 1. A spikelet and some old fruits with decomposed mesocarp, a nut and a kernel of the oil palm. (From R.DODONAEUS. *1618.* Cruydt-boeck. *Leiden).*

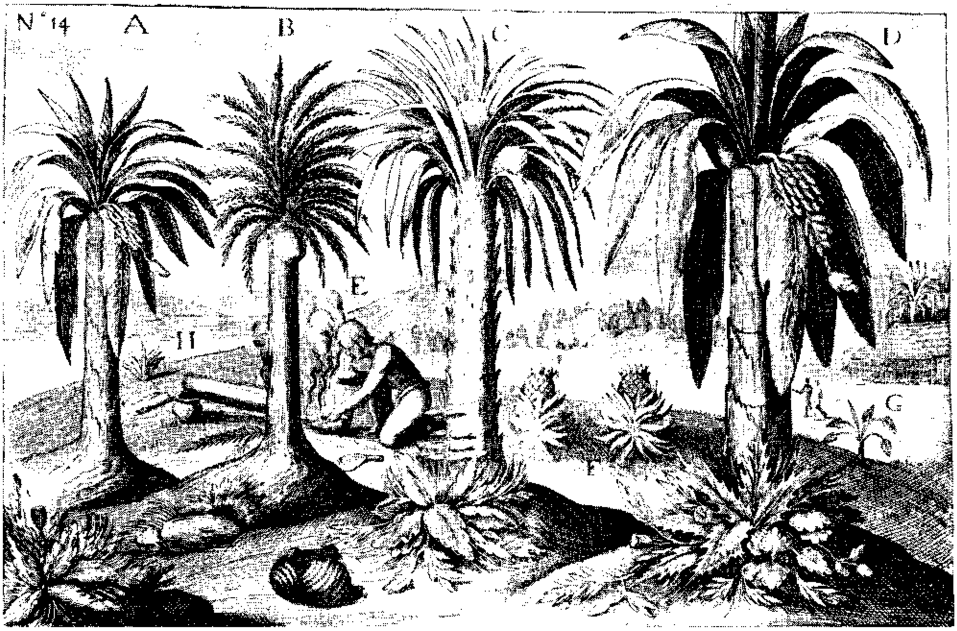

Plate 2. The oil palm (C) depicted amongst two banana varieties (A and D) and probably a species of Raphia *(B). The fruit bunches of the oil palm are rather big. The raphia palm is tapped for wine, while the person (E) drives the sap from the stem by heating one end of it. The sap is used for palm wine preparation. The crop G is probably cocoyam and H is ginger. (From* P. DE MAREES. *1602.* Beschryvinghe ende Historische Verhael van het Gout koninckryck van Guinea, anders de Gout-custe de Mina genaemt, liggend in het deel van Africa. *Reissued by* De Linschoten Vereniging 5, *1912 and commented by* S. P. L'HONORÉ NABER).

Fossil pollen grains similar to the pollen grains of the present day oil palm were found in strata dating from the Miocene period in the delta of the River Niger (ZEVEN, 1964b). The introduction of the oil palm to Asia is well documented (HUNGER, 1924).

The present international trade in palm oil started at the end of the eighteenth century and the kernel trade in the middle of the nineteenth century, but at the end of the sixteenth century palm oil was already known in Europe as a medicine (DODONAEUS, 1608). The palm oil trade began when Great Britain abandoned the slave trade and some of the first palm oil traders, who came from Liverpool, were first prominent slave traders, who turned to palm oil to safeguard their interests in Africa. Fortunately these developments coincided with the demand for lubricant for the new machines of the industrial revolution (DIKE, 1956). The semi- and complete domestication of the oil palm, its present distribution in Africa and its natural habitats will be described and discussed in this work (chapters 3 and 4).

1.3 WAIFOR substation

The oil palm industry in Africa is still mainly a village and cottage industry. In a few cases attempts have been made by farmers to improve the industry, but generally speaking, there is no capital investment in the palm groves other than that involved in harvesting the bunches and processing the fruits. Soon after Tropical and Equatorial Africa were opened up under European influence, it was realised that the production from the existing palm groves could be much improved. As a result of the failure of the early palm grove improvement schemes in Nigeria (chapter 11) it was realised that more research was needed into the oil palm agronomy and some improvement and rehabilitation trials were therefore laid down. At the same time it was thought that an exhaustive study of the palm groves 'as they are', 'as they develop' and of 'how to replace them' should be made because it is very desirable to know what is going to be improved upon or replaced. For that reason the author was posted to the substation of the West African (since October 1964 Nigerian) Institute for Oil Palm Research near Abak, which lies in the dense palm grove belt of Eastern Nigeria. Research was carried out into botanical, social and economic aspects of the palm groves and the methods by which they may be improved. Particularly detailed studies were made of certain groves and of certain subjects.

The substation of the WAIFOR covers about 200 hectares and is situated in the areas of dense palm groves, 7 km south west of Abak (04°58N, 07°46E, see Fig. 1), in undulating upland country lying about 35 to 50 m above sea level, *viz.* altitude in the Ikot Okpong Palm Grove is 50 to 55 m, of the Uruk Enung Palm Grove 45 m and of the Ikot Ntuen Grove 40 m. The Odiong stream forms the western boundary, and

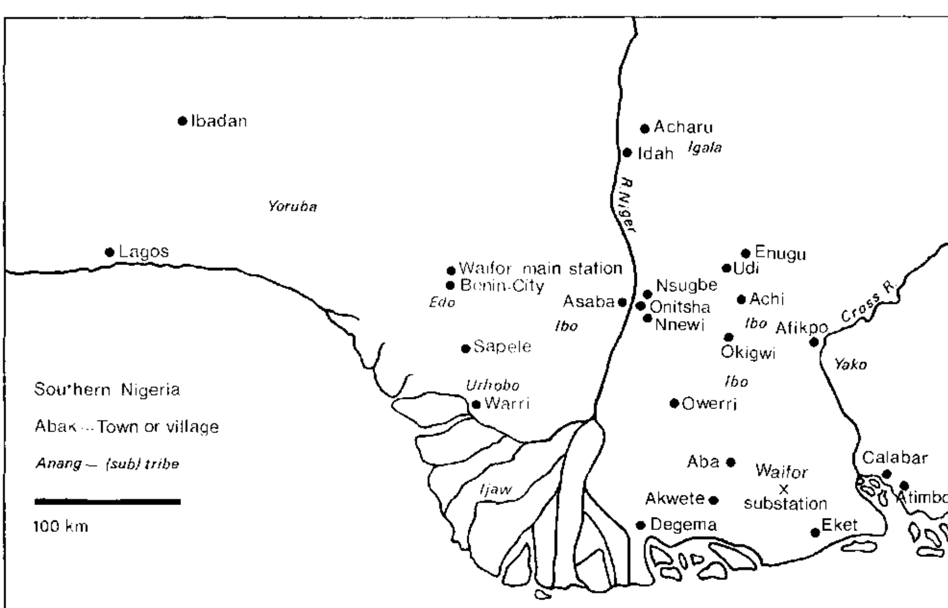

Figure 1. Map of southern Nigeria

flows on the 25 m contour; on the other sides the station is bordered by villages, farmland and palm groves.

The rainfall is high, reaching a total of 2,422 mm per year (average 1949–1963) with a distribution as shown in Table 1, which also gives the average monthly and annual maximum and minimum temperatures and the temperatures and the relative humidity at 8.00 and 14.00 hours (average 1957–1963).

The short Dry Season in August is characterized by a few days of sunny weather and low or no rainfall, but the rest of the month is wet. The average monthly maximum and minimum temperatures oscillate around 31 °C and 21 °C respectively, with the widest range in February (13.5 °C) and the smallest in July (7.4 °C). The relative humidity reaches 100 % at 8.00 h, but at 14.00 h is much lower. No records of sunshine have been kept, but during the Rainy Season the amount of sunshine is very low, because even during spells of dry weather the sky remains clouded. In the Dry Season the sky is also often overcast, a fine drizzle may even fall and 'Christmas' storms may occur at the turn of the year. The dry Sahara wind *harmattan* may blow for two or three weeks in December, January or February, bringing with it conditions of very low humidity. The *harmattan* is laden with dust which has the effect of reducing sunshine intensity.

Table 1. Monthly and annual figures for rainfall, maximum and minimum temperatures, and temperatures and relative humidity at 8.00 and 14.00 hours at WAIFOR substation near Abak

Month	Rainfall (mm)	Temperatures in °C				Relative humidity in %	
		maximum	minimum	at 8.00 hours	at 14.00 hours	at 8.00 hours	at 14.00 hours
January	30	31.7	19.5	22.0	30.1	100	74
February	43	33.4	19.9	22.2	31.9	100	67
March	131	32.8	21.6	23.5	30.9	100	77
April	173	32.2	21.7	23.8	31.1	100	67
May	247	31.9	22.1	24.2	30.2	100	81
June	292	29.8	21.5	23.4	28.7	100	80
July	351	28.7	21.3	22.9	27.6	100	82
August	315	28.7	21.3	23.1	27.2	100	86
September	388	29.1	21.5	23.2	27.9	100	83
October	300	30.2	21.5	23.3	28.9	100	80
November	128	31.1	21.4	23.6	30.1	99	77
December	24	31.7	20.7	22.8	30.6	100	72
Total/Mean	2,422	30.9	21.2	23.2	29.6	100	77

2 Design and execution

2.1 Design of the book

This book is divided into 13 chapters. Chapter 1 – Introduction – gives general information on the subject and on the motives of research; chapter 2 – Design and execution – deals with the design of the investigations and the method used in them. Chapters 3 to 11 include data obtained from research carried out by the author and extracted from literature. The division into these chapters is based on the development of the wild oil palm into a fully domesticated palm. In the third part a critical review is given of the centres of variation (centres of 'origin'), natural habitats and present geographical distribution in Africa. This part is mainly based on data borrowed from literature. Chapter 4 discusses the domestication of the wild oil palm and conscious and unconscious selection in the semi-wild oil palm, an almost untouched subject up to now. The conclusions in this part are based on scattered data derived from literature and on data collected by the author. Chapter 5, Origin and classification of the palm groves, and chapter 6, Yield, make up together with chapter 10 the essential contents of this book. In these parts a description is given of the palm groves as they are, their deterioration and the means of increasing their yields. Data extracted from literature are interwoven with data obtained during the researchwork. Chapter 7 mentions the results of field and literature studies and gives an account of the methods of exploitation, extraction of oil, cracking of nuts, the various rights over palms, and the local use of palm oil. Chapter 8, Diseases and pests, chiefly deals with trunk rot, which is the principal cause of the death of the oil palm and consequently of the change of stand. The taxonomy of the genus *Ganoderma* (KARST.) EM. PAT. is discussed to fill to some extent a gap in the literature. It is believed that chapter 9, Deterioration and retrogression, should follow chapter 8, as the former is mainly caused by the latter. This implied that change of stem type also had to be put here. Chapter 10, Methods of increasing the oil and kernel production, deals with the actual increase in yield per hectare and the increase in output due to a more intensive way of exploitation. This part contains an account of four WAIFOR trials (Expts. 503-2, 505-2, 560-2 and 509-1) dealing with the increase in yield per hectare caused by using fertilizers and the increase in yield per hectare caused by improving the environmental conditions of the producing palms, by stimulating non-yielding palms to fruit, and by replacing the grove palms by material bred for high yield. In the latter case the grove is converted into a plantation which means that the oil palm becomes fully domesticated. A historical review is given of all the improvement and rehabilitation trials known to the author. The three rehabilitation schemes of Nigeria are reviewed in chapter 11. This review was made in order to complete the picture and to make a critical note of the past two schemes and the present third scheme. Mistakes similar to those which caused the failure of the first two schemes are made again and could result in the failure of the third scheme. It is hoped that an early recognition of these mistakes may lead to their correction and thus to the desired success of the present or any future scheme. In chapter 12 a general conclusion has been given.

The book ends with a summary in English and Dutch and a list of references.

2.2 Literature

During the work it appeared that only a few authors dealt with the grove oil palm in equally few articles, but these studies were mostly 'snapshots' and mainly concerned the exploitation and the possible increase in yield.

Many authors have referred to the grove palm in books and articles. However, in general, the comments are very brief and superficial and neither the title of such publications nor any chapter or paragraph indicated that information is given on the grove oil palm. The author intends to compile these hidden data in this work.

As the book includes various subjects it was not possible to deal with the literature in a separate part, or in a certain paragraph of each part. The data extracted from literature are therefore interwoven with consistent data obtained during the work.

2.3 Palm groves studied

The palm groves studied are:

Palm grove	Experimental number	Location	Approx. area (ha)
in Nigeria:			
Rain-forest with oil palms	18-1	near Benin	40
Ikot Okpong Palm Groves I/II	501-1/504-1	near Abak	95 (42) *
Uruk Enung Palm Grove	502-1	near Abak	4.4
Ikot Ntuen Palm Grove	502-2	near Abak	2
Uruk Obong Palm Grove	503-1	near Abak	7.3
Obio Akpa Palm Grove	505-1	near Abak	5.0
Asutan Ekpe Oil Palm Survey	560-1	near Uyo	34
in Sierra Leone:			
Kottopema Palm Grove	920-1	near Kottopema	8.5
Kunshu Palm Grove	940-1	near Kunshu	3.4
Bissao Palm Grove	960-1	near Bissao	4

* The whole grove was 95 ha, but only 42 ha were experimentally used.

No description of these groves are given here as this would require an early introduction of some technical terms.

No further mention is made of the Palm Grove Reserve (Expt. 501–2) which was laid down in Expt. 501-1, plots 26 to 38 with a strip measuring five metres across bordering on this areas. The purpose is to keep a palm grove area free from disturbances other than the conventional ones. So it was believed that the soil survey, leaf and flowering observation and cutting one leaf of every tenth smooth-stemmed palm would not disturb the grove, as at a later stage the area would be farmed which means that shrubs are felled and burnt, leaves of the oil palms are pruned or scorched and the top soil layer is hoed.

Other experiments studied or referred to are:

near Abak: Expt. 502-4 (Nta Arua Palm Grove), Expt. 503-2 (Uruk Obong Palm Grove Manurial Trial), Expt. 505-2 (Palm Grove Improvement/Rehabilitation Trial), Expt. 506-1 (Extension Seed Work Trial), Expt. 508-1 (Plantation Fertilizer Experiment) and Expt. 509-1 (Palm Grove Rehabilitation Trial);

near Akwete: Expt. 651-1 (Plantation Fertilizer Experiment);

near Benin: Expt. 2-1 (Plantation Manurial Experiment) and Expt. 22-1 (Palm Spacing Trial);

near Calabar: Expt. 550-1 (Palm Plots);

near Nsugbe: Expt. 755-1 (Pruning and Wine Tapping Trial); and

near Uyo: Expt. 560-2 (Replanted Palm Grove Plots).

2.4 Available material

At the beginning of the investigation some data obtained from work carried out earlier were available:

1. the rain-forest near Benin-City and the palm groves near Abak were opened up by making harvesting paths through them. The demarcation of the rain-forest area (Expt. 18-1) was done at random except that the paths run North-South or East-West. The paths through the Uruk Enung and Nta Arua Palm Groves were laid out in a wrong way.

   The Uruk Obong Palm Grove (Expt. 503-1) was carefully demarcated in half-acre plots when the Uruk Obong Palm Grove Manurial Trial (Expt. 503-2) was laid down in this grove in 1956. The Ikot Okpong Palm Grove (Expt. 501-1) was believed to be demarcated into one-acre plots, but from measuring some of them it appeared that the demarcation was not done carefully and the size of the plots ranged from 0.5 to 1.2 acre. This partially accounted for some plots formerly known to be low or high yielding;
2. about 20,000 palms had received a number and yield recording per palm was carried out since 1949;
3. spotplans showing the stand of each palm, were prepared in 1949, a code indicating the stem type of the palm;

4. a Palm Grove Improvement/Rehabilitation Trial (Expt. 505-2) was laid down in the Obio Akpa Palm Grove (Expt. 505-1) in 1953;
5. a Palm Grove Manurial Trial (Expt. 503-2) was laid down in the Uruk Obong Palm Grove (Expt. 503-1) in 1956;
6. a Palm Grove Survey (Expt. 560-1) was established in the clan area of the Ibibio-Asutan Ekpe, where 84 one-acre plots distributed over a large area had been marked out and classified according to their grove subtype. Yield recording was carried out from 1948 to 1952 and from 1957 onwards. The first period has been reported by WATERSTON (1953).

These works provided me with early data or with data covering a long period. Some preliminary information on these groves is given by HARTLEY (1954).

2.5 Execution

This study was actually begun in September, 1959 and the author finished his compilation when he was transferred to the Main Station in August, 1963.

Before giving a general account of the work carried out it is necessary to explain the terms seedling, stemless, rough- and smooth-stemmed palms and some methods of research.

2.5.1 Botany

Floral biology. The oil palm can be considered to be an allogamous species, because it produces inflorescences which are either female or male and because these inflorescences flower, in general, at different time. Self-fertilization might occur owing to hermaphrodite inflorescences and as a result of the fact that the flowering periods of male and female inflorescences may overlap to some extent.

Stem type. A seedling is a palm which still lives in dependence on its seed, while a stemless palm* is a young palm in its leaf rosette stage. The rosette increases with age, but before it has reached its maximum size the palm starts to produce a stem and so becomes a stemmed palm.

Stemmed palms are divided into rough-stemmed and smooth-stemmed ones. The rough-stemmed palms still retain the dead leaves or when pruned their remaining bases whereas the smooth-stemmed palms have shed the leaves or when pruned their remaining leaf bases.

* In the English speaking part of West Africa a young, stemless palm is often called a seedling; from a botanical point of view this name is uncorrect, since the palm no longer depends on its seed, or when the term is applied to indicate that the plant grew from seed it may refer to every oil palm irrespective of its age.

Leaf and fruit types. The leaf of the oil palm is normally split and the leaflets stand under different angles on the rachis. These angles may vary between about –30° to about +30°. In some cases palms are found with unsplit leaves, while the 'leaflets' stand with the same angle on the rachis. This character is called *idolatrica* and is inherited by a single, incomplete dominant gene (FICKENDEY, 1944; ZEVEN, 1964a).

The fruit types *dura*, *tenera* and *pisifera* refer to the thickness of the fruit shell. *Dura* palms produce fruits with an endocarp ('shell') thicker than 2 to 2.5 mm, *pisifera* palms, although often carrying only rotted bunches, produce fruit without endocarp, while *tenera* palms produce fruit intermediary to *dura* and *pisifera* fruit, with an endocarp thinner than 2 to 2.5 mm and with fibre strings near the outer surface of the endocarp.

The shell thickness character is inherited by a single incomplete dominant gene (BEIRNAERT and VANDERWEYEN, 1941). The *macrocarya* fruit type is a very thick-shelled *dura*.

The 'mantled' palms produce fruit with six supplementary carpels. This type, scientifically called *poissoni* is also inherited by a single, dominant gene (BEIRNAERT and VANDERWEYEN, 1941).

There are various types characterized by a difference in colour of the fruit. The main types are *nigrescens*, *virescens* and *albescens*. *Nigrescens* fruits are characterized by a brownish to blackish cap and an orangish to reddish base; *virescens* fruits by an orangish to reddish colour of the base and the cap, while the tip of the cap is green; *albescens* fruits are characterized by a blackish cap and a pale yellowish base. The inheritance of these characters is complex.

2.5.2 Climbing

The palms in the rain-forest (Expt. 18-1) were climbed with a sling, while those in the groves near Abak and Uyo were climbed by means of a set of two ropes. These methods are described in section 7.1.2.

2.5.3 Yield recording and forecasting

Yield recording and forecasting introduced in 1948 took place as follows: All the palms were numbered and after having been harvested ripe bunches were weighed at the base of the palm and the weight recorded in a harvesting book. A farmer harvesting 'free' palms or those of his own only climbs a palm when he sees some ripe fruits at the base of a palm, but at an experimental station this is not a satisfactory procedure because the bunches would tend to be overripe when harvested; moreover, *all* palms would have to be inspected for fallen fruit at least once a fortnight. For these reasons a system of bunch forecasting was introduced in 1948 according to which the climber looks for female inflorescences and unripe bunches and estimates when they will be ready for harvest. So the palm need not be climbed until the next bunch is ripe.

2.5.4 Determination of fruit type

The fruit type of the palms was determined. Of course this determination was limited to yielding palms only.

2.5.5 Leaf production and flowering observation

Leaf and flowering observations were made according to the WAIFOR method, which is described by SPARNAAIJ (1960). At the beginning of the period of observation the youngest fully opened leaf is marked. Every two months all newly opened leaves are marked and noted in a record book. At the same time or later note is taken of any inflorescence observed and its sex, and marked against the leaf in which axil it grows. This method provides bi-monthly figures of total leaf production, total female, male and hermaphrodite inflorescences and consequently also figures on floral abortion and sex ratio at time of flowering. This method does not include the observation of the development of the female inflorescence into a ripe bunch, but this could easily be introduced in order to provide data on bunch failure.

2.5.6 Bunch analysis

Bunches were analysed according to the WAIFOR method which is described in detail by BLAAK, SPARNAAIJ and MENENDEZ (1963). The bunches to be analysed are weighed and taken to the laboratory, where a single fruit is taken to determine its shell type. This is recorded on an analysis card on which all details about the bunch throughout the process of analysis are mentioned. Then the bunch is stored overnight. Subsequently, it is weighed again and the spikelets are separated from the stalk with a matchet. The stalk is weighed and so are the spikelets. The latter are thoroughly mixed and afterwards divided into two parts of which one should weigh about five kg. The two spikelet samples are weighed. The sample of about five kg is stored for three days after which the fruits can easily be removed. These three days storage makes picking of the fruits much less time-consuming. The inaccuracy due to the loss of water (0.5–1.0 %) from the mesocarp may be neglected. The fertile fruits, the infertile, parthenocarpic, oil containing fruits and the empty spikelets are weighed separately. The infertile fruits and empty spikelets are discarded. Fruits are taken from bunches weighing less than or equal to 25 kg to make up a quantity of 500 g or when the bunches are heavier, of 1,000 g. The number of fruits is recorded. The following day, the fruit is depulped by cutting and scraping with a knife. The pulp is discarded and the nuts are surface dried for one day and weighed. After three or four days of additional air drying, the nuts are cracked and the kernels weighed.

The fruit to bunch, mesocarp to fruit, kernel to fruit and shell to fruit ratios can be calculated from the data obtained.

2.5.7 Height measurement

The height of a palm being the distance between the base of the lowest green leaf and the soil level was measured by means of a tape. This method had some advantages *e.g.* it was more precise than using an altimeter, it could be carried out unhampered by other palms and it could be done by less skilled workers. The disadvantage was that it was time consuming.

2.5.8 Interviews

Many people were interviewed to gather information on local knowledge of some of the subjects of this study. They could roughly be divided into two groups, one consisting of members of the Senior and Junior Staff of the WAIFOR who came from various districts of southern Nigeria and who could give information on sites which I had not visited, the other consisting of people living near the sites where they were interviewed. The possible drawback of an interview – sometimes caused by the people of the second group – was that a few would rather give an answer which, in the informant's opinion, would please the interviewer, than the correct answer. To avoid this the persons interviewed were first told that the true answer was the most satisfactory and afterwards tested for the rightness of their answers. Following this method it is believed that no wrong information from these informants crept into this work.

The method of interview is difficult to describe, as the interviews often were spontaneous discussions. Thus sometimes a farmer was asked to tell everything he could remember about a certain grove, or what he knew about the oil palm culture in his dwelling-place. In the latter case facts, where possible, were checked on the spot. Special care was taken to dating historical data with the help of well-recorded facts, such as the arrival of the first British soldiers, the construction of a certain motorable road, the second World War or the establishment of the substation. In most cases the interviewed persons spoke (pidgin-)English, but, when necessary, the help of an interpreter was called in.

2.5.9 Start of work

At the end of 1959 the redemarcation of the palm groves into one-acre plots was started and new spot plans were made to compare them with those of 1949, thus showing the density of 1949 and 1960, the number of dead palms and that of those which changed their stem type or emerged since 1949. Yield per palm in number and weight of bunches from 1949 onwards were added and these data were grouped either to give the yields per acre, per acre palm grove subtype, per height group, per stem type or per fruit type. Health surveys were made and monthly health records were kept per palm, thus showing the time of the first observation of symptoms of a disease, the type of disease and date of death. Soil samples were taken and analysed by the members of the Soil Chemistry Division, and leaf samples were analysed by the members of the Plant Nutrition Division. Data on the history of the groves, on farming and local customs were compiled during the work.

3 Centres of variation, natural habitats and present geographical distribution in Africa

3.1 Introduction

Any discussion of the centres of origin or primary variation and centre or centres of secondary variation, must refer to the very remote past – in geological time. In the section on Natural habitats (section 3.3) it is concluded that the oil palm grows naturally on sites which are already too wet for many trees of the rain-forest. These sites are mainly banks of rivers, streams and swamps. Such habitats have occurred in Africa from the remotest time, independently of the expansion and retreat of the rain-forest due to climatological changes. The geographical distribution of the oil palm may also have expanded and retreated, but it is not possible to tell whether palms growing on the boundary of the range e.g. those at Koulikouri in Mali, are a relic vegetation or an introduction by man.

ZEVEN (1964b) postulates that the oil palm originated in the African part of the tertiary landbridges between Africa and southern America. Fossil pollen found in sediments of the Niger delta, are identical with pollen of the present day oil palm. The earliest occurrence of these fossil grains is in sediments which are believed to be of Miocene age. Their frequency is about 0.1 % of the total number of spores and pollen grains, but it tends to increase in younger sediments. Thus in later Tertiary sediments the percentage occasionally becomes as high as 10 % of the total number of spores and grains. In sediments which are recently being laid down, oil palm pollen grains fre-

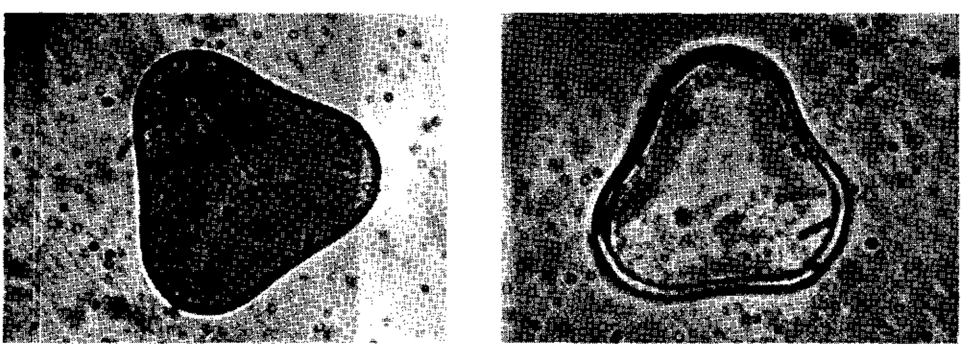

Plate 3. A fossil pollen grain (left) *probably of the oil palm compared with a fresh grain* (right) *of the oil palm. Fossil grains were received by the author from the Shell-B.P. Petroleum Development Company of Nigeria, Ltd. at Port Harcourt and were obtained from a layer about 720 m deep under Elelenwa, Eastern Nigeria. The fresh grain is derived from a* dura *palm. 620 ×. Photograph* NIFOR.

quently comprise up to 30% of the total. If it is accepted that the fossil pollen was produced by the oil palm then it follows that the oil palm occurred at that time in the Niger delta. But further palynological investigations are required to establish whether the oil palm also grew elsewhere. CHEVALIER (1934) believed that Central Africa could be the centre of origin, because he found wild oil palms there. But the question arises, whether these palms were really wild.

In section 3.2 it is concluded that at present it is not possible to define tolerably precisely the centre of dispersion.

3.2 Centres of primary and secondary variations

According to VAVILOV (1926) the centre of origin of a species is characterized by a high variability within that species. On the basis of VAVILOV's postulate CHEVALIER (1943) concluded that the 200 to 300 kilometre wide coastal belt between Liberia and Angola may be considered to be the centre of 'origin' of the oil palm. This centre lies outside one of VAVILOV's centres. More recently it has been realised that these latter centres were not necessarily centres of origin, but were more likely to be centres of dispersion. The work of PORTÈRES (1962) on the African species of the genus *Oryza* L. may serve as an example. PORTÈRES identified a new centre of dispersion in West Africa, which can be split up into a centre of primary variation, defined by a high concentration of dominant characters, and several centres of secondary variation, defined by an abundance of recessive characters.

The varieties of the oil palm have only been studied for the colour of the pericarp, the colour of the mesocarp, the thickness and presence or absence of the shell and to see whether the leaf is pinnate or not. No such investigations have been made for other characters listed by YAMPOLSKY (1922), such as the spines of the bunch or the colour of the rachis.

It would be of interest to examine whether any of these dominant and recessive characters are grouped in a certain area. The dominant characters *dura* shell and coloured mesocarp are commonly and abundantly found throughout the present geographical range of the oil palm, also in areas where the palm is known to have been introduced. The dominant characters *virescens* and mantled fruit are rare, but they occur everywhere in this range. Only in one case a pure stand of *virescens* palms have been reported for Man in Ivory Coast (PORTÈRES, 1937). The dominant character *idolatrica* leaf is the only character concentrated in a certain area *viz.* the area between the Niger delta and south-east Ghana, but there it is rare (ZEVEN, 1964a). Furthermore, it should be born in mind that this character and the *virescens* fruit are subject to man's intentional and accidental selection. The recessive genes, which cause no shell when they are in homozygous condition and a thin shell when they are in heterozygous condition, abound – at least to some extent – in Iboland in Eastern Nigeria and Kasai in Congo (see section 4.3.3), where the farmers carry out a selection pressure on thin shell. But there their frequency is still lower than that of the *dura* shell. The same might be said of the recessive character *albescens*, which is rare throughout the oil palm range, except in an area in Congo, where the farmers select on this character (VANDERWEYEN, 1952). The recessive characters *nigrescens* fruit, fruit without supplementary carpels and split leaf abundantly occur in the whole oil palm area.

So, although in some areas some characters have a relative higher frequency than in the rest of the oil palm range, it is not possible to indicate one or more areas where either the dominant or the recessive characters are frequently found. PORTÈRES (1962) concluded that the centre of primary dispersion of the oil palm is the region described as the Sub-equatorial Sector of the West African Centre *(Berceau afro-occidental-Secteur Subéquatorial)* and the Central African Centre *(Berceau afro-central)*. This region covers a rather large part of Africa and it is probable that after a meticulous study of all the variable characters, the centre of primary dispersion of the oil palm could be defined more precisely.

3.3 Natural habitats

The wide occurrence of the oil palm in situations where the climax vegetation is a rain-forest, is unnatural. This is a result of the disturbance of this climax vegetation by man, who thereby provides the oil palm with a suitable habitat in which to germinate, to grow and to produce fruit. Oil palms do not occur in secondary forests having the characteristics of a primary forest, nor in primary forests. REES (1963a) pointed out that the light-demanding oil palm has a low net assimilation rate, a low leaf area ratio and consequently a low relative growth rate. Thus it grows too slowly to compete with the regrowth of the forest understorey. Due to lack of light old palms stop fruiting and succumb in the end. Seedlings and stemless palms, which are more tolerant to shade, may survive for a number of years, but do not reach the productive stage unless interference by man creates conditions in which they can grow. Thus it is essential to a natural habitat that enough light should penetrate the canopy to allow the oil palm to grow and fruit.

WALTER (1962) showed that tree-monocotyledons are better adapted for growing on water-logged soil than tree-dicotyledons, because the former offer more efficient resistance to a low degree of soil aeration than most of the tree-dicotyledons and hence they can favourably compete with them. So natural habitats for the oil palm are those areas which are too wet for a rain-forest vegetation, but not too wet for oil palms. In such areas the absence of tall trees allows enough light to reach the sun-loving oil palm. Such habitats are the sources and banks of water courses (including WATERSTON's (1953) Fresh water swamps), moist valleys, banks of lakes, swamps, alluvial plains and low lying islands in rivers. Another natural habitat is the forest fringe, especially the forest outliers in the Forest Savanna mosaic vegetation type.

CHEVALIER (1934), GREENWAY (1945) and DESNEUX and ROTS (1959) described what they believed to be the phenotype of the wild oil palm. The stem is thin, covered with epiphytes and old leaves; the bunches are small and so are the fruits, being mainly of

Plate 4. Oil palms and a raphia palm on the river bank of the Osse river near Benin-City, Eastern Nigeria. Such a site may be a natural habitat of the oil palm. Photograph NIFOR.

the *dura* type, with a very thin mesocarp. The crown is referred to as small and sometimes yellowish. CHEVALIER described the wild type as a different species, *E. ubanghensis*, but any oil palm growing under marginal conditions would fit this description.

Many authors have recorded the occurrence of the oil palm in one or more of these habitats, but they do not always state clearly whether the palms were really wild or were naturalized after having been introduced by man.

Within the area of distribution the occurrence of oil palms, even in large dense groves on riverbanks, is widespread (see section 3.4).

Swamps as natural habitats are mentioned for Madagascar by BECCARI (1914) and for Pemba and Zanzibar by GREENWAY (1945). Reports of alluvial plains and low-lying islands in rivers as natural habitats mainly come from Central Africa. Oil palms growing on alluvial plains in Central Africa form part of the pioneer vegetation (AIRY SHAW, 1947; LOUIS, 1947; CHEVALIER, 1948; KADEN, 1955). According to LOUIS, the growing conditions in such habitats are marginal for oil palms which may grow up to a height of eight or ten meters, but often succumb much earlier. In south-west Congo and north Angola the river valleys between the table lands are often mentioned as natural habitats (EXELL, 1944; AIRY SHAW, 1947; DESNEUX AND ROTS, 1959).

3.4 Riverbank groves

Very dense stands of oil palm are sometimes found on the swampy river banks. The palms often stand in water the whole year or a part of it (ANON., 1921; N., 1930; AIRY SHAW, 1947; LEBRUN and GILBERT, 1954). For instance in the Bwado district of the Congo the palms stand in the water for five months (ANON., 1921) and at some parts of the Congo River the whole year, even in the driest season (N., 1930). The reports on the groves – always concise – mainly come from Central Africa (ZIMMERMAN, 1911; ANON., 1922; GERALDES, 1929; DYKE, 1927; JANSSENS, 1927; N., 1930), but some come from West Africa (GRÜNER, 1913; WATERSTON, 1953); the density may be up to 400 stemmed palms per hectare (ZIMMERMAN, 1911) and 6,000 hectares were reported for on the area of such a grove in the Bwado district (ANON., 1921). As the land is too wet it cannot be used for dwelling or cultivation, except for rice (when the grove is not too dense), as was seen at Etinan near Abak. Therefore these groves did not grow up on old village sites, they are probably spontaneous and part of the habitat, *i.e.* the natural vegetative community on the banks of water courses. When studying this phenomenon the history of the watercourse should be taken into account, because a change in the riverbed may have caused the original level of the water to rise. It is also possible that as the palm grows, it sinks under its increasing weight in the swampy soil.

Such groves were studied at Etinan and at Atimbo near Calabar. The density may be up to 300–350 palms per hectare. The palms are of all ages and heights, the tallest one reaching about 15 m. The presence of many healthy young palms points to a natural regeneration of this grove type. Some shrubs and trees fill up open places.

3.5 Methods of spreading

There are numerous 'natural' methods by which the oil palm may have been spread. VANDERIJST (1924) divided them in three groups: physical, zoochorous and anthropochorous. The rolling of fruit on slopes and on the bottom of rivers belongs to the first group. The distance moved on the slope will be quite little and detached *dura* fruits do not float (own investigation), but they may be transported on other floating material. The uncommon very thin-shelled *tenera* fruits float (BLAAK, 1965) and may be transported by water streams and rivers. Of the animals, especially monkeys and apes, should be mentioned, but palm fruits are also spread by rats and other small mammals and by birds like the palm-nut vulture (THOMSON and MOREAU, 1957). These animals eat the fruit and the seeds may be carried internally or externally. The spreading of the oil palm by man is largely unintentional; for example by throwing away sucked fruits in the village, on the road or farm. Deliberate propagation has been discussed in section 4.3.

3.6 Altitude of occurrence

In general the oil palm grows at altitudes below 700 to 800 m, but palms have been observed at sites up to 1,750 m in the Foutouni district of the Cameroons (PORTÈRES, 1947). Most data on the altitude at which oil palms grow are available for the mountains and table lands in Cameroons. On Mount Cameroon palms occur up to 1,300 m and at Santu at 1,600 m (HASSERT, 1917). PREUSS (1902) stated that palms above 700 m do not produce fruit and if this were true oil palm growing at these altitudes must originate from seeds carried up by animals and men; but GRÜNER (1913) saw fruiting palms at 770 m in Togo.

In the Fouta Djalon mountains in Guinea, palms occur up to 800 to 1,000 m (CHEVALIER, 1943). In Togo healthy palms were found at an altitude of 770 m, but according to GRÜNER (1913) the oil obtained from them was not as good as oil extracted at lower levels. This author, however, does not explain his statement, but it might be attributable to differences in extracting methods. The palms growing at high altitudes were often tapped for wine.

In East Africa LIVINGSTONE saw palms at an altitude of 1,000 m near Lake Mweru and at 840 m near the southern part of Lake Tanganyika. Palm groves are said to be seen up to 1,700 m in the mountains of East Africa, while single palms grow at even higher altitudes (SCHAD, 1914).

3.7 Present geographical distribution

SCHAD (1914) gave the first extensive account of the geographical distribution of the oil palm. He surveyed the accounts of explorers and investigators of the oil palm. The present account (see figure 2), which only seeks to define the geographical limits, is based mainly on SCHAD's work.

To the West, the most northerly point where the oil palm occurs under spontaneous or subspontaneous conditions is a site a few kilometres south of Saint Louis in Senegal. Saint Louis lies on latitude 16° North and has an annual rainfall of only 200 to 400 mm. Oil palms also occur around Dakar, in the *niayes*, which is either the name of the swamp areas of which the drier parts are inhabited by clusters of oil palms, or merely the name of these clusters of palms (ADANSON, 1757; RAYNAL, 1963).

Going southwards, the next place of importance in tracing the distribution of the oil palm is Koulikouri near Bamako on the River Niger in Mali (ADAM, 1910). South of Koulikouri no oil palms occur until the Fouta Djalon in Guinea is reached. The limit in Ivory Coast runs from west to east north of Man and south of Bouake (ADAM, 1910; JÄGERSCHMIDT, 1953). In Ghana and Dahomey, the limit runs in a northeasterly direction until it reaches Gaya on the River Niger near the boundary between the Niger Republic and Nigeria (MIN. D'ÉCON. RURALE, 1962). In Nigeria, the boundary runs from Gaya between Kaduna and Zaria, north of Jos and Shendam. Oil palms also occur in Adamawa and Southern-Baghirmi in the former Northern Came-

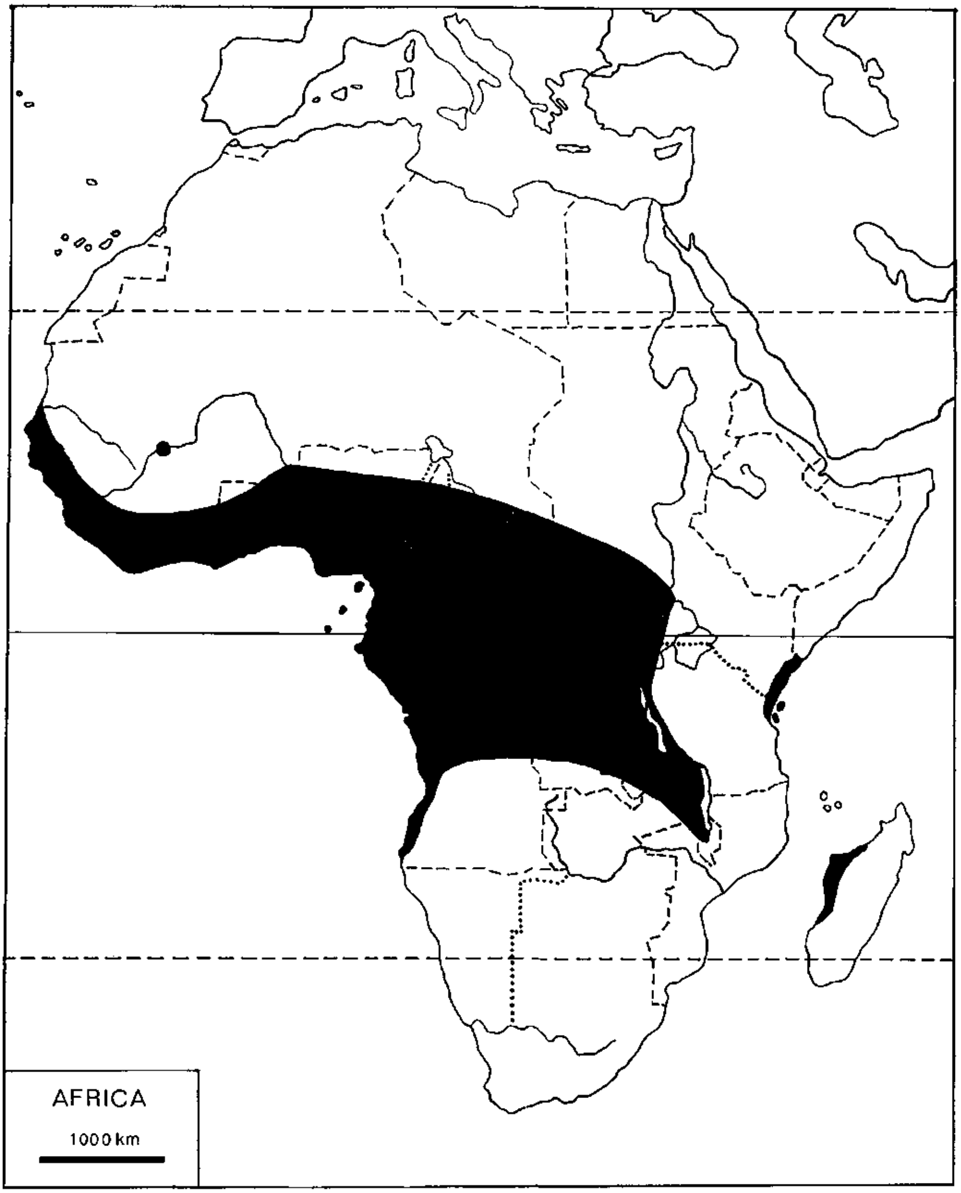

Figure 2. The distribution of the oil palm in Africa

roons. In the Central African Republic, palms are found in Dar-Kouti, Dar-Fertit and Niam-Niam. ANDREWS (1956) considered the oil palm to be indigenous around Yei in the southernmost point of Sudan. EMIN PASCHA (SCHWEINFURTH *et al.*, 1888) observed oil palms growing on an island in the same area.

The eastward spread of the oil palms appears to be still in progress; inhabitants on the eastward limit often remember that the oil palm came from the Congo. Dense stands of oil palms are recorded from Mangbetu and in the Semliki valley in north-east Congo and Uganda (SCHWEINFURTH, 1874; WARBURG, 1895; THOMAS, 1936) and on the Ruzizi plains in Burundi (MILDBRAED, 1914), but not in the valley (GERMAIN, 1952), which probably points to distribution by man. Palms occur in a belt about twenty kilometres wide on the eastern bank of Lake Tanganyika, and were probably also introduced from Congo (CAIRNS, 1937). The limit continues in southern direction to Kota-Kota on the west shore of Lake Nyassa (THISELDON-DYER, 1902; WILLIAMSON, 1955), thence to Lakes Bangweolo and Mweru, through Upper-Lomani, Upper-Lulua, Upper-Kwango in the southern Congo and then in southwesterly direction to the coast of Angola at about latitude 10° S (VELHO and XABREGES, 1950), extending to the south along the coast as far as Moçamedes on 16° S (SOSKIN, 1909; SCHAD, 1914). In general, the coastline, including the coastal islands, forms the southern and western limit, but where mangrove swamps occur the oil palm is found on their inner border.

Oil palms grow on the East African coast between the Tana River and Dar-es-Salaam in Tanganyika, in the islands of Pemba and Zanzibar situated near the East African coast and in the western part of Madagascar between Cape Saint André and the Fiherenana as far south as latitude 21 °S (THISELDON-DYER, 1902; JUMELLE and PERRIER DE LA BATHIE, 1911, 1913; JUMELLE, 1945). The oil palms growing in the swamps of Pemba and Zanzibar gave GREENWAY (1945) the impression that they were wild. It is not clear whether the oil palm was introduced into the coastal belt and the islands Pemba and Zanzibar, but these locations are completely separated from the main centre of distribution. The Arab slave trade, linked Congo with the coast and Arabs were active all up and down the coast so that they and their slaves may have distributed oil palm seed.

3.7.1 The oil palm in Madagascar

JUMELLE and PERRIER DE LA BATHIE (1911) concluded that the oil palm was indigenous to Madagascar, basing their conclusion on the polymorphism of the palm. But later JUMELLE (1945) questioned their conclusion, because the oil palm is only exploited by people of African descent. The ecological conditions on the eastern side of the island, having rain-forest as its climax vegetation (KEAY, 1959), are more suitable for the oil palm than those on the western side (MIN. DE L'AGRIC., 1963), and if the oil palm were indigenous to Madagascar, (which implies it must have occurred there before the island was separated from the continent in the Miocene age) then it is reasonable to expect that at least a few palms would grow at some suitable sites in the eastern part. On the balance it seems probable that the oil palm was introduced into Madagascar when the African element entered that island, as early as the ninth century. On the other hand, the possibility of the oil palm being brought to Madagascar by birds, after this palm reached the African east coast, cannot be excluded.

3.7.2 Nineteenth and twentieth century introductions

The possible centre of dispersion and the range of occurrence of the oil palm in Africa were discussed in section 3.2. Although the oil palm is found on the coast and in the coastal islands of East Africa there is an extensive area between this coast and the first site of occurrence of the oil palm in, for example, western Tanganyika in which no oil palms are found. Several authors suggest that rain is the limiting factor in this area, but trials have shown that the oil palm will also grow and fruit in this area. The landward eastern limit has been steadily moving eastwards as a result of the activities of the local inhabitants and, since the beginning of the twentieth century, because of the work carried out by various agricultural and forestry departments.

SCHWEINFURTH *et al.* (1888) reported that EMIN PASCHA had planted oil palms at Lado in Sudan which lies north of the natural range of the palm. EMIN PASCHA probably obtained the seeds from the Mangbetu in north-eastern Congo. Another introduction is reported by STOCKER (1921); when the Azande in northern Congo were pushed in an easterly direction by the Mopoi, they came in contact with the Amadi, and introduced the oil palm with them. The Mangbetu in north-east Congo extended the oil palm range by planting oil palms in the second half of the nineteenth century (SCHWEINFURTH, 1874). According to THOMAS (1936, 1940) the palm groves in the Semliki valley in Uganda are spontaneous or subspontaneous. But oil palms found elsewhere in Uganda were introduced from Mombasa in Kenya or from Zanzibar. Later, in the 1920's, oil palms were grown on various government stations from seeds obtained first from the Semliki palms and later from West Africa.

In Tanganyika there is a farmer's plot of oil palms at Bukoba on the shore of Lake Victoria. Further palm plots and single palms are found near the eastern shore of Lake Tanganyika. CAIRNS (1937) and GREENWAY (1945) believed that the palm in the Kigoma district were introduced by the Arabs from Kivu in Congo. However, SHEPSTONE (1951) thought that the Congolese were responsible for their introduction. There is a plantation at Zomba in Malawi (WILLIAMSON, 1955).

At the south-western limit the range was extended southwards by the planting of some twenty oil palms on an estate, south of Moçamedes in Angola (SCHAD, 1914). It was reported from the Seychelles that oil palms had once been introduced, probably in the nineteenth century (ANON., 1916).

A rather recent introduction into the Western Sahara was made about fifteen years ago. Oil palms were planted at Beni Abbes (30 °N) aiming at irrigating them (TURMEL, 1952), but the author has not been able to obtain any further information on these palms.

4 Domestication and selection

4.1 Domestication

The domestication of the oil palm occurred in several stages, of which the last stage – the complete domestication – is found only in a few areas, even at present. Domestication means that a wild plant is taken from its natural habitat and reproduced for successive generations under man-made conditions (SEIBERT, 1948). When domestication is only partial, reproduction in anthropogen habitats is subspontaneous.

COOK (1910) pointed out that the domestication of the oil palm would have been virtually complete, had not its ability of subspontaneous growth made this last stage unnecessary. However, the oil palm was not domesticated everywhere or its value recognized. For instance, at the end of the nineteenth century the only employ some tribes in Central Africa made of the oil palm was to use old bunches as brooms (STUHLMANN, 1894), but it is probable that in more recent years some of these people have come to value it as food and cash crop. And yet inhabitants of the savanna of the Central African Republic used the oil only as a chrismal oil up to recent time (TISSERANT, 1953).

IRVINE (1948) records that in the remote past the rain-forests were largely uninhabited by man and only occasionally visited by hunters, looking for smaller game and edible snails. It may be assumed that these hunters carried various fruits with them to eat, among them fruits of the oil palm which do not grow wild in the rain-forest, but which were collected from palms growing in the forest outliers in the Forest-Savanna mosaic. Oil palm fruits might also be taken to camps in the savanna, but owing to the dry conditions only a few of the resulting seedlings grew to maturity. FOGGIE (1947) describes a hunting camp in a very old rain-forest in Ghana. The camp consists of a small hut in a small open area and is used for several years or perhaps even for several generations. Seeds from discarded fruits germinate and some eventually produce trees. FOGGIE observes that deserted camping sites were marked by the occurrence of oil palms and other fruit-trees not belonging to the original vegetation. Later, when agriculture replaced hunting, the oil palm became a common relic of deserted dwelling places and abandoned farmland. It is probable that, when migrating people took various fruits, including those of the oil palm with them and that they also returned to former dwelling sites to harvest the crops and trees, a practice which is still common nowadays.

Other authors have described the domestication of other palm species *e.g.* the peach palm *(Bactris gasipaës* H., B. et K., syn. *Guilielma gasipaës* L. H. BAILEY) which was spread by man from the eastern slopes of the Andes through the river valleys of the Amazone, Rio Negro and Orinoco to the West Indies. During its distribution it was passed from tribe to tribe and from region to region by migrating people (SEIBERT, 1948). The distribution of the oil palm in Africa may well have happened in a similar way, its domestication starting in hundreds of little clearings in the rain-forest used as camping sites or for farmland, and in the drier areas adjacent to this forest. Under traditional agriculture by the indigenous people the oil palm is only completely domesticated in a few areas of Eastern Nigeria and the process of its domestication in those areas has been described in section 4.3.3.

4.2 Natural selection

Natural selection is an important factor in the evolution of cultivated species, prior to partial or complete domestication and probably afterwards as well. The survival of certain genes in an oil palm population forms a particularly interesting part of the detailed study of palm groves, especially the extent to which favourable or unfavourable genes are eliminated from the population. The types of natural selection pressure in the oil palm may be grouped into two classes:

1. population fitness of the oil palm population competing with those of other plant species
2. relative fitness of the various genotypes of the oil palm.

As regards to the former class, survival of palms in a young secondary rain-forest depends on the production of fruiting offspring and this is influenced by a large number of known and unknown genetic and environmental factors. Thus, survival of the oil palm will be favoured by the production of a large number of fruits and this depends again on the number of bunches produced and the number of fruits per bunch. Bunch production is determined by the genetic composition of the palm and by the environment; more light will change the sex ratio, *i.e.* more inflorescences being female and fewer being male (BROEKMANS, 1957). An oil palm receives most light when it is able to keep its crown above the regrowing rain-forest; thus there is a natural selection in the oil palm for quick growth. The survival of the fruit types in a dense grove belongs to the second class. The *pisifera* palm produces a great number of female inflorescences and a small number of male ones (SPARNAAIJ, 1960), but most of the female inflorescences rot prematurely while the few ripe fruits produced rot before the seeds can develop into seedlings. By this and due to the low number of male inflorescences there is a constant selection against *pisifera* genes. On the other hand, it was found in Expt. 501-1 that 14.8% of the fruits produced in this grove was produced by *tenera* palms, although these accounted for only 11.1% of the bearing palm population (see section 6.1.8). So, if all fruits should stand an equal chance to grow into a palm, the reproduction rate of the *tenera* palms would be about 1.4 times $\{(0.889 \times 0.148):(0.852 \times 0.111)\}$ that of the *dura* palms. Owing to this the loss of *pisifera* genes is partly counteracted. Other factors such as germination, precocity and viability must influence the frequencies of *dura* and *pisifera* genes. Unfortunately REES (1963d) tested only *dura* fruits on germination under natural conditions. Furthermore, it is often suggested that the thick shell of *dura* fruits provides a better protection against animals and man, and drying out, but the thickness of the operculum does not depend on shell thickness (HUSSEY, 1959).

There is selection pressure in other varieties. The *poissoni* type is suppressed due to the predisposition of this type to bunch rot, which results in a small number of viable seeds. Palms of the *idolatrica* type growing in plantations (and probably also in groves) produce less fruit than normal palms (ZEVEN, 1964a). These unfavourable influences could eventually lead to the extinction of these characters. No information is available on natural selection in other types.

4.3 Intentional propagation and selection

As domestication of the oil palm proceeded, man sought to increase the production of oil, kernels and wine either by increasing the number of palms or by increasing the yielding capacity of the individual palm or by both methods. The culmination of these activities is seen in modern plantation practice, but the earlier stages can be divided into four:

1. sowing of unselected seeds
2. transplanting of unselected young palms
3. planting of selected seeds and transplanting the resulting palms
4. thinning of the population

These activities are discussed below.

4.3.1. Sowing of unselected seeds

Sowing of unselected seeds is the simplest form of propagation, the main aim being to enlarge the area under oil palms. This method of cultivating oil palms is recorded from Misahöhe in Togo (GRÜNER, 1904), and from the Ivory Coast, where the Ebrie of the Adioukrou, the Bonbouri and Baouli strewed seeds in clearings (BRET, 1911; ANON., 1920).

In the discussion of the geographical distribution of the oil palms in section 3.7.2, it was observed that, particularly on the eastern border of the area of distribution, there are several reports of this limit being extended by the introduction of the oil palm to new areas. Such introductions have also been reported at the southern limit by VANDERIJST (1919) who said that the chiefs of villages on the table lands between the Kwilu and Kasai Rivers introduced seeds which were sown around the villages and on deserted farm lands. They probably obtained the seeds from the oil palms growing on the banks of these two rivers and their tributaries.

4.3.2 Transplanting of unselected palms

Here, too, the aim is to extend the area under palms. The main examples are the oil palm orchards in southern Dahomey, described by DANIEL (1902), CHARABOT (1908), HUBERT (1911), HOUARD (1920), BRASSEUR (1953) and COGNARD (1957). In Dahomey planting of oil palms used to be a royal monopoly of the kings, but under influence of modern times this right has lost its validity. The practice is to plant palms in farmland at a spacing of four to five metres and to intercrop for the first three to eight years. During the eleventh year the plantation is cleaned. Tapping the palms for wine starts in the thirteenth to fifteenth year and goes on for eight to ten years. The palms are then felled and the land is used for farming and afterwards for a new orchard. The palms are tapped instead of harvesting the fruit to oil, because lack of water makes extraction difficult. A higher revenue is obtained from the wine than can be obtained from the oil from the same palms. According to HOUARD (1920) no selection is carried out, but sometimes young palms are sold on local markets (BRASSEUR, 1953).

Transplantion of young grove palms is also recorded from other regions, but not on such a large scale as in Dahomey and the purpose is to grow more palms for oil production. GRÜNER (1904) wrote that at Misahöhe in Togo palms were only transplanted to more suitable sites, and the same practice is recorded for the Ebrie in Ivory Coast by BRET (1911), and for the Lulua in Congo by JANSSENS (1917). In the latter case transplanting was only done in the compound because elsewhere sufficient oil palms grew subspontaneously.

In Western Krobo, in Ghana, more oil palms are planted when the price of cocoa is low; a similar tendency was observed in 1912 and 1918. According to LA ANYANE (1961) the present groves in Krobo originate from the plantings made in 1860. In southern Nigeria young grove palms are sometimes transplanted to fill gaps in the thinning groves.

4.3.3 Planting of selected seeds and transplanting of the resultant palms

Selecting and planting seed occurs rarely and is only done in some districts of Eastern Nigeria and possibly in some areas in Angola and Congo. Selection criteria are: good oil or wine yield or big kernels. The farmers are aware that bunches with *tenera* fruits give more oil than those of the same weight having *dura* fruits, and for this reason fruits harvested from high yielding *tenera* palms or *dura* palms producing fruit with a thick mesocarp, are laid out. The resultant palms are subsequently transplanted to a suitable site. This practice was first reported for Onitsha by FARQUHAR (1913). UNWIN (1920) reported on the planting of selected oil palm seed by the people in Southern Ogoja district; *dura* seeds were planted to raise 'kernel' palms and *tenera* seeds for 'oil' palms. He said that the seeds were imported from the Cross river area because there were not enough local palms. Around Umuahia people select big fruits with big kernels for planting. TOOVEY (1947) described the unusual frequencies of

fruit forms observed in a grove at Ufuma. He found that of the identified palms 53 % were *dura*, 43 % *tenera* and 4 % *pisifera*. In subspontaneous groves the *dura* generally constitutes more than 85 %, while only a few *pisifera* palms occur. In the area between Onitsha, Okigwi, Aba, Owerri and Nnewi SPARNAAIJ and BLAAK (1962) found groves having a high percentage of *tenera* palms. Examination of the map showing the intensity of farming in Eastern Nigeria (JONES, 1943) shows that the areas having a high percentage of *tenera* palms roughly coincide with 'Heavily and Overfarmed Farmlands' having village palm groves. In these areas the people were compelled to increase their income and have turned to the improvement of the oil palm to obtain cash. It is unlikely that planting of selected seeds was practized before the end of the eighteenth century *i.e.* before the oil palm became a cash crop. In these areas seeds obtained from *dura* palms are planted to grow 'big kernels' palms. Seeds harvested from *tenera* palms are sown to have 'oil' palms, while planting of seeds with the aim to grow 'wine' palms irrespective of their shell thickness, influenced the frequency of the fruit types in the grove at Ufuma.
In the Seles region of Angola a *tenera* ratio of 50 % is found and it is said to be the result of selection by man, although nothing particular is stated about the planting of selected seeds. Around Brabanta in Kasai (Congo) a high *tenera* rate of 20 to 25 % was also noticed by JAMES (BEIRNAERT, 1933), but no indication of its cause is given.

4.3.4. Thinning of the population

The purpose of thinning is to obtain farmland and/or an improved grove. During the thinning process, discussed in section 5.4.4, palms known to be good as oil, kernel or wine yielders may be chosen to remain which might change the frequencies of the various types. The frequencies of fruit types of the various experimental plots of Expt. 505-2 can be seen below:

	Treatment	*dura* (%)	*tenera* (%)
A.	Undisturbed plots	93	7
C.	Thinning, palms selected on external appearance	89	11
D.	Thinning, palms selected on recorded bunch yield	98	2

These figures show that in the C-plots *tenera* palms must have looked better than *dura* palms, which resulted in a relative increase of *tenera* palms, and that in the D-plots *dura* palms generally give more bunch yield than *tenera* palms, so relatively more *dura* palms than *tenera* palms remained after the thinning.

4.4 Direct, but unintentional selection by man

Man is also responsible for direct, but unintentional selection, for example the harvester applies positive selection when reaping bunches and bringing them or the fruits to his compound. He selects the bunches having fruits with a thick mesocarp or big fruits with a large kernel, and deliberately avoids bringing home worthless bunches with only a few fruits. Nowadays a rather different practice is observed. The bunches with *tenera* fruits are brought home while the bunches with *dura* fruits are sold. Such a concentration of *tenera* fruits may later result in an increase of the frequency of the *tenera* type in palms growing up on abandoned compounds. Bunches of certain varieties are linked with certain superstitious beliefs and may be left in the grove or brought to the compound of the local priest. For instance in Igala division of Northern Nigeria the bunches with *poissoni* fruits are left to rot in the groves while in the Anang province of Eastern Nigeria the bunches with *virescens* fruits are often collected only by the village priest who will use the oil for certain rites.

When collecting and bringing the bunches to a compound, the harvester restricts himself to palms not too far away from his compound; these palms become the parents of the palms which later grow up on the deserted compound. The repetition of such conscious and unconscious selection over many generations may have given rise to geographical races. Harvesting of palms growing on land of a certain village was often confined to members of this village. Examples are given in section 7.2.

Here the isolating mechanism is the prohibition on harvesting palms outside the village territory. Geographical races may also originate where the isolation is caused by geographical boundaries such as big rivers and large uninhabited areas. But so far, no precise studies on this subject have been made, although it is known that palm oil exported from certain areas is less pigmented than palm oil obtained in other areas. For example the palm oil exported from Eastern Nigeria is more coloured than that from the Cameroons (RAYMOND, 1961). But the carotenoid content in the mesocarp depends on environmental conditions and also on the processing method applied (ARGOUD, 1958). NWANZE (1963), who used a laboratory hand press to extract the oil, found that the mean carotenoid content of oil extracted at Abak was less than that of oil extracted at Warri. Both places are in southern Nigeria, but are comparatively isolated from each other.

A typical example of a geographical race is the oil palm in Madagascar, sometimes referred to as *E. guineensis* var. '*madagascariensis*'. Due to its isolation on this island and probably to its low genetic variability caused by its introduction and genetic drift, an oil palm population with a number of some uniform characters could arise. This variety has been described in section 3.7.1.

Further investigations are obviously needed if a clear picture of the results of unintended selection is to be obtained.

5 Origin and classification of the palm groves

5.1 Origin

Jentsch and Büsgen (1909) were among the first to report that dense groves stand on deserted village areas. Bret (1911) gave the first description of the development of a grove on an old dwelling site which had once been established in farmland. Such hamlets, *fermes à huile*, consisting of two or three houses and a processing hut were erected near palm groves for the sole purpose of processing oil and kernels. After six or seven years the farm was abandoned and a dense stand of oil palms would then grow up, derived mainly from seeds discarded with the bunch refuse. These seeds are often small, deformed and of poor quality, and hence not worth picking from the spikelets. In Abak about 25 seeds on average were counted in the refuse discarded from one bunch. More seeds may get lost during subsequent processing operations, but in areas where soft oil (see section 7.1.4) is prepared, the fruit is boiled and these seeds are not viable. In a trial at Abak, 11 % of fresh seeds planted in soil had germinated after 14 months, but none of the seeds from the same sample which were boiled before planting germinated.

The amount of seed lost or discarded during the few years immediately prior to a compound being abandoned and its chances of survival determine the number of seeds which germinate. Rees (1963c) found that many seeds were damaged by two species of beetles *Pachymerus lacerdae* Chev. and *Coccotrypes congonus* Eggers, losses being particularly high under adult palms and secondary forest trees, but lower on bare soil or in grass which are comparable with the cover of a compound and farmland. In the dense palm belt, up to about 160 bunches per year may be taken to a compound which covers one-eighth to one quarter of a hectare. This figure of 160 bunches is the total of the product of the number of harvesting periods (five to six) during the peak season and the number of bunches harvested during one period (20 to 25 bunches) and about 30 to 40 bunches which are collected during the off-season. Under such conditions, as many as 4,000 seeds may be discarded in one year. But in the secondary rainforest belt, fewer bunches are transported to the compound as the density of the palms is low. Soil factors and (micro-)climate also affect the number of seedlings that will develop and survive.

A few palms may be allowed to grow up while the compound is occupied, but this is not encouraged as long as there are enough palms in the neighbourhood. Many seedlings are deliberately destroyed during the cultivation of compound crops.

Farmland is also a suitable habitat for oil palms to grow up, but such areas will not become covered by a dense stand as the number of seeds per area is small and the soil is poor. However, during the next farming cycle the oil palms are preserved and, when conditions are not unfavourable other oil palms may grow up. The seeds may have been introduced by man (intentionally or accidentally) and by animals, or they may have fallen from nearby palms. But in the farmlands of the Derived Savanna which are annually swept by fire, the small oil palms are killed and the vigour of taller palms is reduced. In this area an oil palm has a poor chance to grow up and fruit.

5.2 Classification of groves

Several authors have attempted to classify the palm groves into types. Generally these classifications have been based on the density of palms and other vegetation, but some have been based on habitat. DESNEUX and ROTS (1959) listed the various factors which give rise to the heterogeneity of groves. The main factors are (1) man and (2) fire; (3) micro-climate, (4) geomorphology and (5) soil are three other important factors. The factor man has been subdivided into (1) 'exploiting' population density in the French text and total population density in the Dutch text, (2) cultural system, (3) social organisation, (4) land tenure, (5) distance from grove to residence, (6) accessibility, (7) agricultural system, (8) extent of fire and (9) presence of intensive, soil exhausting crops *e.g. Urena lobata* L. Unfortunately these authors do not explain these classifications so it is not clear why in the main classification 'fire' is not brought under 'man', unless fire caused by lightning or other natural causes is meant. Similar questions may arise, thus it is possible to include factors (8) extent of fire and (9) presence of crops *e.g.* urena into (7) agricultural system. These authors do not use their classification to classify the palm groves in the Kwango.

An example of classification based on habitat is that of GERALDES (1929) for Angola: (a) palms occuring in forests of the mountain zone, (b) scattered palms in the plateau zone, and (c) palms in gallery forests.

ROY (1957) gave another example for Guinea: (a) dense groves on the dunes of the coastal zone (where they serve to assist in soil conservation), (b) large dense groves having up to 450 palms per hectare, in the lowlands, (c) poor small groves on the hills, degraded by fire and (d) groves extending to about 500 hectares each in the valleys.

An example of a grove type classification, based on density and habitat, is that of DUPIRE and BOUTILLIER (1958), who classified the groves in Adioukrou in Ivory Coast as (a) extensive palm bush, (b) scattered palms among shrubs and (c) palms in groups.

JONES (1943) classified the land of Eastern Nigeria into: (1) swamps, (2) underfarmed land: secondary rain-forest interspersed with oil palms, density of human population about 50 persons/sq.km, (3) heavily farmed land: farmland and palm groves, 100 persons/sq.km, (4) overfarmed land: farmland largely under oil palms, 275 persons/sq,.km, and (5) badlands: erosion areas and poor grasslands with farming mainly confined beneath oil palms around village settlements, 80 persons/sq.km.

WATERSTON's (1953) classification for the Nigerian groves and his views on the development of one grove type or grove subtype into the other, and JONES's work form the base of the classification given by the present author. Only in one instance does WATERSTON make a reference to the population pressure *viz.* when the forest vegetation type changes under high population pressure into a Derived Savanna.

The present author used three main factors in classifying palm groves *viz.* (1) the total human population density, (2) whether the palms originated either from lost seeds or from planted palms, and (3) man's dependence on the palm as a main means of sustenance, which causes many people to be engaged in the oil palm industry.

The density of human population determines the area of land required for residential purposes and for farming (fallow land included), and also – in general – the agricultural system applied. This density and that of the population engaged in the oil palm industry may influence the number of seeds lost per area or decide whether it is necessary to plant seeds or to transplant young palms, either from self-made nurseries or from a grove area, to secure the future of the oil palm industry.

So, as the population pressure increases the number of forest trees decreases in the same area and – within certain limits – the number of oil palms increases.

For the following account the densities of human population (obtained from census figures), the vegetation type and the agricultural system applied (noted from field observations) of the same area in southern Nigeria are compared with each other.

At a density of less than 20 persons/sq.km the vegetation type is a secondary rain-forest with or without oil palms with residential areas and farmland. The agricultural system is shifting cultivation. The farmers prefer to clear 20 to 30 years old secondary forest, as it is easier than felling older forest. The soil fertility is sufficiently restored during this period, the land is underfarmed. Oil palms grow up from lost seeds on abandoned compounds; a few palms may grow up in clearings. This accounts for the oil palms being grouped in the regrowing forest. When the fallow period extends more than a century, oil palms will disappear from the vegetation, but remaining palms will be spared when the forest is cleared again. The number of stemmed palms per hectare may vary from one to 75. This palm grove type is called *Secondary forest with oil palms.*

At densities varying from 15 to 90 persons/sq.km, less old secondary rain-forest is seen, because the area under cultivation is larger and the fallow period shorter (8 to 25 years). Farming may continue for several years on the same land, which is underfarmed to moderately farmed. Oil palms grow up from lost seeds on abandoned compounds, but as the farming period is longer than that of the Secondary rain-forest with oil palms grove type some germinated seeds stand a fair chance to grow into a young palm before the regrowing forest forms a severe competitor. The average density is about 25 stemmed palms/ha. This grove type is named *Palm bush*; it is a transitory stage between 'Secondary rain-forest with oil palms' and the next palm grove type.

At densities of 80 to 220 persons/sq. km the agricultural system is bush fallow rotation; the period of farming being about 1½ years and that of the fallow five to ten years. This period is too short for a forest regrowth to grow into a high secondary rain-forest. It is also too short to restore the soil fertility to its original level. Yet this level is still sufficiently high to give a reasonable crop yield. So the land is moderately to heavily farmed. Oil palms growing up from lost seeds on deserted compounds form a dense stand with only a few trees. In course of time old palms will die, which results in a degraded grove and later in farmland with a few or no palms. There is hardly any natural regeneration. In these farmlands new homesteads may be erected. The density of stemmed palms is on the average 125 to 150 per hectare, but it may reach 350 on some sites. The density of the palm in the farmland is low. This grove type is called *Dense grove/Farmland with or without palms.*

At densities of 200 to 325 persons/sq.km the agricultural system is bush and grass fallow rotation, at which the land is heavily to overfarmed. The farming period is about 1½ years followed by a three to eight years bush and/or grass fallow. During this period the soil fertility which is already very low, is not restored and the result is a very low crop yield. There is a tendency to settle in walled-in or fenced compounds which are more or less permanently sited. This causes the nutrients to be concentrated near the houses. As the crop yields are low more arable land is wanted and farmers start 'reclaiming' palm groves by thinning the grove. On the other hand some gaps in the grove may be used by planting a few oil palms. A few palms are also planted on compounds and even in the exhausted farmland. This grove type is called *Thinned grove*. As there is almost no natural regeneration the final stage of a 'thinned grove' is 'farmland with or without oil palms'. Those groves where felling and dying of palms is counteracted by the growth of oil palms derived from self-sown or lost seeds, and soil fertility is – although on a low level – maintained by applying household refuse, are called *Sparse groves*. Both this grove type and the next grove type form a disclimax vegetation type as the land is permanently covered by a thin stand of palms of all ages.

At densities of over 300 persons/ha the farmland soil has a very low fertility and is mainly covered with grass. This is the 'derived savanna'. The grasslands are annually swept by fire which retards the growth of remaining oil palms or kills them. Villages – permanently sited – lie like green islands in these grasslands. On the compounds the main food crop is grown under oil palms and some trees. These palm gardens where soil fertility is maintained with household refuse give protection against erosion. The palms have been planted with material grown in peasant's nurseries or obtained from another grove. The density of stemmed palms in these gardens is up to 100 per hectare. This grove type is called *Village grove*.

At any time these groves, except the village groves, can be changed by palm grove rehabilitation (see section 10.4) or by planting palms in farmland into a *Peasant's plantation* which often has an irregular lay-out. It has been planted with oil palms obtained from other groves, from own nurseries or from the site itself by leaving some young palms untouched and filling up gaps.

So there are seven palm grove types:

1. secondary rain-forest with oil palms
2. palm bush
3. dense palm grove/farmland with palms

4. thinned grove
5. sparse grove
6. village grove
7. peasant's plantation

5.3 Relationship between grove types

When the change in the human population density of a certain region is gradual the grove type found in that region had time to adapt itself to this change. Rapid changes in population density in the past occurred and at present still occur. In the past a rapid decrease of the number of people might have been caused by the fact that they left their lands, voluntarily or compulsorily or as a result of their death. Rapid increase might have been caused by immigration and at present by modern living conditions (ZEVEN, 1963). After such a rapid change the grove type found is not the one belonging to the actual population density.

Figure 3 gives a picture of the transition of one grove type into another under the influence of a slowly changing population density. It also shows the development cycle within a grove type.

WATERSTON (1953) published a similar figure. The main difference – not relating grove type with population density – has already been mentioned. He also puts 'palm', 'forest' and 'homestead' on a same level referring to these units as oil palm habitats. Besides the fact that a palm is not a habitat of oil palms, it leads to changes of 'high secondary forest' into 'homestead palms', or 'broken forest palms' into 'secondary forest'. Furthermore, WATERSTON (1953) distinguished between habitats with or without fire protection, and stated that palms on compounds are protected against fire. This is not strictly true, because compound gardens are burnt annually, but since the quantity of garden refuse is small the damage done to the palms is only slight. WATERSTON has suggested that compounds are abandoned because the stand of oil palms becomes too dense, but the real reason is that the stand of all compound trees, among which may be a few oil palms, becomes too dense.

The natural regeneration of a Sparse grove has already been mentioned above. In farmland clearings in Secondary rain-forest, or in shrubby areas of the Palm bush and Dense grove districts, where burning is done every five to twenty years a few palms may become established. However, they do not form a dense stand. There is no natural regeneration in a Thinned grove, because if it exists, the grove type is a Sparse grove. Nor is there any natural regeneration in a Dense grove. Seedlings and stemless palms, although more tolerant of shade than adult palms (COOK, 1910; REES, 1963a), will finally succumb due to lack of light and space, root competition, and later owing to trunk rot which eventually kills all the palms. The natural regeneration of the palm stands of a Palm bush was not studied. In a Secondary rain-forest the oil palms are eventually overtopped by forest trees and the reduced light intensity to which they are subsequently subjected does not only influence their assimilation rate, but also their

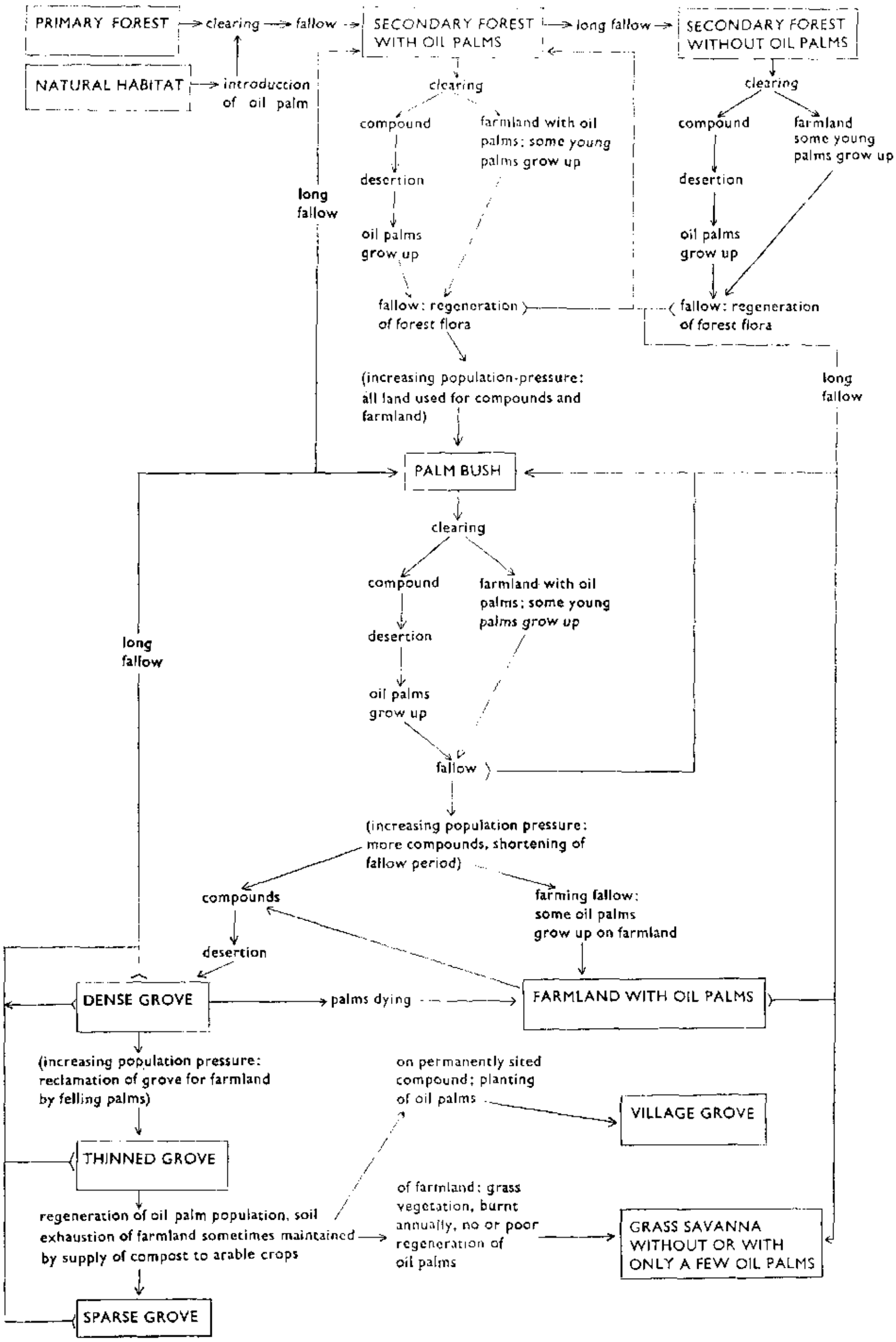

Figure 3. The development and deterioration of palm grove types and subtypes

sex ratio, *i.e.* in conditions of low light intensity less female and more male inflorescences are produced (BROEKMANS, 1957). This causes the palm to produce fewer fruits and consequently fewer seedlings will grow up. Those and stemless palms eventually die due to adverse living conditions. Under such conditions the oil palm disappears from the forest vegetation. The final stage of any palm grove abandoned for a very long time will be a high Secondary rain-forest.

5.4 Description of grove types

5.4.1 Secondary rain-forest with oil palms

In Nigeria this forest type of palm grove occurs mainly in the Mid-West and West, and in the Benin area it covers about 10,000 sq.km. It is mainly a mixture of *Gossweilerodendron balsamiferum* (VERM.) HARMS and *Cylicodiscus gabunensis* HARMS together with other trees and the oil palm, which may occur in groups of up to 69 stemmed palms per hectare (SYKES, 1930). The population figure of inhabitants in this area is less than 20 persons per sq.km and this ensures a long fallow period.

Plate 5. A farm with cassava reclaimed from a Rain-forest with oil palms near Benin-City, Midwestern Nigeria. Big trees and oil palms are left standing. The first because they may be sacred, too heavy to fell or inhabited by ants or bees; the palms because of their economic value. Photograph NIFOR.

HARTLEY (1954) and ZEVEN (1965b) described the Secondary rain-forest with Oil Palms (Expt. 18-1) at the WAIFOR's main station near Benin City. The mean density of the palm stand in this forest was as follows:

Year	Number of palms per hectare		
	Rough-stemmed	Smooth-stemmed	Total
1952	37.8	31.8	69.6
1960 (February)	12.3	37.3	49.6
1963 (December)	7.2	41.0	48.2

The decline in the number of rough-stemmed palms over the period of the observations is striking and is the result of (a) severe competition from the regenerating forest leading to the death of palms, and (b) transition to the smooth-stemmed category which is reflected in the increase in the number of smooth-stemmed palms. Between August, 1960 and July, 1963, regular disease and casualty surveys were carried out. During this period only 0.07 rough-stemmed and 0.12 smooth-stemmed palms died per hectare per year, which indicates that one rough-stemmed palm per hectare per year shed its leaf bases and became smooth-stemmed.

The densities of the palm stands in some other rain-forest areas at the institute's main station were:

Field	Number of palms per hectare			Year of counting
	Rough-stemmed	Smooth-stemmed	Total	
17	14.1	9.6	23.7	1963
30	8.4	20.2	28.6	1962
36	2.7	9.1	11.8	1962

These densities are all lower than in Field 18-1.

It is difficult to find comparable data in the literature, because the density of the palm population is often given without reference to the vegetation type or age of the grove; for example a low density of oil palms occurs in rain-forests, and also in 'Farmland with palms'. In a forest in the Mayumbe in the Congo, DE GROOF (1933a, 1933b) found 24 producing palms per hectare and in another forest 25 to 50, but in two other forests he found only 3 to 4 and 10 to 15 palms per hectare. In the same country DE WILDEMAN (1920) found only 0.5 palms per hectare in a very old forest and 12.5 palms per hectare in a younger forest. These figures agree with those obtained in the Benin forests. In an old secondary forest in the Mayumbe in the Congo, MAUDOUX (1954) found a much higher density of 50 palms per hectare, but only four of these palms exceeded one metre in height.

The mean annual yield per hectare of the stemmed palms in Expt. 18-1 (Secondary rain-forest with palms) at Benin was:

	Number of bunches	Weight of bunches (kg)	Average bunch weight (kg)	Number of palms
ROUGH-STEMMED PALMS				
per hectare	8.5	117	13.7	25.0
per palm	0.3	4.7		
SMOOTH-STEMMED PALMS				
per hectare	106.9	1,537	14.4	34.6
per palm	3.1	44.4		
ALL STEMMED PALMS				
per hectare	115.4	1,654	14.3	59.6
per palm	1.9	27.8		

The yield figures are based on the yields from 1949 to 1959 and as regards densities those of the 1952 and 1960 densities (see p. 41) were taken. Thus, 93 % of the yield was produced by the smooth-stemmed palms, although these palms accounted for only 58 % of the stemmed palms. The much higher yield of a smooth-stemmed palm is mainly caused by the ten times higher number of bunches as compared with that of the rough-stemmed palm.

Comparing the yield per stemmed palm of Expt. 18-1 with that of a Dense grove/ Farmland with palms (Expt. 501-1) it will be noticed that they do not differ much:

	Number of bunches	Weight of bunches (kg)	Mean bunch weight (kg)
Expt. 18-1	1.9	28	14.3
Expt. 501-1 (from Table 7)	1.6	21	12.9

De Wildeman (1920) gave for a rain-forest with oil palm grove in the Congo a yield of 2 to 4 bunches weighing 15 to 18 kg per stemmed palm. This is higher than the weight mentioned in our data.

Purvis (1954) investigated the fruit type and fruit and bunch composition of the palms in Expt. 18-1; 95 % of the smooth-stemmed and 98 % of the rough-stemmed palms were *dura* palms while the overall percentage of *dura* palms was 96 %. No *pisifera* palms were found, but there were a few female sterile palms. The fruit and bunch compositions were studied (Table 2).

The figures in brackets were based on a small number of analyses. Both bunch and fruit compositions are rather poor, the bunch composition being even poorer than in the dense Ikot Okpong grove at Abak (see section 6.1.9). Purvis found that the population of rough-stemmed palms differed significantly (P = 0.001) from the population

Table 2. Expt. 18-1. Fruit and bunch analysis of oil palms in a Secondary rain-forest with oil palms

Percentage	Rough-stemmed palms		Smooth-stemmed palms		Mean of all palms
	dura	*tenera*	*dura*	*tenera*	
Fruit to bunch	63	60	58	52	58
Mesocarp to fruit	40	(61)	41	61	42
Shell and loss to fruit	47	(29)	45	27	44
Kernel to fruit	13	(10)	14	12	14

of smooth-stemmed palms with regard to fruit and bunch composition. This difference might be attributable to a difference in environment, as the rough-stemmed palms receive less light than the smooth-stemmed palms, but age and genetical composition must also be considered. The average age of the rough-stemmed palms is less than that of the smooth-stemmed palms; the retardation in shedding their leaf bases may be connected with vigour and may also find expression in the bunch composition.

5.4.2 Palm bush

The Warri Province and Asaba Division of Mid-Western Nigeria have a population figure of 50 to 125 people per sq.km and SYKES (1930) designated the 'Open Forest' in the area as 'Oil Palm Bush'. In the areas with the higher human population densities the land is covered by dense oil palm groves and those with the lower densities with young secondary forest mixed with variable numbers of oil palms. No data about densities of stand and yield are available for the area, but examination of the groves shows that they are intermediate between those of Experiments 18-1 and 501-1.

The palm groves in the Kabba Province of Nigeria may also be classified under this type, although they are situated in Derived Savanna. CLAYTON (1958) described the palm groves in Western Kabba Province as *Daniellia/Elaeis* savanna with *D. oliveri* (ROLFE) HUTCH. ET DALZ. dominant. Groves in this area are not necessarily confined to the neighbourhood of water courses, as is the case further north. CLAYTON stated that the controlling environmental factors in this area are the rainfall averaging of 125 cm per year and the fairly high human population density, which, for instance, in the Igbirra Division, is 51 persons per sq.km. BROWN (1945) stated that in this Division the oil palm industry was declining because the old palms were becoming senile. LOMAX (1962) studied the palm bush in the Igala Division of Eastern Kabba Province, where the average density of population is 27 persons per sq.km, but in some areas reaches 100 persons per sq.km. These densely populated areas are also the Palm bush areas. Palm density in an area of 1.8 hectares of palm bush at Acharu was 59 smooth- and 17 rough-stemmed palms, making a total of 76 stemmed palms per hectare, their average height being about 13.5 m. Their mean yield in 1961–1962 was 2,371 kg per hectare or 2.0 bunches of 15.6 kg each per palm, a total of 31.2 kg. The percentage of bearing palms was 79% in 1962. One random fruit sample was analysed and the composition found to be 45.2% mesocarp, 41.2% shell and 13.6% kernel and loss (LOMAX, 1962), figures which are similar to those for fruit found at Benin and Abak (see section 6.1.9). The fruit to bunch ratio was 60%.

The Palm bush type is of common occurrence in Africa, but it has not previously been described. MARTIN (1938) included it in his classification 'High Bush' which then covered 20 to 25% of Sierra Leone, but which also included some Secondary rain-forest. However, as MARTIN observes, these forests are rapidly disappearing and since the oil palm occurs frequently and often densely in them, it is considered appropriate to refer to the Sierra Leonean 'High Bush with Palms' as Palm bush. Nevertheless, Dense palm groves do occur, for example in Bonthe district (HARTLEY, 1961).

HARTLEY classified the groves in Sierra Leone as:

X = Farmland with palms (common),

Y = Palm grove with occasional farming (uncommon),

Z = Palm land not farmed (very uncommon).

Work by the WAIFOR on palm groves in Sierra Leone was restricted to the yield recording of three groves, one at Kottopema in the Colony area (Expt. 920-1), one at Kunshu in Bombali district (Expt. 940-1) and one at Bissao in Bonthe district (Expt. 960-1). The Kottopema and Kunshu palm groves belong to HARTLEY's 'Farmland with palms' grove type and in them farming had occurred roughly once in seven years. The Kottopema grove covers 8.5 hectares and consists of tall palms with poor crowns and numerous stemless and young rough-stemmed palms. The Kunshu palm grove which covers 3.4 hectares is situated in an area where the Dry Season lasts four to five months, a period which HARTLEY considers to be marginal for the oil palm. The crowns of the palms had only a few fronds, and palms near the road or villages were tapped for wine. When the land was farmed, the refuse was gathered into heaps before burning in order to reduce the fire damage to the palms, but the palms were pruned when necessary to allow the cultivation of rice and cassava. The poor appearance of the palms in these groves is probably due to food cropping having exhausted the soil and in the case of the Kunshu palms, to the unsuitable climate and the tapping for wine.

The Bissao palm grove covers 4.0 hectares, and comes in HARTLEY's 'Palm grove with occasional farming' group. The palms in this grove are well developed and healthy and it could be classified as a 'Dense grove', but the 20–25 year interval between periods of cropping is unusually long. Yield data for these groves are presented in Table 3.

The yield per hectare of these groves is higher than that of the Palm bush in the Igala Division of Nigeria. The number of bunches per bearing palm is high, probably indicating a high sex ratio which SPARNAAIJ (1960) found to obtain for planted palms in Sierra Leone, and which is probably attributable to a greater number of hours of sunshine.

However, the average bunch weight is low as compared with the palms in Igala and

Table 3. Expts. 920-1, 940-1 and 960-1. Annual yield of the Kottopema, Kunshu and Bissao palm groves in Sierra Leone

Expt.	Density		Yield per hectare			Number of palms bearing 1961	Percentage of palms bearing	Yield per stemmed palm		Period of recording
	smooth-stemmed (ha)	rough-stemmed (ha)	number of bunches	weight of bunches (kg)	mean bunch weight (kg)			number of bunches	weight of bunches (kg)	
920-1	86	103	595	2,893	4.9	147	77.8	3.1	15.3	1958–1961
940-1	112	33	370	3,124	8.4	122	86.2	2.6	21.5	1959–1961
960-1	58	169	892	6,900	7.7	184	81.1	3.9	30.4	1959–1961

the yield per bearing palm is considerably lower. The percentage of bearing palms is, however, the same as in the Igala Division despite the higher density of the Sierra Leonean groves.

The bunches and fruit are of poor quality, the fruit being mainly of the *dura* type *macrocarya*, while fruit composition is probably similar to that in Casamance (Senegal) where the mean fruit weight was only two grams, and the fruit composition: mesocarp – 20%; shell – 50% and kernel – 30% (ROUSSEAU, 1950).

The groves in eastern Nzima in Ghana, which have a mean density of 47 palms per hectare and a fallow period of ten or twenty years (WILLS, 1962), could be regarded as also belonging to the Palm bush grove type.

5.4.3 Dense palm grove/Farmland with palms

Studies of Dense palm groves 'as they are' outside Nigeria have often been comparatively superficial. Generally speaking the surveys give the average density of some sample plots and the assessed yield per palm from which the yield of the grove is calculated. The surveys then conclude with an account of the present exploitation and suggestions for improving the output. Such surveys have been made for the groves of the Adioukrou in Ivory Coast (ANON., 1957a; DUPIRE and BOUTILLIER, 1958), the groves of southern Ghana (reviewed by LA ANYANE, 1961 and WILLS, 1962), and the groves in the Kwango district of the Congo (DESNEUX and ROTS, 1959).

Dense groves are characterized by an almost pure *Elaeis* community with shrubs and arable crops in the underlayer. The main difference between the Dense grove proper and Farmland with palms lies in the density and age of the oil palm stand. There may also be a difference in the composition of the shrub vegetation. The very dense groves are not farmed and the forest regrowth is limited by lack of light. In a less dense grove or in farmland the short fallow period prevents the development of a high regrowth vegetation.

Palm groves 'as they are' in Nigeria were studied at the beginning of the century, but it was not until 1946 that a comprehensive study was begun in palm groves owned and rented by the WAIFOR. They are sited on the Institute's substation near Abak in

Eastern Nigeria and are: Ikot Okpong (Expt. 501-1), Uruk Enung (Expt. 502-1), Ikot Ntuen (Expt. 502-2), Uruk Obong (Expt. 503-1) and Obio Akpa (Expt. 505-1).

Classification of subtypes. WATERSTON (1953), describing the groves of the Asutan Ekpe area in Eastern Nigeria, believed that these groves belonged to the grove type Dense grove/Farmland with palms. He apparently did not take account of the deliberate felling of oil palms which goes on in this area with the aim of creating sufficient farmland. So these groves belong to the grove type Thinned grove (see section 5.4.4). HARTLEY (1954) noticed that there were some differences between the groves at Abak and Asutan Ekpe, but he did not mention the cause. He recorded the following characteristics:

	Abak	Asutan Ekpe
density of dense grove:	high	not so high
percentage of rough-stemmed palms bearing:	low	not so low
change of grove to farmland:	abrupt	gradual
farming:	not in dense groves	in all grove subtypes

Although WATERSTON's classification of a Dense grove/Farmland with palms into subtypes is based on the Thinned groves of the Asutan Ekpe area, it can be used for setting up a classification of the subtypes of a Dense grove/Farmland with palms and of a Thinned grove. WATERSTON's classification was:
subtype A – Primary compound palms;
subtype B – Palms in typical dense groves;
subtype C – Farmland palms in degraded groves;
subtype D – Open farmland palms;
subtype E – Compound palms near homesteads set up in farmland.
Palms in subtype A grow around homesteads which WATERSTON believed to have been set up originally in high forest. Subtype E is composed of palms growing on compounds, which were established on farmland on which palms of subtype D would occur. It is difficult to accept WATERSTON's explanation of the origin of subtype A, because this area has long been densely populated and high forest could hardly have existed at the time these compounds were established. It is more probable that groves of subtype A are in fact an advanced stage of subtype E. The author suggests that subtype B should be split into B_1-young dense grove and B_2-adult dense grove.

So the present author suggests the following subtypes for the grove type Dense grove/Farmland with oil palms:

E_2 Grove of compound palms near homesteads set up about 12 to 20 years earlier in farmland (E_2 was formerly A under WATERSTON's classification);

B_1 Grove of young palms on abandoned compounds;

B_2 Grove of adult palms in dense stands;
C Thinning grove with patches of farmland;
D Grove of open farmland palms;
E_1 Grove of compound palms near homesteads recently set up in farmland.

This cyclic classification allows the age of the palms to be estimated and the following time-scale is put forward:

Grove subtype	Number of years since compound was set up	Mean age of all palms years
E_2	12–20	(0–10, 81–90)
B_1	21–30	0–10
B_2	31–60	11–40
C	61–80	41–60
D	81–100	61–80
E_1	0–11	(70–90)

This rough time table could be set up thanks to the information received from some inhabitants. This work was mainly carried out with the aid of Chief J. U. U. EBONG in the WAIFOR's Uruk Obong grove (Expt. 503-2) and other grove areas formerly the site of the village Uruk Obong (see description of the Uruk Obong grove, p. 49). Palms of all ages may occur in the subtypes C, D and E_1, but the number of young palms is small in comparison with older palms of 40 to 80 years of age.

Description of five Dense groves

The *Ikot Okpong Palm Grove* (Expt. 501-1) covers about 95 hectares, but only 42.5 ha were used for experimental purposes. The above classification holds for this grove, in which grove subtypes B_1, B_2, C and D are present, some areas having been occupied by villages up to 1930–1940. These areas now carry a dense stand of the B_1-grove subtype. Many clusters of bamboo (*Oxytenanthera* MUNRO sp.) grow in the open parts of this grove, but only a few tall trees, mainly *Ceiba pentandra* (L.) GAERTN. occur. Yield recording of individual palms started in this grove in 1949 and some early data were given by HARTLEY (1954). In 1960 the grove was demarcated into 105 one acre plots and the density of the palm stand and yield of fruit bunches per palm and per plot calculated from the records which had been kept.

The *Uruk Enung Palm Grove* (Expt. 502-1) of 4.4 hectares has the same grove subtypes as Experiment 501-1, but the B-subtype is in the deteriorating B_2-stage. There is a large open space with some moribund palms in the centre of the grove. At the time the grove was purchased by the Institute a small patch of sanctuary forest remained, but it has since been opened up for farming, although some tall trees still indicate its site. Yield recording of individual palms started in 1949 and the grove was demarcated into 22 half-acre plots in 1960.

Plate 6. A recently abandoned compound near Abak, Eastern Nigeria. The various crops are:

1. *banana,* Musa *sp. (probably the table banana and plantain);*
2. *cocoyam,* Colocasia *sp.;*
3. *stem of a raphia palm,* Raphia *sp.;*
4. *stem of a coconut palm,* Cocos nucifera L.;
5. *cocoyam,* Xanthosoma *sp.;*
6. *dwarf cavendish,* Musa *sp., the original stools came probably from a plot of the nearby substation of the* WAIFOR;
7. *oil palm,* Elaeis guineensis JACQ.;
8. *a seedling of a raphia palm,* Raphia *sp., marked by two small sticks;*
9. *probably yam,* Dioscorea *sp.;*
10. *cassava,* Manihot utilissima POHL;
11. *unidentified crops;*
12. *a juju-site, marked by beer bottles and a 'livestick';*
13. *the dilapidated house marked by remains of the palm leaf thatch and the heightened floor.*

Plate 7. An E_2-grove area with young palms grown up since the compound was abandoned. The area is situated in the Ikot Okpong palm grove, near Abak, Eastern Nigeria. Old oil palms and coconut palms grew up while this area was still occupied. Photograph NIFOR.

The *Ikot Ntuen Palm Grove* (Expt. 502-2), a small grove of 2 hectares, was situated in open farmland and at the time it was felled in 1959, it was in its optimal B_2-stage. As this grove had not been farmed for several years, the mean height of the regenerating forest flora was 4 to 5 m, but there were no tall trees. The grove was divided into 1/2-acre plots, but as the abrupt boundary between grove and farmland ran through the centre of several plots (resulting in low average densities and yields in such plots), data from the grove as a whole have been studied. The yield was recorded from 1949 to 1959.

The *Uruk Obong Palm Grove* (Expt. 503-1) covers 7.3 hectares divided into 36 half-acre plots. At one end it is of the D-subtype, but it changes along a north-south traverse into the C-subtype and then into a young B_2-subtype. The height of the forest regrowth within the grove varies according to the length of time since the land was last cropped. There are a few tall trees and some coconut palms. The history of this grove has been studied in detail in order to obtain knowledge about the precise age of certain parts of the grove and thus of the grove subtypes in general.

The present D-subtype area was abandoned by the villagers in 1870 and this allowed a dense grove to grow up. The palms gradually died out, until the area became of the

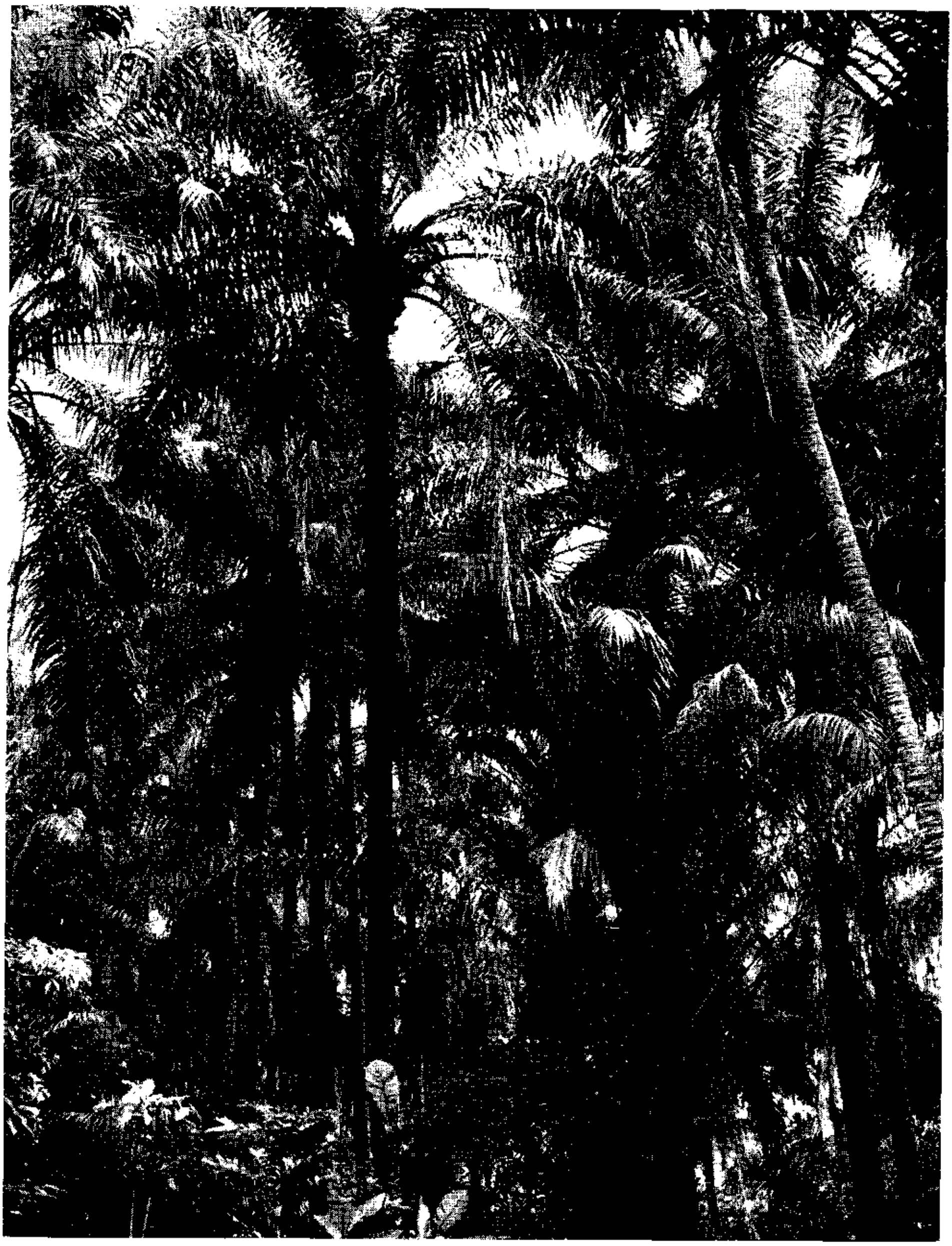

Plate 8. A dense part (B_2-grove subtype) of the Ikot Okpong palm grove near Abak, Eastern Nigeria. The density of the stemmed palms is about 320 per hectare. The average height of the tall palms is about 16 m. The rough-stemmed palm in the foreground is overtopped by other palms; it will not fruit and many of such palms will suffer from a stem rot and die in due course. The whitish stem (right) is of a coconut palm which still remains as a relic of the original compound crops. Photograph NIFOR.

D-subtype, and by 1950 it was sufficiently open to permit resettlement, although, actually, this did not take place. The present old B_2- and C-subtype areas were abandoned in 1900, and the area now covered by a young B_2-grove was abandoned in 1930. When the grove was taken over by the Institute the palm population numbered 1,233 smooth-stemmed and 1,242 rough-stemmed palms and 625 stemless palms. They were individually owned by 19 people, one man owning 27% of the smooth-stemmed palms, 29% of the rough-stemmed palms and 30% of the stemless palms, whereas the smallest owner had only four smooth-stemmed palms, three rough-stemmed palms and two stemless palms. The average number of palms per owner was 65 smooth-stemmed palms, 65 rough-stemmed palms and 33 stemless palms. More detailed information is given in section 7.2.2.

Yield recording started in this grove in 1949, and in 1956 it was used for the Palm Grove Manurial Experiment (Expt. 503-2).

The *Obio Akpa Palm Grove* (Expt. 505-1) covers five hectares and is situated on the edge of a plateau. It consisted mainly of B_2- en C-grove subtypes when taken over. There was also one compound (E_1-grove) in which a few palm seedlings grew up after it was abandoned. Yield recording started in 1949 and in 1953 this grove was used for the Palm Grove Rehabilitation Trial (Expt. 505-2).

5.4.4 Thinned grove

The introduction of modern customs and amenities is attended by a rapid population increase, and a corresponding rise in requirement of farmland. In the districts of Eastern Nigeria having a population density of 250 to 300 people per sq.km, the need to utilise the palm grove for farmland becomes more and more inevitable. Then the oil palm, as a cash crop, has to give way to arable food crops, only a sufficient number of oil palms being retained to satisfy the demand for household oil. In this way the Thinned Grove is derived from a Dense Grove. The WAIFOR Oil Palm Survey in the Asutan Ekpe area is situated in such a district.

The *Asutan Ekpe Oil Palm Survey* (Expt. 560-1) was started in the clan area of the Ibibio Asutan Ekpe near Uyo in 1948 and has been described by WATERSTON (1953) and HARTLEY (1954). The original object of this survey is the study of various subtypes of the Dense grove/Farmland with palms grove type as the Thinned grove type was not recognized before 1960. Yield recording and the collection of other information was therefore carried out on 84 selected plots of one acre, covering all subtypes to which the present author refers as:

- E_2 Grove of compound palms near homesteads set up about 12 years earlier in farmland;
- B_1 Grove of young palms on abandoned compounds;
- B_2(a) Grove of adult palms in dense stands, at an old stage gradual introduction of thinning and farming;
- C(a) Thinned grove, some young palms growing up;

D Grove of old and some young open farmland palms;

E_1 Grove of compound palms near homesteads recently set up in farmland.

This classification is based on that made by WATERSTON (see section 5.4.3). The decrease of the oil palm stand is striking as is shown in Table 4.

Table 4. Expt. 560-1. Number of stemmed palms per hectare in 1950 and 1963 for each grove subtype in Asutan Ekpe

Grove subtype	1950			1963		
	rough-stemmed	smooth-stemmed	total	rough-stemmed	smooth-stemmed	total
E_2	42	25	67	7	44	51
B	111	84	195	27	89	116
C(a)	49	91	140	10	69	79
D	27	49	76	15	49	64
E_1	74	54	128	17	52	69

The decline in the number of rough-stemmed palms is particularly evident, which is not the result of natural causes. From 1961 to 1963 the number of palms felled each month over an area of 26 ha was counted, and this showed that an average of about two palms per hectare is felled annually during preparations for farming. The farming rotation taking up a period from three to five years implies that during clearing of the fallow regrowth six to ten palms per hectare are felled. The total number of palms cut down each month was as follows:

Stemtype	Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Stemless	0	2	1	0	0	0	0	0	0	0	0	0	3
Rough-stemmed	5	38	38	3	1	1	1	0	4	4	4	0	99
Smooth-stemmed	6	21	17	3	0	0	0	0	1	0	3	0	51
Total	11	61	56	6	1	1	1	0	5	4	7	0	153

Local inquiries made into the second felling periode in September to November did not produce any explanation for felling palms at this time of year. The palms chosen for felling are non- or low-yielding; for instance in 1961 only eight of the 38 rough-stemmed palms felled had produced about 14 kg of fruit bunches per palm between 1957 and 1960 and in the same period only ten of the 15 smooth-stemmed palms felled in 1961 had yielded, and this at an average of about 18 kg of bunches annually.

In the plots of the B_2(a)-subtype (following thinning) and in the plots of the C(a)- and D-subtypes, sufficient light penetrates the canopy to allow not only food crops to be grown beneath the palms, but also palm seedlings to develop and thus maintain the stand of palms.

HARTLEY (1954) pointed out that harvesting by the farmers, prior to the 'official' recorded harvesting operation, resulted in a lower yield than the potential assumed being recorded, and estimated the loss to be about 20%. This preliminary harvesting is still going on, but to a smaller extent, the loss probably being about 5% in the early sixties and possibly somewhat higher in the case of palms on and near compounds.

In the Thinned groves of Asutan Ekpe more light reaches the ground, so seedlings have a chance to develop, and 'natural' regeneration may occur. In such groves more young palms produce fruit than in a dense grove.

Table 5. Expt. 560-1. Density of producing palms, percentages of palms, number and weight of bunches, and mean bunch weight per fruit type of five grove subtypes in Asutan Ekpe over 1958-1960

Grove subtype	Number of plots	Mean annual number of producing palms per ha	Percentage of palms per fruit type		Percentage of number of bunches per fruit type		Percentage of weight of bunches per fruit type		Mean bunch weight (kg) per fruit type	
			D	T	D	T	D	T	D	T
E_2	3	30.8	83.9	16.1	83.7	16.3	86.7	13.3	24.4	19.2
B	39	62.7	88.0	12.0	87.3	12.7	89.0	11.0	17.5	14.8
C(a)	12	47.3	84.5	15.5	82.8	17.2	84.8	15.2	17.3	14.3
D	9	37.5	84.5	15.5	81.2	18.8	85.5	14.5	16.8	12.3
E_1	9	39.2	85.3	14.7	80.2	19.8	83.1	16.9	18.3	14.8
Mean		53.7	86.8	13.2	85.1	14.9	87.3	12.7	17.6	14.7

D = *dura*; T = *tenera*

In Table 5 yield data were divided into yields produced by *dura* and by *tenera* palms. This Table also shows the average annual number of palms productive per hectare, their division into fruit types and the average bunch weight per fruit type.
The percentage of *dura* palms does not differ significantly. This is somewhat higher for the B grove subtype and consequently the percentage of number and weight of bunches produced by *dura* palms is somewhat higher at the same time.

Table 6 gives the number and weight of bunches per hectare and per stemmed palm, the average bunch weight and the percentage of palms bearing.

These yields were more or less similar to those for the period 1948–1951 (HARTLEY, 1954) with the exception of C(a)-grove plots in which the annual yield in the first period was 2,523 kg/ha. Between 1948–1951 and 1957–1962 the annual yield per stemmed palm in all but E_2-grove subtypes increased from 16–17 kg to 24–26 kg. The yield per stemmed E_2-palm over the first period is not given by HARTLEY (1954), but reached 58 kg in the second period.

HARTLEY (1954) subdivided the yields of a grove subtype into various density groupings in order to be able to compare the yield of similar density in different grove subtypes, thus eliminating the effect of density differences; but the information available relative to the data in Table 6 is insufficient to allow subdivision of yield on the basis employed by HARTLEY.

Table 6. Expt. 560-1. Yield of the five grove subtypes in Asutan Ekpe and percentage of palms bearing. Mean annual yield for the period 1957–1962

Grove subtype	Number of plots	Yield per hectare			Yield per stemmed palm		Percentage of stemmed palms bearing
		number of bunches	weight of bunches (kg)	mean bunch weight kg	number of bunches	weight of bunches (kg)	
E_2	3	136	2,961	21.3	2.7	58.1	74
B	39	178	2,942	16.5	1.5	25.4	52
C(a)	12	131	2,060	15.7	1.7	26.1	58
D	9	114	1,589	13.9	1.8	24.8	61
E_1	9	119	1,903	16.0	1.7	27.6	51

5.4.5 Sparse grove

A Sparse Palm Grove is a palm grove having a thin stand of palms which is maintained by 'natural' regeneration and felling when necessary. This grove type could therefore be termed 'disclimax' oil palm community. Examples of this subtype are the palm groves around Porto Novo in Dahomey, in which the density varies from about 40 to 90 palms per hectare. The palms are of all ages, stemless palms may grow up rapidly to take the place of palms which are felled or dead. For more than 50 years these groves have been farmed, two crops a year being taken at short fallow intervals. The arable crops are of primary importance and soil fertility is maintained by the application of compost. In one grove having a density of 40 palms per hectare, the annual yield of fruit bunches was estimated at 40 kg per palm, or 1,600 kg per hectare, and the yield in denser groves may well be higher. These groves at Porto Novo are described by BRASSEUR (1953) and CLERC, ADAM and TARDITS (1956).

5.4.6 Village grove

This grove type which was first mentioned by FAULKNER and MACKIE (1933), is found in the very densely populated areas of Eastern Nigeria and southern Dahomey (around Porto Novo), where the population density is more than 300 people per sq.km. In the Derived Savanna areas these groves are easily observed as green 'islands' in the grassland, but in districts in which Dense groves also occur they are less easily detected. This grove type is also a 'disclimax' oil palm community; regeneration is effected by planting, sometimes with stemless palms obtained from *tenera* seeds. GROVE (1951) described these village groves ('oil palm gardens') in Oku near Awka in Eastern Nigeria, where they are intensively farmed each year, and provide the people's main food supply. A certain level of soil fertility is maintained by applying household and plant refuse.

No precise data are available concerning these groves, but their bunch yield may be compared with that from compound palm groves at Asutan Ekpe (subtype E_2).

Plate 9. A village grove in the 'Bad Lands' near Awgu, Eastern Nigeria. Note the sharp boundary between the grove area and the grassland. The grove consists mainly of oil palms, but some coconut palms are also planted. See for instance the two tall palms at the left part of the grove. The grassland at the left is terraced. The 'stones' in the foreground will be used for building a house.

5.4.7 Peasant plantation

Peasant plantations arise from the planting of palms in farmland or on land which is suitable for farming. The planting is generally finished in one year, but may sometimes be extended over several years. Due to inadequate maintenance and absence of manuring with appropriate fertilizers the yield of these plots is generally rather low. One such farmer's plot at Akwete in Eastern Nigeria which was planted in 1929 and is well maintained, produced an average of about 2,800 kg of fruit bunches per hectare over the period 1959–1962. Bunch and fruit quality in such plantations depends on the origin of the planting material. Potassium deficiency is of widespread occurrence in Eastern Nigeria and other densely populated areas, in which palm plantations are often established on exhausted farmland. Applications of potassium fertilizer raised the yield of the Akwete plot by 60%. A single dressing of potassium fertilizer in 1948 to palms planted about 1930 in an area which has not been farmed since, more than doubled the yield of the palms over a period of at least 13 years.

The policy of the Ministries of Agriculture in Nigeria concerning the establishment of peasant palm plantations is discussed in section 11.7.

6 Yield

6.1 Factors influencing yield

6.1.1 Introduction

The main components of yield of a palm are the number of bunches and their average weight. The number of bunches which ripen is the final expression of complex reproductive processes of which the main components are discussed in section 6.1.5.

These production components themselves are subject to internal and environmental influences during the period between inflorescence initiation and maturity of the bunch. The environmental influences are of a climatic, edaphic and biotic character.

The level of soil fertility at the time the grove originated has an influence on the level at the present time, even after normal exploitation of the grove. This is discussed in section 6.1.10. Human activities, chiefly farming and wine tapping, greatly affect the yield of the palms. Effects attributable to farming are the reduction of the leaf area by pruning up to the 'spear', scorching by fire (see section 6.1.7), soil cultivation and the removal of plant nutrients in farm produce. Any reduction in assimilation depresses the number of female inflorescences, hence a reduction of the leaf area has an effect not only during the time – about 22 months – taken by the palm to produce a full crown again, but also for another period of about 25 months, during which the sex ratio of the inflorescences produced is low. The effect of tapping wine from standing palms on their fruit production is discussed in section 6.1.11.

6.1.2 Density

In 1949 the mean density of the palm stand in all the groves (Dense grove/Farmland with palms) on the substation at Abak covering about 61 hectares was 99 smooth-stemmed and 57 rough-stemmed palms, a total of 156 stemmed palms per hectare. The densest stands occurred in the Ikot Okpong grove where in two areas the density was 170 and 210 smooth-stemmed and 140 and 121 rough-stemmed palms respectively, which is more than twice the normal density of a plantation. In 1963 the average density in the B_1- and B_2(a)-plots of the Thinned groves at Asutan Ekpe (Expt. 560-1) was 89 smooth-stemmed and 62 rough-stemmed palms per hectare, but the average density of the whole area is, of course, much lower being 75 smooth-stemmed and 29 rough-stemmed palms per hectare. JEFFRIES (1927) recorded the palm population in the Dense groves around Ikot Ekpene in Nigeria as 133 palms per hectare. DUPIRE and BOUTILLIER (1958) recorded 180 to 200 palms per hectare in a grove at Grand-Drewin in Ivory Coast, while BAPOYO (1960) found 300 palms per hectare in groves east of Bangui in the Central African Republic. The density of the dense groves in the Kwango district in Congo is given as 'some hundreds' per hectare by DESNEUX and ROTS (1959) and 193 palms per hectare by HARTLEY (1958).

Other information on the densities of groves which appears in the literature is difficult to interpret because the stem type of the palms is not mentioned. For instance, WILLS (1962) mentioned that the densities of groves in Ahanta in Ghana reach 720 palms per hectare, but this figure must include seedlings and stemless palms.

The density of the stand in degrading groves is discussed in section 9.1.

The density of the stand is one of the main factors determining the yield of a grove and thus in obtaining the maximum yield the optimum density has to be calculated. The problem has been discussed in section 6.1.12.

The yields by number and weight of fruit bunches for some groves near Abak are given in Table 7. The mean yields per plot in the Ikot Okpong grove over 1949 to 1962 are given by ZEVEN (1965b: appendix II p. 3).

Table 7. Yield per hectare and per stemmed palm, percentage of stemmed palms bearing, actual and optimum density per hectare for five groves

Grove	Average yield per hectare			Average yield per stemmed palm		Percentage of palms bearing	Density per hectare		Years of observation
	number of bunches	weight of bunches (kg)	mean bunch weight (kg)	number of bunches	weight of bunches (kg)		actual	optimum	
501-1	220	2,839	12.9	1.6	20.6	54	136	343	1949–1962
502-1	237	2,484	10.5	1.8	18.7	58	133	188	1949–1961
502-2	336	4,947	14.7	1.9	28.2	63	175	–	1949–1959
503-1	279	2,956	10.6	1.3	13.7	54	215	356	1949–1956
505-1	284	3,060	10.8	1.1	12.0	61	254	173	1949–1952

6.1.3. Height

The average height of the bearing palms has an influence on the harvesting economy of a grove and the height is in turn influenced by such factors as density (SLY and CHAPAS, 1963) and average age of the grove, and by factors of a climatological and genetical nature (ZILLER, PRAQUIN and BRUNEL, 1955). The average height of the palms (to the base of the crown) in a part of the Ikot Okpong grove in 1961 and 1962 is:

	Rough-stemmed palms	Smooth-stemmed palms	All stemmed palms
Number of palms	46	238	284
Mean height in 1961 in m	4.6	15.2	13.5
Mean height in 1962 in m	5.6	15.5	13.9

The annual increase in height of the rough-stemmed palms is 1 m and for the smooth-stemmed palms 30 cm. The fast growth of the smaller rough-stemmed palms growing under the higher smooth-stemmed palms is shown below:

Height (m)	Rough-stemmed palms		Smooth-stemmed palms	
	number	height increase (m)	number	height increase (m)
0–5	26	1.20	1	0.69
5–10	19	0.96	10	0.36
10–15	–	–	84	0.30
15–20	1	0.26	136	0.27
20–22	–	–	7	0.18
Total/Mean	46	1.06	238	0.30

The rough-stemmed palms hardly produce fruit (see section 6.1.5). The very tall palms have a big respiratory load, which requires a great part of the absorbed light energy (REES, 1963b) and this affects their ability to produce fruit and hence the yield. No data were collected on the relationship of height and average age of palms in a grove, nor on the influence of climatic and differences in genetical composition. The relationship between yield and height is discussed below. The distribution by height group and stemtype for the palms in plot 33 of the Ikot Okpong grove is shown in Table 8.

Table 8. Expt. 501-1. Distribution by stem type and height group of palms of plot 33 (0.4 ha) of the Ikot Okpong grove

Height (m)	Rough-stemmed		Smooth-stemmed		Number of palms	Mean height (m)
	number of palms	mean height (m)	number of palms	mean height (m)		
0– 5	84	2.4	0	–	84	2.4
5–10	35	6.8	5	8.6	40	7.0
10–15	10	10.7	17	13.6	27	12.6
15–20	7	17.6	119	17.4	126	17.4
20–25	0	–	7	21.4	7	21.4
0–25	136	5.0	148	16.8	284	11.2

All the rough-stemmed palms were smaller than 20 m, the height of the tallest being 19 m. Smooth-stemmed palms exceeded 5 m in height and those of only 6 to 10 m were often moribund, being, in fact, of the same age as the taller palms. Only seven palms exceeded a height of 20 m. In the Uruk Obong grove only 7.3% of the palms were taller than 18 m, and the only two palms of a height of 26 m were attacked by trunk rot (ZEVEN, 1965b).

Table 9 shows the relationship between yield per hectare, percentage of palms bearing, mean height of bearing palms and production per yielding palm, in five height groups. No distinction is made as to stem type of the palms. From this table it is evident that height group 15.1 to 20.0 m is the most important. This group contains 45.3% of the palms, but produces 77.2% of the yield. Almost all these palms are bearing and it may be assumed that under grove conditions height from 15.1 to 20.0 m is the optimum height. When exceeding 20 m the palms become senescent and trunk rot takes its toll. When still in production, the yield decreases, but nevertheless these palms produce more than smaller ones. Although the mean bunch weight generally increases with height, the palms of the 0–5 m group produced bunches of a higher average weight than the palms in the next height group. This phenomenon is not understood, but it should be borne in mind that the yield came from only four palms. Above 10 m the average number of bunches produced by the producing palms remains about the same *viz.* 1.25 bunches per year, the yield differs owing to differences in mean bunch weight. The average height of the stemmed palms is 16 m.

From similar investigations in the Uruk Obong grove it was found that the height group 12 to 18 m is the most important *viz.* 65.7% of the yield is produced by 37.6% of these stemmed palms. In this grove, however, there was a greater portion of less tall palms that yielded better than the same category of Expt. 501-1, *viz.* 20.7% of its yield came from palms smaller than 12 m, whereas for Expt. 501-1 the palms smaller than 10 m produced only 1.3% and the smaller than 15 m only 20.0% of the total yield (ZEVEN, in the press).

Height and change of stem type. From observations made in the Uruk Obong grove (Expt. 503-2) the average height at which a rough-stemmed palm sheds its leaf bases and develops into a smooth-stemmed palm was calculated:

Group	Number of palms shedding	Mean height (m)
A	29	8.6
B	17	7.9
C	25	7.2
Total/Mean	71	7.9

The average height at which a rough-stemmed palm grows into a smooth-stemmed palm is about 8 m.

Table 9. Expt. 501-1. Yield per producing palm and per hectare, and percentage of palms bearing per height group. Data obtained from plots 33 and 34 (0.81 ha) of the Ikot Okpong grove. Yield averaged over 1960–1962

Height (m)	Number of palms per hectare			Mean height of bearing palm (m)	Yield per year per hectare				Mean bunch weight (kg)	Yield per producing palm	
	total	producing	% producing of total		bunches		weight of bunches			number of bunches	weight of bunches
					number	% of total	kg	% of total			
0– 5.0	58	4	6.9	3.8	1.2	0.5	11.4	0.3	9.5	0.25	2.3
5.1–10.0	47	9	19.1	8.4	6.2	2.4	33.3	1.0	5.4	0.6	3.4
10.1–15.0	51	37	72.5	13.9	49.9	19.4	629.0	18.7	12.6	1.2	15.0
15.1–20.0	135	129	95.6	17.2	193.9	75.3	2,589.3	77.2	13.4	1.35	18.1
20.1–25.0	7	4	57.1	21.1	6.2	2.4	96.8	2.8	15.6	1.25	19.6
Mean/Total	298	183	61.4	16.6	257.4	100.0	3,359.8	100.0	13.0	1.3	16.4

Table 10. Expt. 503-2. Age, grove type, density, R/S quotient and yield of the Uruk Obong grove

Roughly estimated age in 1960	Grove sub-type	Number of stemmed palms per hectare		R/S quotient		Yield per hectare[1]			Yield per palm[2]		Average height of the palms in 1960		
		1954	1960	1954	1960	number of bunches	weight of bunches (kg)	average bunch weight (kg)	number of bunches	weight of bunches (kg)	rough-stemmed (m)	smooth-stemmed (m)	mean (m)
(30)	B_1	274	277	0.8	0.65	341	3,652	10.7	1.2	13.3	2.9	13.1	9.1
40	B_2	326	316	1.2	0.8	282	2,892	10.2	0.9	8.9	3.7	13.5	9.2
50	B_2	205	190	1.0	0.8	282	2,746	9.7	1.4	13.4	3.2	11.8	8.4
60	B_2	242	230	0.45	0.2	383	5,045	13.2	1.6	20.8	2.9	12.3	10.5
70	C	215	193	0.4	0.3	262	3,206	12.2	1.2	14.9	3.1	13.0	10.8
80	C	198	173	0.3	0.25	272	2,807	10.3	1.4	14.2	5.8	13.8	12.6
90	D	59	57	0.0	0.0	94	979	10.4	1.6	16.6	–	14.3	14.3

[1] Average annual yield over 1949–1956
[2] This mean yield divided by density in 1954

6.1.4. Age of palm grove plots

The investigations into the age of some plots in the Uruk Obong Palm Grove (Expt. 503-1) have made it possible to relate age with density, R/S quotient, yield per hectare and per palm. On p. 49 the way of estimating the age has been described. The R/S quotient *i.e.* the ratio between the number of rough-stemmed palms and smooth-stemmed palms is introduced in order to obtain information on the relative ages of parts of the grove. As a grove gets older the number of rough-stemmed palms decreases whereas the number of smooth-stemmed palms increases, remains the same or decreases. For example the part of the Uruk Obong grove which was in 1960 about 70 years old had, in 1954, 71 rough-stemmed and 144 smooth-stemmed palms per hectare, and in 1960, 44 and 149 palms respectively. The R/S quotient changed from 0.5 to 0.3 indicating an increase in age. The R/S quotient is of no value at low densities, because under these conditions a single palm can exert too great an influence on the quotient. The data in Table 10 show the decrease of the R/S quotient not only between two times, but also when comparing the young part of the grove with the other, older part. The low R/S quotient of the part of the grove which is 30 years old may be due to the presence of some smooth-stemmed palms which had already grown up in the compound before it was deserted. That this may be the case might be also inferred from the average height of the smooth-stemmed palms. Unfortunately it is impossible to disentangle the various influences on the yield as the data concern plots with different and unknown initial densities; for instance the fifty-year-old B_2-plots have a much lower density than the forty- and sixty-year-old plots of the same grove subtype. The initial stand was quite probably lower which would have its effect on the yield per hectare and per palm, height of the palm, average bunch weight and density. The decrease in density with age is evident, and so is the decrease of the R/S quotient and the increase in the height of the average palm.

6.1.5. Production of leaves and inflorescences

The oil palm produces female and male inflorescences in alternate cycles. Plantation palms produce occasionally hermaphrodite inflorescences at the changeover of the cycle, but grove palms rarely do so. The maximum potential number of inflorescences is equal to the number of leaves produced, but is seldom attained owing to floral abortion. The sex ratio is defined by BROEKMANS (1957) as the ratio between female plus hermaphrodite inflorescences and the total number of inflorescences. However, the common meaning of sex ratio is the ratio between female and male inflorescences. It is genetically determined, but may be strongly modified by external influences. The sex ratio can only be observed in practice at the time of anthesis, but this is not the true sex ratio *i.e.* the ratio at the time of initiation of the inflorescences; however BROEKMANS supposed that the abortion of inflorescences before anthesis occurs irrespective of their sex.

BROEKMANS (1957), SPARNAAIJ (1960) and others have investigated the relationship between the sex ratio and one or more external factors, with the object of attempting to raise the yield by improving the environment or of forecasting yield. Sunshine, rainfall, mineral nutrition, temperature, mutilation, grafting and application of chemicals or hormones may influence the leaf production, floral abortion and sex ratio of a plant, and a fungal infection can sometimes lead to changes in the sex ratio (BAKER, 1957). For the oil palm, studies carried out to date have mainly considered the first three factors, but HEMPTINNE and FERWERDA (1961) have included the factor temperature. Grafting and probably mutilation are not relevant to the oil palm, but chemicals or hormones might be used in future.

As part of the study of the palm groves it was thought desirable to examine the leaf and inflorescence production of grove palms despite the fact that it would be difficult to interpret the information obtained. Three parts of the Ikot Okpong palm grove (Expt. 501-1, plots 33 and 34, plot 58 and a plot outside the experimental area, referred to as plot 106) were studied. Plot 58 had to be abandoned because the area was used for another purpose. Plots 33 and 34 which are described in section 6.1.10, were chosen for their high density. Plot 106 is a young B_I-subtype grove, with many developing rough-stemmed and several poorly developed smooth-stemmed palms. There were only two tall smooth-stemmed palms.

The first and only previous study of the growth and flowering of grove palms was carried out by MASON and LEWIN (1925), who investigated 77 palms near Ibadan for eighteen months. The present study covered three years because it could not be extended over a longer period; the annual figures have therefore been averaged. Several palms were not included in the survey as they were too dangerous to climb. The number of smooth-stemmed palms studied had to be limited to reduce the risk to the climbers of ascending from the climbing ropes into the crown and back again. When comparing the results with those given by BROEKMANS (1957) and SPARNAAIJ (1960) it should be borne in mind that they were dealing with comparatively young plantation palms, *viz.* up to 25–30 years, whereas the grove of plots 33 and 34 was about 60 to 70 year old, and that of plot 106, 30 year old.

The annual leaf production for palms of both stem types and stemless palms in relation to the exposure of the crowns to sunlight is given in Table 11. The exposure was estimated by eye.

It appears that a smooth-stemmed palm produces about 15 to 16 leaves per annum provided the crown receives direct sunlight. This does not agree with the results of BROEKMANS (1957) and SPARNAAIJ (1960) who considered that after the age of eight years the annual leaf production reached a constant level of 22 to 24 leaves. Either the annual production of leaves decreases to a level of 15 to 16 leaves at an age of 60 to 70 years or the external conditions reduce the rate of growth of the grove palms or both. The palms growing in the shade produced ten leaves per annum. Similar data of palms either planted in cleared plots or in thinned groves are given in Table 29, but a comparison between these rough-stemmed grove palms which resemble more or less plantation palms as far as appearance and height are concerned would be difficult,

Table 11. Expt. 501-1. Mean annual number of leaves, female, male and hermaphrodite inflorescences, floral abortion and sex ratio at time of flowering per palm. Average of 1961 to 1963

Plot	Approximate crown exposure	Number of palms	Number of leaves	Number of female and hermaphrodite inflorescences	Number of male inflorescences	Floral abortion (%)	Percentage of female and hermaphrodite inflorescences
SMOOTH-STEMMED PALMS							
33 + 34	4/4	7.3	15.3	5.2	7.0	21	43.6
33 + 34	3/4	12.0	15.3	5.5	7.6	14	46.2
33 + 34	2/4	4.0	16.0	5.6	7.7	17	42.1
33 + 34	0/4	6.0	10.1	0.3	0.7	81	33.3
106	4/4	2.0	15.8	6.8	7.2	11	46.6
106	0/4	17.0	10.4	0.0	0.0	100	–
ROUGH-STEMMED PALMS							
33 + 34	4/4	15.3	16.2	5.2	8.5	16	38.0
33 + 34	3/4	2.0	15.7	3.8	3.5	53	52.3
33 + 34	1/4	3.7	14.8	3.2	3.6	52	46.7
33 + 34	0/4	4.7	11.0	0.0	0.0	100	–
106	4/4	18.0	19.0	4.1	7.3	45	35.1
106	2/4	23.0	17.6	3.4	5.4	50	38.5
106	0/4	7.0	10.4	0.1	0.3	96	25.0
STEMLESS PALMS							
33 + 34	0/4	33.0	8.5	0.0	0.0	100	–
106	4/4	5.0	8.7	0.0	0.0	100	–
106	2/4	4.0	11.2	0.0	0.0	100	–
106	0/4	23.0	6.6	0.0	0.0	100	–

Key: 4/4 = full sunlight; 3/4, 2/4, 1/4 part of the crown directly exposed to sunlight; 0/4 = no direct sunlight

because the planted palms are well maintained. Rough-stemmed grove palms receiving direct sunlight for at least part of the day on a section of the crown produced 15 to 19 leaves per annum. The higher leaf production of the rough-stemmed palms in plot 106 is probably a result of their average age which may be lower than that of the palms in plots 33 and 34, and of better growing conditions (lower density and probably more fertile soil in this young B_1-subtype grove). As the completely shaded smooth-stemmed palms the completely shaded rough-stemmed palms produced only 10 to 11 leaves per annum. For stemless palms the annual production of leaves was less than 12 per plant.

From the mean annual leaf production figures (table 11) and the average number of green leaves per rough- and smooth-stemmed palm (table 14) the average leaf age *i.e.* the period between central spear stage and withering of the leaf could be calculated and was 20.7 months for rough-stemmed and 21.7 months for smooth-stemmed palms. From an adjoining part of the Ikot Okpong Palm Grove II the average number of green leaves per palm was determined in the same way as it was done for the area at present known as Expt. 508-1 (see Table 14). These numbers were 31.7 for rough-stemmed and 32.8 for smooth-stemmed palms (figures based on 15 rough-stemmed and

28 smooth-stemmed palms) with crowns receiving direct sunlight for part of the day at least. Applying the similar figures from Table 11 to annual leaf production the average leaf age is 22.4 months for rough-stemmed and 25.6 for smooth-stemmed palms. The corresponding leaf age of a mature plantation palm was estimated from Nigerian data (SPARNAAIJ, 1960) to be about 18 months. These data suggest a positive correlation between leaf age and palm age. It is suggested that it is a result of a retardation in the development of the palm with age. The above observation is further supported by the fast development *i.e.* the rapid ageing of leaves of nursery palms which only live a few months. It corresponds with the results found by PREVOT and BACHY (1962) and SMILDE and LEYRITZ (1965), *viz.* that the 17th leaf on a young palm is physiologically older than the corresponding leaf on an old palm (see section 6.1.6).

The difference in the pattern of leaf production of grove and plantation palms is shown in Table 12 for the percentage of the annual production of leaves which occurs in each two-monthly period.

Table 12. Leaf production of plantation and grove palms expressed as a percentage of the annual production of leaves per bi-monthly periods

	Jan.– Febr.	Mar.– April	May– June	July– Aug.	Sept.– Oct.	Nov.– Dec.
Plantation palms:						
Expt. 2-1 for 1948 (BROEKMANS, 1957)	14.3	17.3	18.5	16.5	16.5	16.5
Grove palms:						
Expt. 501-1, S.S. palms	18.4	16.7	15.7	15.3	15.3	18.4
Expt. 501-1, R.S. palms	18.7	16.6	16.5	16.5	15.3	16.6

Key: S.S. = Smooth-stemmed palm; R.S. = Rough-stemmed palm

BROEKMANS found that in Nigeria maximum leaf production in plantation palms occurs in April-May, but for smooth-stemmed grove palms this maximum occurs in November-December and January-February. Conversely the minimum leaf production of plantation palms occurs in January-February and for smooth-stemmed grove palms in July-August and September-October.

Shift in peak yield season. From the above it is observed that leaves of young palms mature quicker than leaves of old palms. Furthermore, BROEKMANS' (1957) statements that the peak in bunch production in mature plantation is mostly formed around July to August, that the peak in bunch number for young plantation palms may be earlier in the year, and that the peak in female flowering of young plantation palms is earlier than that of mature plantation palms, also suggest a quicker development of leaves and inflorescences of young palms in comparison with older palms. Although many authors (vide review by SPARNAAIJ *et al.*, 1963) have dealt with the relationship between annual weather conditions and annual yield variations, none (except BROEKMANS' short statement) have brought the age of the palm into account. This is unfortunate as differences in age of the palms might well have caused the differences in time between a certain weather condition and a peak in yield.

The peak in yield of plantation palms is caused by two factors. The first is the relation between (parts of) the Dry Season and the increase of the proportion of the inflorescences which are at the stage of sex differentiation to become female. This results in an increase of the yield about 30 months later (BROEKMANS, 1957). The second factor is the Dry Season about six month before the peak, as in this period the development of immature bunches is retarded. These bunches become ripe at about the same time as bunches which result from inflorescences which flowered a few weeks later. The development of the leaves of planted palms is also retarded during the Dry Season and this is shown by a number of folded leaves – 'spears' – and the flush in opening of these leaves after the onset of the rains (Table 12).

For smooth-stemmed grove palms occurs the flush in opening of the leaves in November-February, which is the Dry Season. The cause of this peak is not understood, but it seems that lack of water does not play a role. It is possible that the greater stem and root volumes form a buffer against water deficiency in the palm, and that during the Dry Season sufficient assimilates are produced to allow for young leaves to grow. However, the generally occurring constrictions in the upper stem of tall smooth-stemmed palms must originate in periods of poor growing conditions and the regular distances between them (about 40 to 50 cm) suggest an annual repetition of these periods. During such periods fewer leaves and consequently fewer inflorescences are initiated and this results in a low yield at a later time. A cause for a seasonal low yield also forms indirectly a seasonal peak in the yield.

Table 13 shows the relationship between the age of a plantation or a grove in Eastern Nigeria and the month(s) of the peak yield. So four-year-old palms produce their peak yield in April-May and five to eight-year-old palms three to seven months later *viz.* July-November.

Twentytwo-year-old palms have their peak yields in February which is ten months later and 45 year old palms in February-March, so 11 months later. Tall smooth-stemmed palms which almost produce the whole yield of a grove and which are about 70 years old, have their yield peak in March-April, eleven to twelve months later. This gradual increase of number of months suggests a shift of the season in which the peak yields fall to a later time. This is expressed in Figure 4. Refering to BROEKMAN's (1957) statement that bunches of very young plantation palms mature quicker than those of older plantation palms and applying the knowledge that with age the speed of development of the leaves slows down it is suggested that the speed of the development of the bunches is also retarded with the increase of the age of the palms until an age of 40 to 50 years has been reached after which the speed of development remains about the same. As long as the factors causing an annual peak in the yield of old palms are not determined it is impossible to conclude in which season or seasons peaks in the yield originate(s).

Table 13. Age of palms of some plantations and groves in Eastern Nigeria and their period of peak yield. This table also gives the length of time between initiation of a female inflorescence and ripening of the resulting bunch

Experiment	Site	Age[1] of palms at time of observation	Months of peak yield	Number of months after the time of the peak yield of a four-year-old plantation (April)
Plantation:				
507-1/2/4	Abak	4	April	–
506-5/6	Abak	4	April–May	0–1
505-2 (planted palms only)	Abak	5	July–August	3–4
506-2	Abak	8	July–November	3–7
506-1	Abak	8	July–August	3–4
651-1	Akwete	22	February	10
550-1	Calabar	ca. 45	Febr.–March	10–11
Grove:				
501-1, 502-1, 502-2, 503-2, 504-1, 505-2 (grove palms only)	Abak	ca. 70	March–April	11–12

[1] For plantation palms the age is the number of years since planting, for grove palms the age is since abandoning of the compound

Height and leaf production. The area now used for a planted palm fertilizer experiment (Expt. 508-1) used to be a part of the Ikot Okpong Palm Grove II (Expt. 504-1). When clearing this area (24.7 ha) 96 rough-stemmed and 253 smooth-stemmed palms were felled. The density of this area (14.1 stemmed palms/ha) was so low that almost all palms received direct sunshine at least for a part of the day. The number of green leaves of these felled palms were counted and the height of the palms measured. The average number of leaves per palm, per stem type and per height group are shown in Table 14.

The average number of green leaves of all palms per height group or stem type is remarkably identical, with the exception of the palm of 25.6 m high. This palm was probably senescent and would have died fairly soon. The low number of green leaves for the smooth-stemmed palms of 0 to 6.0 m points to the poor quality of these palms. They are still under 6 m whereas other palms of the same age are much taller. These palms are slow in development probably owing to a genetic cause. Anyhow, they number only 2% of the total number of stemmed palms.

Floral abortion. In a mature plantation floral abortion *i.e.* abortion of the entire inflorescence prior to flowering is considered to be an important yield limiting factor. It amounts to five to ten per cent of all inflorescences (SPARNAAIJ, 1960), but is much

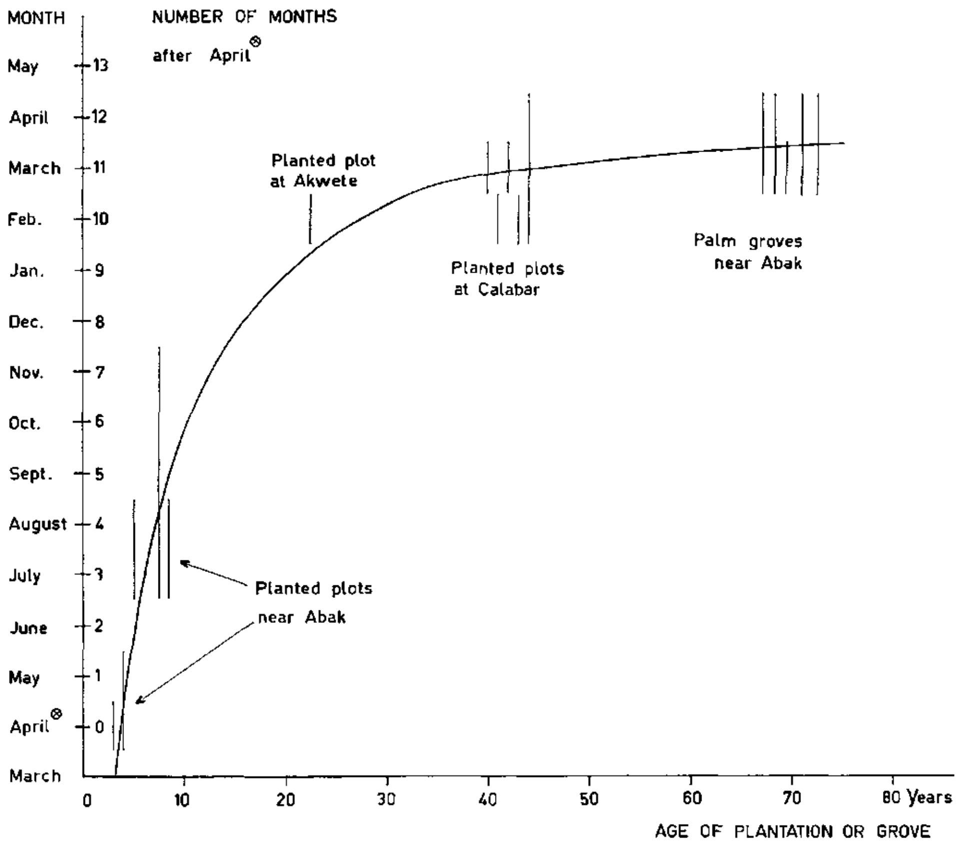

Figure 4. The relationship between the (mean) age of a palm grove or plantation and the month(s) of peak yield

Table 14. Expt. 504-1. Number of green leaves per palm, per stem type and per height of palms in the Ikot Okpong grove II

Height (m)	Rough-stemmed		Smooth-stemmed		Total	
	number of palms	mean number of green leaves per palm	number of palms	mean number of green leaves per palm	number of palms	mean number of green leaves per palm
0– 6.0	82	28.8	7	20.7	89	28.2
6.1–12.0	14	32.9	73	27.4	87	28.3
12.1–18.0	–	–	140	28.8	140	28.8
18.1–24.0	–	–	32	28.7	32	28.7
25.6	–	–	1	23.0	1	23.0
Total/Mean	96	29.4	253	28.1	349	28.5

higher when the palms grow under old palms, as is shown in Table 11. This table indicates clearly that the floral abortion increases with the number of remaining old palms. The floral abortion for grove palms fully exposed to sunlight is found to be much higher than for planted palms, and may even approximate 100% when the palms are fully shaded. A low nutrient level may also cause the floral abortion to increase, as was found by BROESHART, FERWERDA and KOVACHICH (1957). These authors observed that the floral abortion of palms grown in soil lacking either nitrogen, phosphorus or magnesium was significantly increased and reached 100% in the case that the first-mentioned element was lacking.

In the case of smooth-stemmed palms exposed to full or partial sunlight the author found that the highest percentage of abortion occurred in July-August (38%) and the lowest in November-February (6–9%); thus the lowest rate of abortion coincided with the highest production of leaves. And it appears that the Dry Season is the optimal period for the smooth-stemmed palms. For rough-stemmed palms in sunlight the corresponding extremes occurred in May-June (45%) and January-February (27%).

Ratio of female inflorescences. During the work it was found that grove palms hardly produce hermaphrodite inflorescences, so the inflorescences recorded are either female or male.

The average ratios of female inflorescences of the grove palms (Table 11) are higher than those given by BROEKMANS (1957) and SPARNAAIJ (1960) for mature plantation palms. SPARNAAIJ suggested that with increasing age of the palms the ratio of female inflorescences will decrease accordingly, but this is not supported by Broekman's data for palms older than the years or by the data for the grove palms. The seasonal trend of the ratio of female inflorescences of all the rough-stemmed palms follows that of the plantation palms, but the peak falls in November-February and not in February-March. The seasonal fluctuation for all the smooth-stemmed palms appears to follow a cycle of four months. This is shown in Table 15, which gives ratios of female inflorescences for the rough- and smooth-stemmed palms of plots 33 and 34 in the Ikot Okpong grove.

Table 15. Expt. 501-1, plots 33 and 34. The average bi-monthly ratio of female inflorescences in per cents

Stem type	Jan.–Febr.	Mar.–April	May–June	July–August	Sept.–Oct.	Nov.–Dec.
Rough-stemmed	47	40	38	35	33	54
Smooth-stemmed	47	30	44	31	46	39

Bunch failure. Bunch failure *i.e.* the premature rotting of bunches is high for grove palms. This can be seen from Table 11 which shows that smooth-stemmed palms receiving direct sunlight produce five to six female inflorescences which reach the stage of anthesis and from the average bunch production which is one or fewer bunches per palm, indicating a bunch failure of more than 80%. In most cases this failure rate is 100% for rough-stemmed palms.

6.1.6 Nutrient status of leaves

The nutrient status of leaves of grove palms was studied to obtain information on this status and to be able to compare it with that of plantation palms. Sampling procedures have not been investigated, because the author was not competent to do so. In Nigeria the 17th leaf of plantation palms is sampled. For fear of the possibility that not all palms would carry a healthy 17th leaf the ninth leaf, immediately situated under the 17th leaf, was chosen. Leaflet samples were taken of rather more than 10% of the smooth-stemmed palms growing in each plot (0.4 ha) of the strip which had also been soil sampled, of the Ikot Okpong grove (see section 6.1.10). The chemical analyses were carried out by the staff of WAIFOR's Plant Nutrition Division. The results of the analyses shown in Table 17 are presented to give the reader an idea of the nutrient status of sixty- to seventy-year-old grove palms. It is rather difficult to interpret the data as nothing is known about the optimum level of the major elements in the ninth leaf of such old palms. Leaves of the same order do not necessarily have the same physiological age, due to differences in age of the palms, in rate of leaf production and in climatological conditions. Ageing of a leaf means, physiologically speaking, a continuing decrease in nitrogen, phosphorus and potassium and an increase of calcium content. As this process occurs more rapidly in young than in old palms a certain leaf on a young palm is physiologically older than the corresponding one on an old palm (Scheidecker and Prevot, 1954; Smilde and Chapas, 1963; Smilde and Leyritz, 1965). The data for the grove palms should be seen in this light.

The higher levels for phosphorus of the leaves of the palms of plots 26 and 27 as regards those of other plots may be attributed to a high phosphorus level in the soil of these plots which were occupied by a village up to 1930. But the phosphorus content of the soil was not determined. A positive relationship between Mg(soil) and Mg(leaf) was established, which corresponds to observations on planted palms (Prevot and Ziller, 1958).

Prevot and Ollagnier (1958) stated that the sum of the leaf contents of potassium, calcium and magnesium is constant. Our data show that the sum of these elements per sample varied from 1.73 to 2.13% and that the points for each group of three elements when plotted on isometric paper fit well within the limits given by Prevot and Ollagnier (1958).

Leaf nutrient status of other groves. Rancoule and Ollagnier (1952) and Prevot (1955) dealt with the leaf nutrient status of grove palms in southern Dahomey and southern Ivory Coast. They believed that the potassium levels of the leaves were in all cases low, as were the levels for nitrogen. The levels for phosphorus, calcium and magnesium were in most cases high. Application of potassium fertilizer resulted in increased yield per palm and although no data are given it is probable that the potassium level in the leaves also increased. This was found to occur when planted palms growing on the same soils were similarly manured.

6.1.7 Reduction of leaf area

The leaf area is reduced by pruning and scorching of the leaves, often in such a way only 'spears' are left. Leaves are used for thatch, for the protection of walls (notably in the area east of Onitsha), as a source of fibre and for decorative purposes. Leaves are also pruned to let in more light for crops planted under the palms, and the remaining leaves may be damaged by fire, the extent of the damage depending on the amount of trash being burnt, the height of the palm and the cleanliness of the crown.

The depressive effect of pruning on yield is shown by BLOMMENDAAL (1937) and GUNN and SLY (1959). Besides this direct effect on yield, the reduction of leaf area also lowers the ratio of the inflorescences becoming female during the period of low leaf area. Thus the effect of pruning or burning lasts considerably longer than the time taken to restore a full leaf canopy which is about 22 months for smooth-stemmed palms. This is illustrated by our observations made in a district where the land is farmed on a five year cycle.

Stage	Month	Crown	Ratio of female inflorescences at their stage of sex differentiation	Yield
Ia	0	BEGINNING OF CYCLE I Pruning of all leaves, scorching of spears	–	–
Ib	0–22	Number of leaves increasing from 0 to 33 (full crown)	First low, later increasing to normal level	First low due to lack of assimilates, later increasing
Ic	22–35	Normal crown	Normal	Normal
Id	35–60	Normal crown	Normal	First low due to low ratio of stage Ib, later increasing to almost normal
IIa	60	BEGINNING OF CYCLE II		
Id(cont.)	60–67	Number of leaves from 0 to 10 (stage IIb)	Low (stage IIb)	Low (stage IIb)
Ie	67	END OF CYCLE I		

N.B. The number of months or leaves are approximately determined.

Plate 10. An area prepared for farming near Abak, Eastern Nigeria. The bush cover was cut and the leaves of small palms pruned. After drying the rubbish was burnt scorching the remaining green leaves of the small palms, and often also leaves of tall palms.

So the effect of pruning lasts about 67 months, of which the last seven months (stage Id (cont.)) fall into cycle II. The yield only is at a normal level during about 13 of the 60 months.

6.1.8 Frequency of fruit and leaf types in Dense and Thinned groves

In the Abak and Asutan Ekpe palm groves 99 to 100% of the palms is of the *nigrescens* type, *virescens* palms accounting for the remainder. The highest concentration of *virescens* palms occurs on some old compound sites, which were formerly used for ceremonial purposes. The same high frequency of *nigrescens* palms is found in other groves. The *albescens* fruit type is generally very rare and was not found in the Abak and Asutan Ekpe palm groves, although a few palms produce fruits with a pale yellowish coloured oil. In 1950 only one palm which produced fruit with the 'mantled' *(poissoni)* character was found among the 3,500 fruiting palms. This type was not

Table 16. Frequencies of fruit types of seven palm groves near Abak

Palm grove	*dura* (%)	*tenera* (%)	*pisifera* (%)	*virescens* (%)	Years of determination
501-1	88.8	11.1	0.066	0.1	1960–1962
502-1	91.7	8.3		0.9	1960–1962
502-2	93.6	6.4	–	1.0	1949–1950
502-4	89.7	10.3	–	0	1949–1950
503-1	92.2	7.8	–	0.5	1949–1950
504-1	87.5	12.5	–	0	1949–1950
505-1	85.3	14.7	–	0	1960–1962

found in others groves on the substation, but in the Asutan Ekpe area it occurs with a frequency of 0.05%. The frequencies of the various fruit types are shown in Table 16. No palms with the *idolatrica* leaf character were found in the Abak and Asutan Ekpe groves, but in the groves of southern Dahomey and Togo, where this form probably originated (ZEVEN, 1964a), the frequency may reach 0.1% (CHEVALIER, 1910).

In section 5.4.4 it has been explained that in the groves in the Asutan Ekpe area *tenera* palms yield less – expressed in bunch weight – than *dura* palms. *Pisifera* palms have hardly any production, so where groves are found with a high *tenera* and *pisifera* palm frequency (*e.g.* the Ufuma grove, see section 4.3.3) a lower bunch yield might be obtained than from groves with a low frequency. Similarly groves with a high frequency of either 'mantled' palms or *idolatrica* palms might produce less than groves with a low frequency of this fruit or leaf type, because of the predisposition of the 'mantled' palm to bunch rot and the low yield of the *idolatrica* palm (see section 4.4).

6.1.9 Bunch and fruit composition

The average composition of fruit bunches may vary from district to district due to genetical and ecological factors which are sometimes intentionally or accidentally influenced by man. It is, however, difficult in random sampling of bunches from grove palms to separate the genetical from the ecological factors affecting bunch composition. In 22 of 26 lots of data for fruit to bunch ratio found in the literature the figure quoted fell between 55 and 67%, but the figures given for Nigeria (probably Eastern Nigeria) by FARQUHAR (1913) and BILLOWS and BECKWITH (1913), are higher (about 70%) despite the fact that the fruit composition suggests the *tenera* type in which a lower fruit to bunch ratio might be expected.

The fruit and bunch composition of the produce from the Ikot Okpong grove was determined over a period of two years. The average fruit to bunch ratio was 69.3% and mesocarp to bunch ratio 31.4%. With the facilities available the proportion of oil to mesocarp could not be measured. It was assumed to be 50%, giving an oil to bunch ratio of 15.7%. The kernel to bunch ratio was 9.7%. The potential monthly yield of oil and kernels per hectare for this grove is shown in Table 21. It is interesting to compare the average ratios in the Ikot Okpong grove with those found near Benin (Expt. 18-1) and at Acharu in Igala Division (LOMAX, 1962):

	Abak	Benin	Acharu*
Percentage fruit to bunch	69.3	58.5	60
Percentage mesocarp to fruit	45	42	45
Percentage kernel to fruit	14	14	14
Percentage shell-and-water-loss to fruit	41	44	41

* At Acharu only one sample was analysed.

The fruit composition in the three areas does not differ very much, but it is the fruit to bunch ratio that varies. Although these variations might have been caused by genotypic differences, it is likely that they have been influenced by environmental factors. The low ratios are obtained from Acharu and Benin which have a drier climate than Abak.

6.1.10 Soils

The main area of the Nigerian oil palm belt lies on deep sandy latosols called 'Acid Sands', the geology, physical and chemical properties of which have been described by VINE (1956) and TINKER and ZIBOH (1959). The latter gave an account of the soils supporting planted oil palms.

VINE divided the 'Acid Sands' into the 'Benin Fasc' and 'Calabar Fasc', largely on the basis of colour, the 'Benin Fasc' soils being reddish and the 'Calaber Fasc' soils being yellow to yellowish brown. The soils in the Anang and Uyo Provinces belong to the 'Calabar Fasc'. VINE also described some soil samples taken from the Ikot Okpong, Uruk Obong, Obio Akpa and Asutan Ekpe Palm Groves. These samples were taken from pits and not by general sampling and this may account for inconsistencies such as the top soil in pit 1 in the Ikot Okpong grove having a pH* of 4.8 whereas the pH of the subsoil (at 150 cm depth) was 5.4.

The pH of the soil in the top 10 cm of VINE's pit samples around Abak varied between 4.5 and 5.5, the level of exchangeable potassium (K) from 0.06 to 0.13 m.e./100 g soil, and the nitrogen from 0.05 to 0.10%. It is remarkable that the two samples taken at Asutan Ekpe, one from farmland and the other from a grove, both show a high potassium level. Potassium is generally markedly deficient in the soils of Eastern Nigeria, but the only commonly occurring deficiency symptoms observed in grove palms are those associated with an inadequate supply of magnesium. Sometimes a group of palms show these symptoms, which may indicate that the Mg/K ratio in the soil of a small area is low. Single palms also may show symptoms of magnesium deficiency,

* In this work pH stands for pH – H_2O.

but this may be attributable to some metabolic disorder.

In August, at the height of the Wet Season, the palms between Ikot Okpong and Umuahia often exhibit the 'Orange Frond' condition, while the palms near Calabar show these symptoms throughout the year.

The soils of the groves at Abak are very sandy, and the top 10 cm has a pH of about 4.5 to 5.0, exchangeable potassium from 0.05 to 0.17 m.e./100 g soil, and total nitrogen from 0.05 to 0.15%. HARTLEY (1954) mentioned that one special part of the Ikot Okpong grove gave unusually high yields and attributed this to high soil fertility. In a soil sample from this area the exchangeable potassium was 0.13 m.e./100 g soil, whereas in the soil from two pits in neighbouring areas it was between 0.06 and 0.08 m.e./100 g. It seems, therefore, that HARTLEY was right and that the high yield may be attributed to the high potassium status of the soil since no other marked differences between the samples were apparent.

Own investigations. Cultivation of the soil creates favourable conditions for palm seeds to germinate and seedlings to grow, but also involves the cutting of many surface roots of existing palms. This has the beneficial effect of forcing the palms to produce new roots, but at the same time the damaged roots may afford access for fungi. Burning the trash when land is cleared, releases additional minerals and the palms may benefit from this temporary increase in soil fertility. Near compounds the soil fertility is more permanently increased and this results in a higher yield from palms growing there than from palms growing on exhausted farmland.

Where farming continues without a fallow period, soil fertility can be maintained with compost from which the palms may also benefit.

Ikot Okpong Palm Grove. The data presented in Table 17 show palm density, yield and chemical properties of the soil.

Each plot is 0.4 hectare in area and the yield is given per hectare. The density of stemmed palms per hectare and the assumed age of the plots are also given. The density depends on the original density of the stand and the number of years since the compound (plot) was abandoned. The fertility of the soil of a plot depends on its original level, time and human activities. A description of the plots follows.

Plots 26 and 27: Mixture of tall old palms and young short palms; this area was occupied by a village (Esa Ekpo) up to 1930, the old palms belong to the E_1-subtype, the young ones to B_1-subtype. Both plots are about 30 years old.

Plot 28: The southern part is as plot 27; the remaining area is of D-subtype, of incertain age.

Plot 29: D-subtype grove, about 85 years old.

Plot 30: D-subtype grove, (except for a small part which is a E_1/B_1-subtype), about 80 years old.

Plot 31: C-subtype grove, about 75 years old.

Plots 32, 33, 34, 35 and 36: B_2-subtype grove. The average age of the palms of plots 32, 33 and 34 is higher than in plots 35 and 36, *viz.* about 70, 65, 60, 55 and 50 years respectively.

Table 17. Expt. 501-1. Soil and leaf nutrient status of smooth-stemmed palms of the Ikot Okpong grove. Composite sample of top 15 cm layer

Plot	Number of stemmed palms/ha	Weight of fruit bunches (kg)	Soil nutrient status												Leaf nutrient status % dry weight					
			pH	m.e./100 g					%V	Mg/K	Mg+Ca/K	%C	%N	C/N						
				K	Mg	Ca	Na	C.E.C.							N	K	Mg	Ca	P	K+Mg+Ca
26	151	2,348	5.1	0.03	0.12	0.28	0.3	2.63	17.5	4.00	13.3	0.58	0.040	14.5	2.49	1.18	0.30	0.52	0.21	2.00
27	151	2,807	5.1	0.03	0.11	0.23	0.3	2.38	16.8	3.67	11.3	0.62	0.042	14.3	2.71	0.89	0.28	0.56	0.20	1.73
28	153	3,011	5.0	0.04	0.08	0.26	0.4	2.63	16.4	2.00	8.5	0.61	0.042	14.5	2.72	0.90	0.34	0.54	0.19	1.78
29	57	1,774	4.8	0.04	0.14	0.16	0.2	2.50	14.0	3.50	7.5	0.56	0.042	13.3	2.55	1.02	0.30	0.51	0.18	1.83
30	96	2,844	4.9	0.04	0.14	0.22	0.3	2.75	15.7	3.50	9.0	0.68	0.045	15.1	2.55	0.90	0.30	0.63	0.17	1.83
31	202	3,639	5.1	0.04	0.12	0.74	0.3	3.00	30.7	3.00	21.5	0.71	0.047	15.1	2.48	0.89	0.35	0.66	0.17	1.90
32	168	3,639	5.1	0.04	0.24	0.46	0.2	2.75	28.8	6.00	17.5	0.74	0.050	14.8	2.59	0.91	0.32	0.64	0.18	1.87
33	235	4,451	5.2	0.03	0.20	0.50	0.1	3.13	24.0	6.67	23.3	0.72	0.047	15.3	2.54	0.87	0.32	0.68	0.18	1.87
34	331	4,502	5.2	0.03	0.24	0.48	0.1	3.13	24.6	8.00	24.0	0.65	0.045	14.5	2.59	0.83	0.34	0.76	0.18	1.93
35	309	4,538	5.1	0.03	0.12	0.40	0.2	2.75	21.1	4.00	17.3	0.66	0.042	15.7	2.55	0.79	0.34	0.70	0.18	1.81
36	220	4,100	4.9	0.03	0.18	0.28	0.2	3.00	17.3	6.00	15.3	0.68	0.045	15.1	2.60	0.92	0.30	0.68	0.19	1.90
37	62	1,096	4.8	0.04	0.10	0.18	0.3	3.63	9.6	2.50	7.0	0.82	0.050	16.4	2.56	0.92	0.28	0.54	0.18	1.74
38	44	639	4.8	0.03	0.14	0.20	0.1	3.15	10.7	4.67	11.3	0.88	0.055	16.0	2.65	0.86	0.34	0.68	0.18	1.88
47	286	5,847	5.5	0.03	0.36	1.08	0.2	3.38	44.7	12.00	48.0	0.80	0.050	16.0	2.58	0.95	0.42	0.76	0.19	2.13

N.B. Plots 26 to 38 form a strip in this grove; plot 47 lies adjacent to plot 34

Plot 37: Situated on a slope with a thin stand at the upper end of the slope; of uncertain age.

Plot 38: Situated at the bottom of a slope, one part covered by a B_1-subtype grove of uncertain age.

Plot 47: This plot lies adjacent to plot 34 and is of the B_1-subtype, about 60 years of age and has been included because the yield from it is high for a dense grove.

Not much can be derived from Table 17 which is only presented to give the reader an idea of the soils which support the palm groves. Any influences of the soil properties on yield is blurred by the effect of the density on yield. The fact that VINE (1956) found a high level of exchangeable potassium in the high-yielding grove area (plot 47) could not be corroborated, this level may have lowered over the years. It is probable that an application of potassic fertilizer would have a marked effect on yield, probably greater than that obtained in Expt. 503-2 (see section 10.3).

TINKER and ZIBOH (1959) found that when the Mg/K ratio and the Mg + Ca/K ratio are lower than 2 to 2.5 and 8 to 9 respectively, planted palms would show symptoms of magnesium deficiency, but there is no evidence found in palms of this grove. Furthermore, FERWERDA (1961) indicated that as the Mg/K ratio markedly varies with the season it is unfit for use as an indicator of the nutrient status of these two elements. It is advisable to take the presented figures for these ratios with a grain of salt as small analysing errors may result in significant changes. Moreover, it could be that as palms grow older TINKER and ZIBOH's critical levels decrease.

No response to application of lime to oil palms has yet been obtained in West Africa. BULL's (1957) suggestion that natural selection has adapted the oil palm to growing on soils with a very low calcium content is difficult to prove.

Other palm groves. The soil of a grove (Expt. 504-1) situated near the Ikot Okpong grove was analysed at the time when the old palms were felled to allow the establishment of a fertilizer trial (Expt. 508-1). It was found that the levels of potassium, sodium, carbon and nitrogen were higher than in the soils of the Ikot Okpong grove *viz.* potassium, 0.06 m.e./100 g; sodium, 0.03 m.e./100 g; carbon, 0.76%; and nitrogen, 0.05%. The magnesium and calcium levels were similar to those in the Ikot Okpong grove. No symptoms of magnesium deficiency were apparent in the palms at the time they were felled. The C/N ratio was the same as in the Ikot Okpong grove. The groves in the area of Expt. 504-1 were of B-, C- and D-subtypes and had not been farmed for at least twelve years, which may account for the soil fertility being higher than in the neighbouring Ikot Okpong grove.

Bulk samples were taken from the two control plots of the Uruk Obong grove (Expt. 503-2) and this soil proved to be similar to that in the area of Experiment 504-1, except that the level of sodium was rather high and the C/N ratio low as is shown in Table 18.

The soil of the Uruk Enung grove (Expt. 502-1) is unusual in that many areas are covered with a layer of blackish soil. Its thickness varies from 25 to 50 cm, but on the boundaries of the black patches where the colour of the soil is greyish, it is much thinner, whereas where pits were filled it may reach 2 m. The black colour may be due

Table 18. Expt. 503-2 and 504-1. Soil nutrient status of the Uruk Obong grove and the Ikot Okpong grove II. Composite sample of top 15 cm layer

Sample	pH	m.e./100 g					% V	Mg/K	Mg+Ca/K	% C	% N	C/N
		K	Mg	Ca	Na	C.E.C.						
Expt. 503-1	5.4	0.06	–	0.52	0.12	4.8	–	–	–	0.65	0.048	13.5
Expt. 503-1	5.2	0.06	–	0.44	0.10	5.0	–	–	–	0.64	0.058	11.0
Expt. 504-1	–	0.08	0.22	0.54	0.03	6.4	13.6	2.75	9.5	1.02	0.07	14.6

to the presence of charcoal and black humic acids. These soils (called in Ibibio: *mbri*) are also found in other places and are ex-compound soils, but some special conditions must have existed to create them as not all ex-compound soils have this black colour. The importance of these soils is that they are rather fertile for arable crops of which many have their roots in this layer, and that they are believed to have an effect on the frequency of palms attacked by trunk rot (see section 8.2). A soil survey of the area was made, but the structure and texture of the soil are so uniform that only locations of this blackish soil and the thickness of the layer could be recorded. No relationship could be found between the occurrence of the patches of *mbri* soil, and the density or yield of the palms. VINE (1956) analysed one soil sample from this grove and found the potassium level to be high 0.09 m.e./100 g at 0–10 cm depth and 0.17 m.e./100 g at about 150 cm depth, but a completely black sample taken from a pit by the author had a potassium level of only 0.035 m.e./100 g, which is low.

Two samples taken from farmland and from a dense grove in Asutan Ekpe were analysed by VINE (1956). The pH was about the same as found in soils at Abak, but the levels for potassium and nitrogen at 0.12 and 0.14 m.e.K/100 g and 0.09 and 0.07 % N respectively were much higher. The difference between the farmland soil and the grove soil is only small, which is unusual. The high potassium levels may have contributed to the high yields occasionally obtained from the palms of some of the survey plots in this area.

Compound soils. Compound soils deserve specific discussion as they are the soils in which the various main grove types originate, and on which the village groves occur. The decline in soil fertility with increasing distance from a compound into the adjacent farmland, is sometimes clearly reflected in the appearance of the palms. An instance of this was seen in planted palms growing in a plot in the neighbourhood of Ikot Ekpene in Eastern Nigeria. The palms near the houses were three to four metres in height, with a stem girth at breast height of about 180 cm, whereas palms further away, planted on a slope, were only just over one metre in height, much smaller in girth and had tapering stems. The compound palms had large and dark green coloured crowns whereas the crowns of the planted palms in farmland were small and yellowish, which was obviously the result of magnesium deficiency. TINKER and ZIBOH (1959) give chemical analyses of similar soils at Achi also in Eastern Nigeria which were carrying planted palms exhibiting the same kind of differences in appearance as those described above. The compound soil was rich in all the main plant nutrients, while the soil of the farmland was rather poor. Unfortunately no yield data for these palms are available. It is difficult to separate the effect on yield of the varying soil fertility of the palm groves from the effects of other environmental factors, but the high bunch weight in the E_1-subtype grove can certainly be attributed to the fact that these palms grow on fertile compound soil. This explanation was suggested by FARQUHAR as early as 1913.

Groves outside Nigeria. The author has not been able to find any data about soils supporting grove oil palms in countries outside Nigeria, except some rather vague results given by LIVENS (1947) for the Kwango in Congo where healthy palms were growing on soils with a pH of 3.8. LIVENS tried to derive a positive relationship from the health status of the palms and the soil phosphorus level, but the total amount of exchangeable cations is also positively correlated with increasing health of the palms. The lack of description of soils carrying groves in French-speaking African countries arises from the fact that, in general, in these countries it is the leaves and not the soils that have been analysed to give information on the nutritional condition of the palms.

6.1.11 Palm wine tapping

Tapping palms for wine is common practice. In Africa south of the Sahara, the oil palm is most tapped, but where other palms are present these may also be tapped, for instance in West Africa: *Borassus aethiopum* MART., *Phoenix reclinata* JACQ. and several species belonging to the genus *Raphia* P. BEAUV. Before palm oil and kernels were in great demand, palm wine was the principal economic product of the palm. Early sixteenth and seventeenth century visitors to West Africa described the tapping process, its properties and the local palm wine trade.

In this present account, tapping for wine is only discussed in so far as it influences the fruit production of the oil palm.

The various methods of wine tapping are:

1. the palm remains standing:
   (a) the sap is derived directly from the stem by making a hole in it;
   (b) the sap is derived from the unbranched part of the stalk of an inflorescence; in the case of the male inflorescence by cutting the unbranched part of the stalks and in that of the female inflorescence by making a hole in that particular part of the stalk;
2. the palm is felled by cutting the stem or by digging out;
   in both cases a hole is then made in the apical tissue and sometimes a fire is lit at the foot of the stem to drive the sap out.

The last methods have a disastrous effect on the oil palm economy, and can only be justified when there is a relative abundance of oil palms or when lack of water makes the preparation of oil impossible. In the Tanga district of Congo, CHAMBON and LERUTZ (1954) estimated that 15 to 20 palms per family could be felled each year without diminishing the oil palm 'capital'. This figure seems very high. The advantage to the tapper of the felled palm method is that in a short period a great quantity of wine is obtained with a minimum of labour. When the other methods are employed the intensity of tapping determines the future fruit yield of the palm; when a high tapping intensity is applied, the palm ceases to fruit and when the intensity becomes too high it will die.

In 1917 a trial was started at Ibadan, Nigeria with the object of collecting data on the wine and fruit production of ten palms (FAULKNER, 1922). Interest centred in the wine production, and little information was published on the fruit production. In 1953 a pruning trial was started in a farmer's oil palm plot at Nsugbe, Nigeria (GUNN and SLY, 1959). One treatment involved tapping for wine, but the main aim was to obtain information on the yield of fruit from the palms under various pruning regimes which were employed by local farmers. The wine tapping treatment is accompanied by a severe pruning treatment, and thus the yield of fruit of the palms is strongly influenced by this combined treatment. TULEY (1965) estimated that tapping of every male inflorescence for wine production would decrease the yield of a plot of oil palms at Umudike, Nigeria from 600 to 250 kg of oil per annum.

No other data on the influence of wine tapping on the fruit production are available, but it is obvious that tapping a palm for wine should reduce its production of fruit. It would be valuable and, in fact, essential to obtain precise information on this subject.

In several countries in Africa the Governments have attempted to put an end to or, at least to reduce, tapping of palms for wine especially by the felling method. In the Cameroons the widespread felling of palms was ruining the oil palm economy of several districts in which it was estimated two or three palms per inhabitant were felled each month. A local law was enacted requiring that a licence be obtained for tapping and permitting the tapping of standing palms only. Similar measures were enacted in other countries including Dahomey, Togo, Nigeria, and the Kigoma district of Tanganyika (SHEPSTONE, 1951). In the case of the latter it would have been better to change the rules concerning the inheritance of the palms (see section 7.2). Formerly, in Togo, a peasant had to plant three seedlings for every palm felled (BÜCHER and FICKENDEY, 1919). Other methods which aimed to stop the tapping of oil palms were the introduction of European alcoholic beverages, the introduction of raphia palms and nipa palms (*Nipa fruticans* WÜRMB.) (WALLACE, 1946). Moreover, the peasants were instructed in the use of the wine of these palms. However, inability to enforce the regulations on felling palms made them largely ineffective. The introduction of raphia palm species in areas where these palms are absent and of the nipa palms from Malaya into southern Nigeria and the demonstration of the method of tapping standing palms in districts where this method was hitherto unknown did not produce the desired effect. Not only were the inhabitants unfamiliar with these palms or the tapping of standing palms, but the tapping of these palms also requires more skill and the tapping of standing palms involves more labour in climbing the palms, than tapping a felled oil palm.

In section 8.2.4 it is pointed out that every wound affords a point of ingress to fungi, insects and *Platycerium* spp. which may reduce the yield of fruit and even eventually kill the palms.

6.1.12 Competition between palms or between palms and forest trees

In secondary forest, dense palm groves and farmland palms have to compete with trees, other oil palms and the general undergrowth. In secondary forest the palms eventually become overtopped by forest giants, and their leaf development and pollination are hampered until ultimately they can neither survive nor regenerate. In dense groves inter-palm competition is severe, especially in the early stages of the formation of the grove when the ability to grow rapidly is an important selection and survival factor. Palms which become slightly shaded will reduce their rate of growth (see Table 11), but those which are heavily shaded almost stop growing or entirely cease to develop and many succumb. Palms of the same height which are densely planted show an etiolated growth as is shown by data presented by SLY and CHAPAS (1963). As the oil palms have only one growing point, it is unable to extend into any open space by the production of new fruitbearing branches or suckers and its production is limited to this single growing point.

The main difficulty in spacing trials with perennial crops is the change in the competition factor with time which results in a change in optimum density, but such trials have the advantage of fully systematic planting arrangements. In a grove the density varies considerably, even with the plots chosen as units, and shrubs, big trees and bamboo clusters may also compete with the 'crop', particularly towards the end of the fallow period when the competition from the regenerating bush must be considerable. In a plantation, competition is reduced to its economic minimum by proper spacing, maintenance and applications of fertilizers to the palms. Growing oil palms and farm crops together is obviously not disadvantageous to the production of the oil palm, for it has been observed with planted palms that when they are intercropped with food crops during the first or more years of establishment their development is accelerated and they yield earlier. The full explanation of this effect is complex, but reduction in competition for water, nutrients and space is in part responsible since soil cultivation without cropping, produces the same effect. OCHS (1963) suggested that the effect is partly due to crop residues acting as mulch. SPARNAAIJ (1960) suggested that reduction in and alternation in the balance of nitrogen concentration in the soil has a favourable effect on the sex ratio of the palms and leads to higher yields long after intercropping has ceased. Spacing trials with plantation palms were discussed by BEIRNAERT and VANDERWEYEN (1940) and MARIJNEN (1963) in the former Belgian Congo, by PREVOT and DUCHESNE (1955) in Ivory Coast, and by SLY and CHAPAS (1963) in Nigeria.

Optimum density. HARTLEY (1961) suggested that the optimum density might be different for different groves and different periods *i.e.* the competition factor changes from grove to grove and from time to time, just as in a plantation. The optimum density as assessed by yield alone does not tally with that assessed on an economic basis, which for a plantation is assumed to be 140 to 150 palms per hectare. On the basis of cumulative yield alone the calculated values for optimum density in the trials referred to above, approximate this figure except in the case of the trials at Benin (Nigeria) and Yangambi (Congo):

	Series	Optimum density/hectare
1.	Triangular (Benin, Nigeria)	228
2.	Various spacings (Benin, Nigeria)	243
3.	Square (La Mé, Ivory Coast)	153
4.	Triangular (La Mé, Ivory Coast)	147
5.	Rectangular (Yangambi, Congo)	203
6.	Various spacings (Bembelota I, Congo)	145
7.	Various spacings (Bembelota II, Congo)	163
8.	Various spacings (Bembelota III, Congo)	171

The densities of series 1, 2 and 5 are rather high. SLY and CHAPAS (1963) explained that although high densities might give higher yields, the economic life of the plantation was much reduced owing to the etiolated growth of the crowded palms. However, this is a difficult point to explain to the average farmer who generally thinks that 'the more the better' and is concerned much more with the present than the future.

Although the author is aware of the fact that the existence of a significant correlation between yield per plant and density need not result in a significant correlation between estimated and observed yield, the parabolic equation for 'yield per unit area and density' is used to calculate the optimal density of a grove because the equation agrees with the observed data.

An example of such a calculation is given for the Ikot Okpong grove (Expt. 501-1). The plots were classified according to their number of stemmed palms in groups; the classification being 1 to 10, 11 to 20 etc. stemmed palms per plot (0.4 ha). The average density of all plots per density group was calculated and so was the average yield per stemmed palm per density group. The yields over 1949 to 1962 were taken for the calculation of the mean yield. As for densities the relation between these two variables was found to be greater than 20 stemmed palms per density group (50 stemmed palms per hectare) a linear one *viz.*

$$y_p = 28.4 - 0.102d \quad (r = -0.919^{***})$$

in which y_p is the yield of bunches in kg per stemmed palm per density group and d the mean density of stemmed palm per plot per density group. The relationship between yield in kg per plot (y_a) and mean density was obtained by multiplying y_p by d giving

$$y_a = 28.4d - 0.102d^2.$$

Table 19. Expt. 501-1. The average density of stemmed palms, the observed and calculated yield per stemmed palm and per plot (0.4 ha) per density group for the Ikot Okpong grove

Density group	Number of plots	Mean density per plot	Yield (in kg) per stemmed palm		Yield (in kg) per plot (0.4 ha)	
			observed	calculated	observed	calculated
1–10	6	4.7	45.1	–	212	–
11–20	7	15.9	33.0	–	525	–
21–30	15	24.7	25.4	25.9	628	639.7
31–40	12	35.2	26.5	24.8	929	873.0
41–50	7	46.0	24.8	23.7	1,141	1,090.2
51–60	12	56.2	24.2	22.7	1,359	1,275.7
61–70	15	65.1	19.4	21.8	1,266	1,419.2
71–80	6	75.7	19.0	20.7	1,436	1,567.0
81–90	9	83.9	18.7	19.8	1,571	1,661.2
91–100	5	97.4	17.4	18.5	1,695	1,801.9
101–110	5	105.8	18.7	17.6	1,984	1,862.1
111–120	2	115.5	19.2	16.6	2,223	1,917.3
121–130	3	125.3	13.9	15.6	1,747	1,954.7
134	1	134	15.4	14.7	2,064	1,969.8
1–134	105	55.9	20.7	22.7	1,159	1,268.9

For densities higher than 20 stemmed palms per plot:
$y_p = 28.4 - 0.102\ d$ (y_p is yield in kg per stemmed palm); $r = -0.919$
$y_a = 28.4d - 0.102\ d^2$ (y_a is yield in kg per plot)

This method of calculation was used by PREVOT and DUCHESNE (1955), who calculated the optimum density of an oil palm plantation. The function is unsatisfactory at low and probably also at high densities. In the Ikot Okpong grove it appeared that at densities lower than 50 stemmed palms per hectare the yield per palm increased considerably. In rain-forest with oil palms pollination of single standing oil palms may be a limiting factor which could result in a reduction in the yield of that palm.

These two above equations were used to calculate the yield per palm and per hectare (Table 19) and in Figure 5 they have been shown. The - - - - - line is an extrapolation of the ——— line, whereas the - · - · - · - line was calculated by using the mean densities of the three lowest density groups and their mean yield per palm. Similar equations were made for three other Dense groves and a Secondary forest with oil palms; the results are given in Tables 7 and 20.

In one case is the optimum density lower that the actual stand while in three groves the stand is sub-optimal which had already been noted for the Ikot Okpong grove by HARTLEY (1954). The optimum density of one grove could not be calculated because the grove was too small to divide it into plots. The actual data of this grove have been added to compare them with those of other groves. HARTLEY suggested that when the crowns occupy different layers the optimum density may be higher than when the crowns are all at the same level. This suggestion, however, may be incorrect because the loss in yield of palms shaded by taller palms may exceed the additional yield from

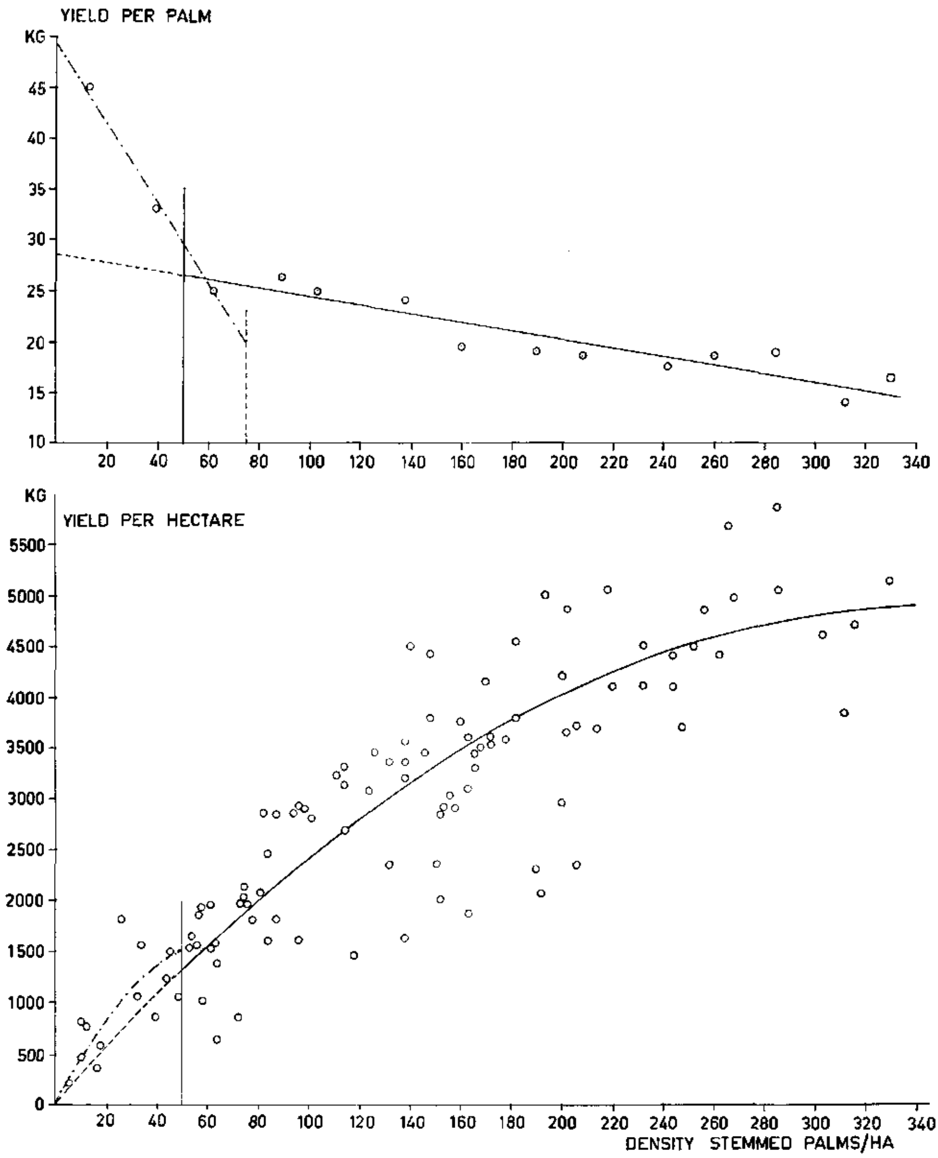

Figure 5. Expt. 501-1. The relationship between the mean yield per palm or per hectare and density of stemmed palms per hectare

the latter. This matter has not been investigated because no trial can be established in which an oil palm grove with palms of different height could be compared with a grove with palms of equal height. The difference in the optimum density between the four groves is not understood, but age of the grove and soil fertility are two factors which probably have an influence. The effect of age on yield has been pointed out by REES (1963b) and is discussed in section 6.1.14. The data for Experiment 22-1 are

Table 20. Optimum density, maximum yield and yield per palm for four palm groves at Abak, palms in secondary forest and a plantation near Benin

	Dense palm grove				Secondary forest	Plantation
Experiment	501-1	502-1	503-1	505-1	18-1	22-1
Optimum density per hectare	348	188	356	173	190	228
Max. potential yield (kg/ha)	4,941	2,989	2,908	3,997	3,043	7,367
Yield per palm (kg)	14.2	15.9	8.2	23.1	16.0	32.3

given by SLY and CHAPAS (1963), and hold for triangular spacings only. The differences in optimum densities and potential maximum yield for the palm groves may be due to differences in age, soil fertility and size of the groves. The higher yield in Experiment 22-1 although still very low, is a result of genetically better palm material and better growing conditions. These calculations are based on bunch weight. The effect of inter-palm competition on the fruit and bunch composition is unknown, as is the effect of density on the soil conditions. The effect of thinning is discussed under Palm Grove Improvement.

MARIJNEN (1963) concluded from his results that the optimum plant spacing with the same density will be the spacing which spreads the palms most evenly over the area. This probably holds true for a palm grove too, but in the latter the different heights of the palms are very likely to be of influence too.

It is not understood why the equation between yield and density for the Secondary forest with oil palms is parabolic, as in this grove type the author observed that a space is filled either by a forest tree or by an oil palm.

6.2 Yield

6.2.1 Introduction

ZEVEN (1965b) postulated that the maximum bunch yield of a grove palm growing under optimum conditions is between 135-180 kg annually, but this potential is only rarely achieved owing to the depressing effect of various factors discussed above.

The groves around Abak have an average annual yield of about 2,800 kg of bunches per hectare, but the yield may be higher in parts of the grove which approach the optimum density of stand or have optimum growing conditions. The yield of the grove in Experiment 502-2 is higher than usual because this grove was in its optimum stage of development and being a small cluster of palms in open farmland, the yield of the fringe palms would be high. For comparison, plot 47 of the Ikot Okpong grove yielded a mean of 5,853 kg of bunches per hectare annually over 14 years.

These figures agree well with those given in the literature by VAN PELT (1920) and DUPIRE and BOUTILLIER (1958) for Ivory Coast (2,500 kg and 1,200 to 1,500 kg/ha respectively); BUCKLEY (1938) for Eastern Nigeria (500 to 4,500 kg/ha; mean 2,200 kg/ha; LEPLAE (1939) for North-East Congo (Amadi, 1,500 kg/ha); HARTLEY (1958) for Kwango in Congo (4,500 kg/ha) and ANON. (1930) for Congo (3,750 kg/ha).

In the Abak groves the percentage of palms bearing in one year varied from 54 to 63% of all stemmed palms. In Expt. 503-2 only 7 (22%) of the rough-stemmed and 38 (66%) of the smooth-stemmed palms were bearing. Many palms have yet to bear fruit for the first time and some will never do so, whereas others only produce fruit at irregular intervals. HARTLEY (1954) calculated that in Expt. 501-1, 96.6% of the total yield came from smooth-stemmed palms. Non-yielding smooth-stemmed and unthrifty rough-stemmed palms form a permanent obstacle to the development and production of the neighbouring palms and should, therefore, be removed.

The yields for each grove subtype in the Asutan Ekpe area were given in table 6 (see section 5.4.4).

The percentage of bearing palms is determined by the density and follows this rule:

$$\% = 75.9 - bd$$

where $b = +0.34 \pm 0.16$ and d is density of stemmed palms per hectare. With increasing density the percentage of bearing palms decreases, but the actual number of bearing palms increases.

6.2.2 Annual variation of yield

There is a considerable variation in annual yield and the pattern of variation often differs from grove to grove. Sometimes all groves show a yield depression or peak in the same year which should almost certainly be attributed to the effect of climatic conditions in the preceeding $2\frac{1}{2}$–3 years. All the groves at Abak and Benin gave a very low yield in 1951, while the groves at Abak gave a high yield in 1953, but in other years the yield of different groves have fluctuated quite independently.

Attempts have been made to detect a cyclic pattern in the yield fluctuations of planted palms similar to the yield cycles found for other crops. WEBSTER (1939) found a two year cycle and CHAPAS (1961) an indication of a four year cycle, while HAINES and BENZIAN (1956) found a three to four year cycle for single palms and one of five years for a large number of palms. This phenomenon is not fully understood, although certain cycles in climatic conditions, and hence in soil conditions, have been suggested as causative factors. No such cyclic patterns could be detected for the whole Ikot Okpong grove, but a four year cycle was found for plot 93 ($r = +0.8324$**), peak yields occurring in 1949, 1953, 1957 and 1961. Some other plots (*e.g.* plot 47) showed similar yield variation, but many other plots of this grove exhibited no cyclic pattern.

6.2.3 Seasonal variation of yield

In section 6.1.5. the seasonal variation of the yield of a grove which mainly comes from the smooth-stemmed palms (HARTLEY, 1954) has been discussed. Figure 6 shows the monthly distribution of the bunch yield of the number of bunches and their average weight. The variation of the number of bunches closely follows that of the total weight, whereas the variation of the average bunch weight shows a different pattern.

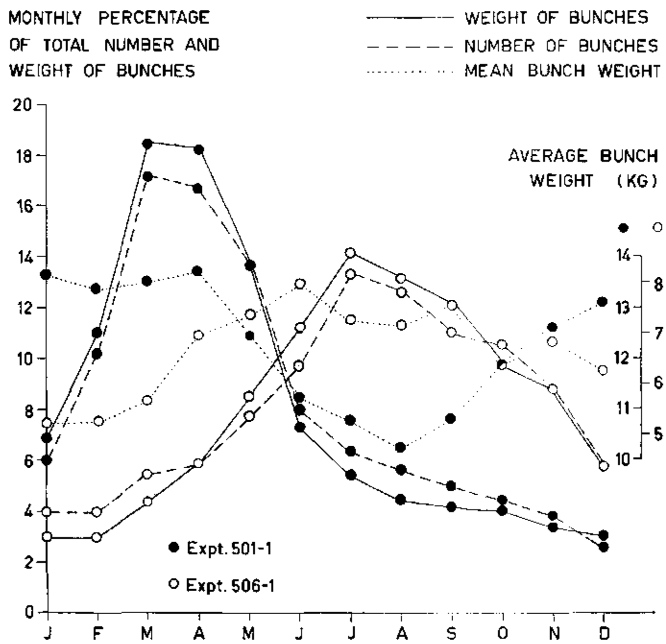

Figure 6. Expts. 501-1 and 506-1. The monthly production of 60 to 70 year old palms of the Ikot Okpong grove and of an eight year old Extension Work Seed trial

The monthly variation of the oil and kernel to bunch ratio also has its effect on the potential monthly output of oil and kernels (Table 21). This will be discussed in section 6.2.4.

A point of interest, especially where fruit is milled, is the pattern of yield distribution which can be expressed as the quotient of the highest monthly yield and the lowest monthly yield. This 'regularity ratio' for groves at Abak is about 5 to 6, but for some groves in Sierra Leone it is 20 to 30 making the local operation of mills rather uneconomic.

6.2.4 Potential and actual output

Thus the potential monthly output of oil and kernels from a grove depends on the bunch yield and the oil and kernel to bunch ratios for that particular month. In the

Table 21. Expt. 501-1. The oil and kernel to bunch ratios, and the potential oil and kernel weight per hectare per month, per six months and per year of the Ikot Okpong grove

Period	Oil to bunch ratio[1]	Potential weight of oil (kg/ha)	Kernel to bunch ratio	Weight of kernels (kg/ha)
July, 1961	12.7	22.3	10.4	18.3
August	13.0	18.0	10.6	14.7
September	13.5	16.4	10.4	12.5
October	13.7	17.6	10.0	12.9
November	14.4	19.6	9.4	12.8
December	16.2	27.3	9.2	12.4
January, 1962	15.7	25.2	9.4	14.9
February	16.1	38.1	10.0	23.6
March	16.3	71.9	9.4	41.1
April	16.1	68.5	10.4	44.2
May	18.4	60.1	9.7	31.7
June	14.6	24.5	10.4	17.5
July	13.7	17.7	11.3	14.6
August	13.7	14.9	9.4	10.2
September	14.8	14.6	9.9	9.7
October	14.6	15.1	10.3	10.6
November	15.0	16.4	9.9	10.9
December	16.2	10.1	9.6	6.8
January, 1963	14.8	31.9	9.4	20.3
February	15.3	42.0	9.4	32.6
March	16.6	66.5	9.9	36.2
April	17.8	75.0	9.8	41.3
May	16.4	48.7	9.9	29.5
June	15.0	28.4	10.2	19.3
July–December, 1961	13.8	121.2	9.7	83.6
January–June, 1962	15.7	288.3	9.1	173.0
July–December, 1962	14.4	88.8	10.2	62.8
January–June, 1963	17.1	292.5	10.1	179.2
Total/Mean	15.6	395.4	9.7	249.3

[1] 50% of the mesocarp to bunch ratio

Abak area the oil to bunch ratio is low in the second half of the year *i.e.* during and immediately after the rainy season. APPAH (1951) also observed that this is the case in the Brass area in Nigeria. The kernel to bunch ratio does not fluctuate very much over the year.

The actual output of fruit from a grove does not reach the potential output. Factors such as harvesting restrictions, wine tapping, felling of palms on a large scale and farming lower the production of the groves. Moreover, the traditional methods of oil and kernel extraction are only, at best, 70 to 80% efficient.

7 Exploitation, extraction of oil, cracking of nuts, rights over palms and consumption

7.1 Exploitation

Many factors, which are often inter-related, have an effect on the exploitation of grove palms. For example, rights on palms is a direct result of interest in the palm, which in turn depends on the number of palms available per man, the local prices of palm produce, the quantity of oil required and the possibility to produce other more profitable crops. When the price is low, for instance in areas lacking in outlets to export markets, the people are only interested in the oil palm as a source of household food and restrict their exploitation to the limit set by this requirement. In the drier areas palm wine is often the only palm product which is used because lack of water restricts the yield of the palms and makes processing of the oil impossible.

In several countries or districts the production of other commercial crops, for example coffee, cocoa or rubber takes precedence over exploitation of the oil palm.

7.1.1. Harvesting arrangements

The various rights over the oil palm affect its exploitation. At any time 'free' palms may be harvested by all members of a group which has a right on the land on which the palms are standing. Palms on the produce of which individuals have the right of harvest may often be harvested in accordance with the wishes of these individuals. In both cases the only restrictions on harvesting bunches of the palms are the harvesting taboo days and in the first case when a palm is tapped for wine. In cases in which the economic value of the palms increases the rights on these palms become stronger and harvesting rules come into force. For instance, in some areas of the southern part of Eastern Nigeria (Figure 7) harvesting of palms on which the village community exercises rights, is forbidden by the village authority for several weeks at a stretch, the idea being to wait until sufficient fruit is ripe to give every interested villager a fair chance to harvest on authorized harvesting days his share. It prevents harvesting of unripe bunches, since no one need be afraid someone else will steal a bunch. Moreover during a close period anybody found in the area with palm bunches will be suspected, and harvesting out of the official days is punishable by a fine. The system undoubtedly leads to harvesting of overripe fruit, but this has to be set against the probability that without some periodic restriction on harvesting the majority of bunches would be harvested under-ripe.

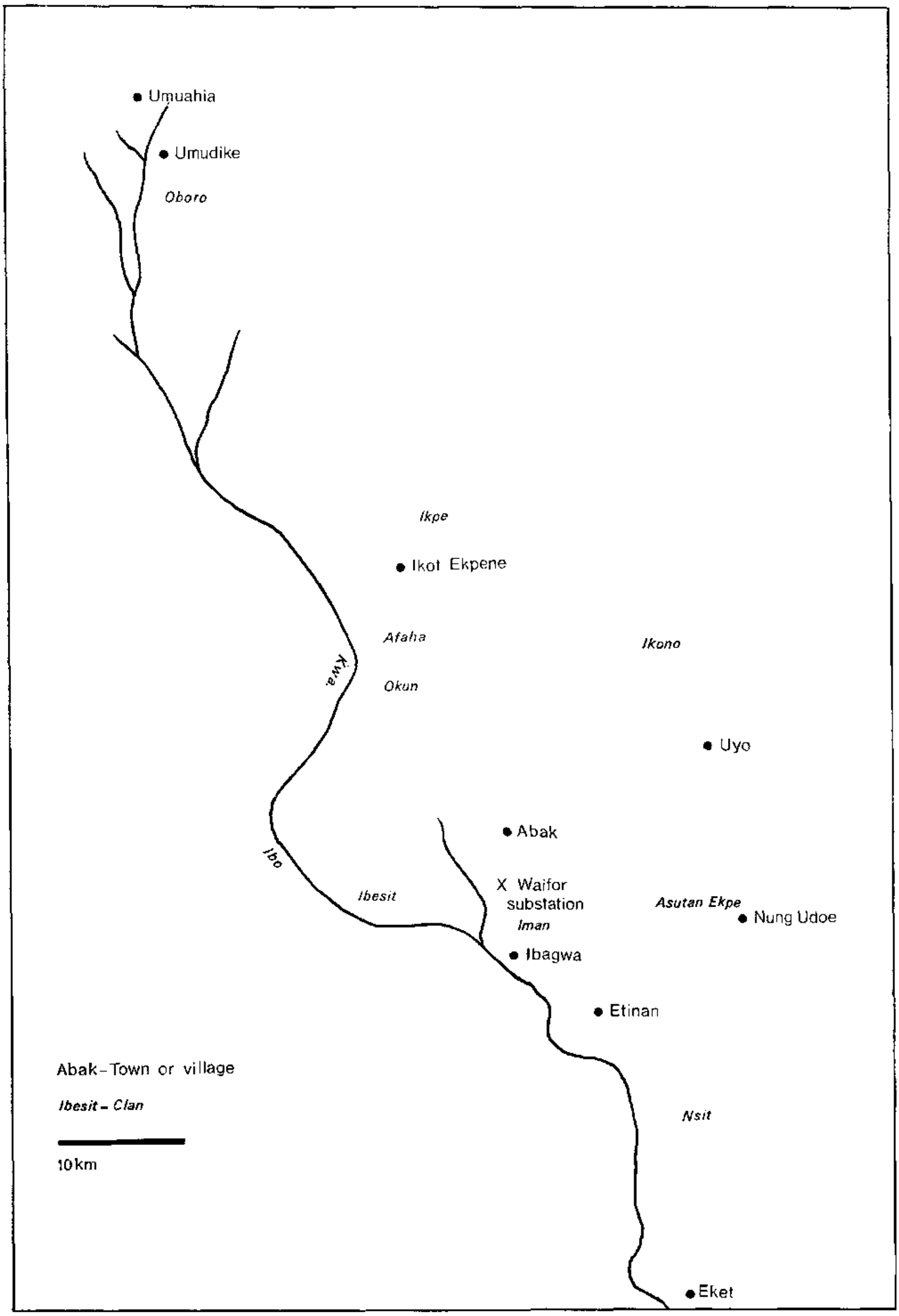

Figure 7. Map showing the locations of the WAIFOR substation near Abak, various towns, villages and clan areas in a part of Eastern Nigeria

In the past when village-owned palms were harvested, no payment to the village treasury was required, but now a harvesting share has to be purchased. Those villagers who cannot climb (generally women and old men) hire a climber from a neighbouring village to harvest their share. This climber is paid in cash and/or in kind. Some examples of village harvesting arrangements in Eastern Nigeria are now described.

In the village of Ikot Itina of the Ibibio-Iman clan, harvesting is allowed on one day in every four weeks (the week consisting of eight days) and a share costs 3 to 5 shillings. Recently communal harvesting has been introduced. Under this system a number of harvesters are selected by the village council to harvest all the palms and the bunches are taken to a particular centre where they are offered for sale. The harvesters receive 4 shillings or 4 bunches per 20 bunches harvested, which represents about a day's work for one man. This system is said to be more profitable to the village than selling harvesting shares. It is also found in the village of Ndueduo of the Ibibio-Nsit clan, but has not yet been adopted in the village of Uruk Obong of the Anang-Ibesit clan. There, the price of a share ranges from 1/6 d to 5 shillings. The pay of a hired climber also depends on the number of bunches harvested, but varies from a quarter to a third of the total harvest, and he also receives free food and drink the whole day. Formerly, in the village Amaoba Ime of the Ibo-Oboro clan, shares needed not be paid for, but now a hundred selected villagers are allowed to harvest on payment of a fee of £ 1 and each may hire as many climbers as he wishes. The bunches they harvest belong to the hirer who will give his climbers 3 shillings a day and free food and drink. In this way the village receives £ 100, and the share-holders compete with each other. They have to be careful, for if they hire too many climbers, the number of bunches harvested per climber will not suffice to meet his wages. ARDENER (1953) reported that at Mba Ise in Ibo land palm fruits may be processed by women who carry out their appointed task in return for the nuts, the oil being sold by the village community.

The exploitation of palms growing in secondary forest is facilitated by the fact that they are grouped on old village sites, and bunches are often harvested from palms which are being tapped for wine. In such cases the villagers make a path between their farmland and village and open side-paths to nearby palms in the forest. These paths are maintained as long as the farmland is cropped. When new farmland is prepared new paths are made, other palms tapped and harvested, and the old paths and palms are abandoned (FORDE, 1937; KADEN, 1955). DUPIRE and BOUTILLIER (1958) described the temporary harvesting camps of the Adioukrou in Lower Ivory Coast. These camps were set up in groves which are either village- or family-owned. During the short dry season the members of the community or family are free to harvest the palms. In the wet season the palms are not climbed, but during the main Dry Season (the peak yield season) fruit is harvested by communal effort. The men do the heavy work of climbing, chopping and pounding, while the women helped by the children transport water, fire wood and the fruit bunches, pick the fruits, process the oil and crack the nuts. From the income obtained, tax is paid, the men and women who help with the work are rewarded and the remainder is paid to the village elders and village fund. From this fund public works are financed. At present the harvesting camps are no longer set up and instead the harvesters return to the village at night taking with them the day's harvest to be processed. Another development is the sale of the fruit to the mill, which allows the men much more time to attend to the growing of cash crops, but causes the women to lose their income from kernels and from a percentage of the oil.

7.1.2 Climbing

There are two basically different ways of climbing an oil palm. One method (the 'Ibibio' rope) is described by MESTDAGH (1921) and BALBOUR (quoted by HODGE, 1958). The climbing set is composed of one long rope with a stirrup at both ends, or of two ropes, each with a stirrup at only one end. The ropes are put around the stem, the climber inserts his right leg up to the thigh into one stirrup, and in the other he places his left foot. With a seesawing motion he shifts his weight from one stirrup to the other, and simultaneously with his hands moves the slack part of the rope upwards when climbing or downwards when descending. This method is safer than the second method of climbing, the 'Yoruba' rope. On the other hand the latter method

Plate 11. Two ways of climbing an oil palm. The sling (left) is used by almost all oil palm exploiting Africans. The two-ropes-set (right) is only used by members of some tribes in Ghana, Nigeria, former Belgian Congo and in probably some other countries. Photograph NIFOR.

(described by FICKENDEY, 1929) is much quicker and in more common use in Africa. A single rope is passed around the stem of the palm and the body of the climber and the ends are tied together. The climber reclines with his hips against the rope and places his feet against the stem of the palm. He climbs by jerking the rope upwards and 'walking' up or down the stem. Accidents are common, the rope may be worn, the stem of the palm may be wet and slippery or the climber may jump down to avoid a snake, ants or bees. WILSON (1959) described a safety climbing harness, but it was of little practical use even in plantations for which it was designed. Some varieties of both types of climbing ropes are known. A few men can climb palms without ropes, but this is uncommon.

Climbing is often a factor which limits the exploitation of wild palms. The Adioukrou in Ivory Coast stop climbing during the Rainy Season because the palm stems get too slippery (DUPIRE and BOUTILLIER, 1958). Again the number of climbers may be limited owing to other available employment or may in any case be inadequate to cope with all the palms. The number of bunches harvested per climber in one day varies with the season, the density of the palms, the climber's knowledge of the grove, the average height of the bearing palms, the method of climbing, the condition of the crown and the stem and the skill of the climber. On average a climber can harvest 20 to 30 bunches daily.

7.1.3 Harvesting and processing economy

The only data that the author knows and relate to harvesting economy concerns the average height of bearing palms as well as the climbing economy using an 'Ibibio' rope.

WILLIAMS (1930) gave the yield of an improved palm plot at Odumase in Ghana by height group. The average height of the palms was three to four meters, which is rather low and the bunches could therefore have easily been harvested with the help of a bamboo 'ladder'. The taller palms had probably been felled for wine tapping. The grove palms in Eastern Nigeria are much taller and the amount of fruit which can be harvested with the help of a bamboo 'ladder' is negligible as is shown in Table 9 (see section 6.1.3).

The average height of the bearing palms of Expt. 501-1 was 16.6 m and of Expt. 503-2 13.8 m, so the total distance climbed to harvest the annual yield from one hectare was 4,273 m and 3,407 m respectively. This also shows that the yield from Expt. 503-2 came from a lower average height than that of Expt. 501-1.

The time taken to climb about 15 m high palms measured by the author in several groves was found to be:

Experiment	Climbing and descending	Climbing, harvesting and descending
501-1	8.8 min.	11.0 min.
503-2	8.8 min.	9.0 min.
504-1	–	13.0 min.
Mean	8.8 min.	11.0 min.

The groves were harvested by different gangs and this may have its effect on the time factor per grove. It must not be forgotten that a considerable part of the climbing time is taken up by the tying of the ropes around the palm stem. The 9.0 minutes in which time a palm of Expt. 503-2 was climbed, a bunch harvested and the climber had come down looks a bit doubtful as compared with the 8.8 minutes that the climbing and descending took. However, we may assume that climbing and descending of a 15 m high palm takes about nine minutes and harvesting about two minutes. Thus the total time required to harvest the total amount of fruit shown in Table 9 would be about 47 man hours, or 14 man hours per ton. In addition it takes some time to go to the grove, to walk from palm to palm, and transport the bunches to a particular place.

On village harvesting days women who buy a share have to hire a climber. The economics of such a share were investigated at the Ikot Inyang village of the Ibibio-Asutan Ekpe clan where the cost of a climber in 1963 was 9/- a day (4/- in cash and 5/- for food and palm wine). He worked for 5 hours and thus received 1/9d. per hour, which compares very favourably with the rate for unskilled labourers in the area who were then paid 2d. per hour. The cost of the share was 2 tins (32.4 kg) of oil, which was equivalent to £ 1.5.6 d. The woman who engaged the climber thought that the oil extracted would bring in enough money to pay for the share, while the kernels would fetch about 10/-. She agreed that her profit for several days work would then be only about 1/-, but this was apparently sufficient to induce her to undertake the work.

It is interesting to check her estimate. In that area the average bunch weight is quite high, about 16 kg; the climber would harvest 24 bunches yielding 39 kg of oil and 33 kg of kernels worth when sold, £ 1.10.8 d. and £ 0.14.11 d. respectively, making a total of £ 2.5.7 d. The woman paid £ 1.14.6 d. for her share and the climber, thus her true profit was £ 0.11.1 d. This shows that although the people knew they made a profit they had little idea of the actual amount. In addition, it has also to be remembered that the processing of palm fruit provided one of the few ways of obtaining cash income. In other cases the cost of a share or the climber was smaller than in the case quoted, and this depended to some extent on the length of the prohibition period and the state of the village treasury.

When men and women work together in oil and kernel processing, the men generally receive the oil (except a little for household use) and the women the kernels as rewards for their labour. Thus (in the example above) the man earns £ 1.10.8 d. for climbing, harvesting, chopping and pounding, while the woman receives £ 0.14.11 d. for her work of transporting bunches, water and fire wood, picking fruits, processing the oil and cracking the nuts.

This traditional division of labour between the sexes is found more or less throughout Africa, the men being engaged with the heavy work for a relatively short time while the women and children do the lighter but time-consuming work. But when processing of oil and cracking kernels are carried out on a commercial scale, this division of labour disappears and men undertake tasks which tradition leaves to the women. The introduction of hand presses and nut crackers, operated by men, depriving the women of their traditional work and its proceeds, led to the Aba riots in Nigeria in 1929.

No investigations have been carried out to assess the percentage of time spent by farmers and their families in harvesting and processing the fruits of the oil palm, but it will vary widely. FORDE (1937) found that 48 of the 103 able-bodied men in Yakur near Afikpo (Eastern Nigeria) were engaged in oil production while 50 were tapping for wine. On communal harvesting days everybody may be engaged in the palm oil economy for the whole day, but the following day, when the bunches are left to ferment, the work is much reduced, although women and children may continue to crack nuts collected from a previous harvest. On days when harvesting or processing are taboo, nobody is allowed to do any work on the oil palm for instance among the Ibibio of south Eastern Nigeria three days of each eight day week are taboo for harvesting and processing of palm oil. The explanation given for the taboo is the belief that if oil is spilled on the ground it removes the 'power' of that ground, which has an adverse effect on the practices observed by secret societies in the neighbourhood.

Estimates by various authors of the time needed to process one ton of oil vary from 132 man days for hard oil to 630 or more man days for soft oil (FAULKNER and LEWIN, 1923; RANCOULE, 1945), FORDE and SCOTT (1946) quote 186 to 310 man days, DE GROOF (1933b) 313, BÜCHER and FICKENDEY (1919) 400 to 600, MULHEIM (1937) 454 and LA ANYANE (1961) 617, but it is not always clear whether the estimate includes time spent in harvesting and transporting the bunches.

7.1.4. Extraction of oil and cracking of nuts

Before palm oil became an export commodity, only oil for household use was prepared. There was an abundance of fruit, thus efficiency of extraction was not of any importance. At that time preparation of oil was the work of the women although the men would help by harvesting the bunches. Nuts may have been cracked for preparing kernel oil for use in lightning or cosmetics, and some kernels were eaten, especially during famines. The household oil had a low f.f.a. content even in areas where export oil with a high f.f.a. is nowadays produced. In Nigeria oil is prepared in the house compounds, but in some other countries temporary harvesting camps are made near the palm groves.

The traditional methods of extraction and hand presses. Accounts of traditional methods of oil extraction have been given by FARQUHAR (1913), GRAY (1922), FAULKNER and

LEWIN (1923), MANLOVE (1931) and BUCKLEY (1938). No mechanical aids are used in these methods. The oil produced for export was classified as soft, semi-soft or hard; some very hard oils were named after the port of export. This classification was based on the percentage of f.f.a. present, oil with an f.f.a. content lower than 12% being edible.

The classification of soft oil has varied over the years. FAULKNER and LEWIN reported that in 1923 (at Liverpool) soft oil had an f.f.a content of less than 26%, but in 1938 BUCKLEY said it had to have an f.f.a content of less than 23% and according to NWANZE (1961) less than 12%. Oil of low f.f.a. content is obtained by boiling the fruit to soften the mesocarp; this also destroys the lipases which would otherwise hydrolyse the oil to produce free fatty acids.

Soft oil is prepared as follows: The bunches are left for two or four days after harvest until the fruits become loose. The fruits are then boiled and pounded and the first oil is expressed by hand. The remaining oily pulp and nuts are stirred in cold water and then boiled. The oily scum is skimmed and added to the first lot of oil which is then 'fried' to remove the water. This also has the effect of sterilizing the oil although the operator is not conscious of this. The extraction rate is 8–13% oil to fruit. The nuts are separated from the pulp by hand picking.

Hard oils have an f.f.a. content of more than 43%. They result from processes which involve fermentation of the fruit, during which the lipases remain active. After being harvested the bunches and loose fruits are left to ferment for two weeks or more before the fruits are pounded with water. After pounding the pulp and nuts are placed in an elongated pit or (dummy) canoe and the oil which has been expressed during pounding is collected. Water is then added and the mixture trodden to express the remaining oil and separate the nuts. The oily scum which collects at the water surface is collected and 'fried' and subsequently mixed with the oil collected after pounding. The extraction rate obtained by this method is 10–16% oil to fruit.

Another hard oil producing process is described by JANSSENS (1927) from Portuguese Congo. The fruits are left to ferment for two to four days and are then put in baskets and immersed in a pool. After a few days in the water the fruits are taken out, placed on mats and beaten with sticks; the nuts are picked out and the pulp is left in heaps for some days before being put into nets and immersed in boiling water. It is not surprising that the oil which is then skimmed off has a high f.f.a. content.

Semi-soft oil is processed by methods intermediate between those described.

The advantages of the hard oil method are that less labour is required for stripping the fruits from the bunches, collecting fuel and separating the nuts from the pulp. It also gives a higher oil to fruit ratio, but the oil is of much poorer quality than that obtained by the soft oil process.

BARNES (1924) devised an improved process which combined the advantages of both methods. In stead of boiling or fermenting the fruit he steamed it, but although this was an improvement the process gave unsatisfactory results.

Not only did the traditional processing methods give oil with a high f.f.a. content, but also a low rate of extraction estimated at about 55% of the available oil, or even less, whereas with a screw hand press 65% of the oil can be extracted and with a mill or hydraulic hand press, 85%. RAYMOND (1961) states that in Nigeria in 1950 92.2% of the oil was extracted by traditional methods, 6.7% by hand press and 1.1% in Pioneer mills, whereas by 1960 the corresponding percentages were 25–30%, 65% and 5–10%, and this means that as a result of improved processing about 13% more oil was being obtained from the same amount of fruit. RANCOULE (1945) found that during extraction by traditional methods at least 40% of the oil was lost, 18% in the washing water, 15% in the pulp and 7% adhering to nuts, pans, etc. Generally speaking, when fruit from grove palms is extracted by traditional processing methods the oil to bunch ratio is 8–10% in the wetter areas and 5–6% in the drier areas.

The hydraulic hand press with ancillary equipment for sterilization, maceration and clarification, and the economics of its operation is described by NWANZE (1965), whose investigations have also been reported by CORNELIUS (1963).

Mills. The first palm oil mills to be established in West Africa were built in Cameroons in 1902 and in Dahomey in 1908 (FICKENDEY, 1929). The advantages of a mill over traditional methods or screw type hand presses are high oil extraction efficiency and economy in labour. Although these are valid commercial points the mills are not popular with farmers because they do not fit into their local socio-economical pattern and for this reason many mills are operated on an uneconomic basis because the supply of bunches or fruit offered by the farmers is inadequate to keep them working to capacity.

Harvesting schedules are often based on intervals of 30 days; no climbing to harvest palm fruit is carried out by the Urhobo in Midwestern Nigeria (NWANZE, 1961) and the Adioukrou in Ivory Coast (DUPIRE and BOUTILLIER, 1958) during the early part, and the whole rainy season respectively; middlemen and women trading in fruit, oil and kernels are denied their source of income, which upsets the whole village economy in palm grove areas and the women lose their income from cracking nuts, on which the family economy is partly founded; flooding of palm groves which prevents harvesting; the rising of rivers which facilitates transport; the seasonal pattern of fruit production and in many area the poor quality of the fruit; all these factors affect the economy of a mill. Local processers operating a screw hand press can work more cheaply than the commercially run mill and as there is much less money invested in their operations and equipment they are economically stronger. These presses can also be easily moved from site to site in accordance with the supply of fruit, and it is, of course, easier for farmers to carry fruit to a nearby local press than to some remote central mill. In the 1920's the construction of central mills was given Government backing, the intention being that all the fruit within a certain radius should be brought to the mill. In Sierra Leone the radius of the concession of the only mill built in 1920 was 16 km giving the mill a supply area of 800 sq.km (REPORT, 1924). However, this distance was shown to be too great and the radius was reduced to 8 km to give a concession of 200 sq.km. The plan envisaged a general intensification of oil palm exploitation involving some rehabilitation of the groves, and assumed, wrongly, that the farmers would be prepared to walk the long distance to sell their fruit, which they could otherwise process themselves, Since the concession owners could not force the people to bring the fruit to them, it was not surprising that an inadequate supply was the result. Thus the mills could not operate economically and had to close down.

NWANZE (1961) stated that all the 99 mills in Eastern Nigeria were working for at least part of the year, but that three of the 13 in Western Nigeria and three of the seven in Northern Nigeria (Kabba Province) had ceased to operate by 1957. After 1957 several mills in Eastern Nigeria were closed down and where possible moved to a more promising area. Since 1962 the local communities have been allowed to buy the mills. These communities are economically stronger as they are able to compel their people to bring the fruit to the mill, to forbid the operation of presses and to pay lower wages than a Government sponsored concern. It must not be forgotten that the original intention was that the mills would be sold once they were in good working order.

In some areas plantations have been created around the mill, to safeguard the minimum economic input of fruit to the mill. Lorries may also be used to collect bunches and fruit from remote collecting points, but this increases the overall cost of operating the mill and can only be justified when sufficient fruit can be collected. A variant of this is to use hired labour to collect the bunches. Attempts have been made to operate mills on a base of returning to the farmer oil and kernel equal to the quantity he himself would have obtained by processing the fruit he brings to the mill, the operating costs and profit for the mill being met by the additional oil which can be extracted by modern milling machinery (RANCOULE, 1945).

NWANZE (1961) concluded that in many areas in Eastern Nigeria the mills could not compete with the screw hand presses and this situation may be worsened by the introduction of the hydraulic hand presses which, of course, will also have to meet the same competition. Clearly, therefore, no new mill should be constructed in any area until it has been clearly established that an adequate supply of fruit will be forthcoming to enable it to run economically.

Cracking of nuts. The traditional way of obtaining kernels is the cracking of nuts by hand, the work being carried out by women and children using two stones. Men do not crack nuts unless they want the kernels for immediate consumption.

In Asutan Ekpe near Uyo the author found that a woman could crack 23 kg of nuts, yielding 5 kg of kernels in an eight-hour day. For seven tins of kernels (each containing 0.4 kg) she received 1/-, which makes the return for one day's work about 1/9 d. BILLOWS and BECKWITH (1913) stated that as much as 10.6 kg of kernels could be extracted in a day; FORDE and SCOTT (1949) gave 6.3 kg, DE GROOF (1933b) 3 to 4 kg and BÜCHER and FICKENDEY (1919) 2 kg, but the last figure is too low. Nut cracking is often done in leisure hours and visitors may occasionally assist. From export figures (see section 7.1.5) it is clear that cracking of nuts is deferred until after the peak yield period for palm fruit and the food crop planting season.

7.1.5 Time between harvesting and export

Time between harvesting of the bunches and export of oil and kernel is shown in Figure 8. The monthly harvesting figures for oil and kernel are expressed in percents of the annual production of Expt. 501-I and are derived from Table 21. Groves in West Nigeria show a similar distribution of the yield. The monthly export figures are percentage of the total export in 1960 (FEDERAL GAZETTE..., 1960; 1961). The curves show that at the beginning of the peak production of oil – January to March – it takes about one to three weeks before the oil reaches a Governmentally Registered Palm Produce Buyer, but this period greatly increases at the end of the season of the peak harvest – May to June. The curve for kernel export gives a completely different picture, as cracking of nuts, delayed due to the time to dry them before cracking, is time consuming and cannot be done during the peak yield season as time is needed to harvest the bunches and especially to prepare the farm and plant crops. Therefore cracking must wait till less busy times and the peak export is two months after the peak of harvest.

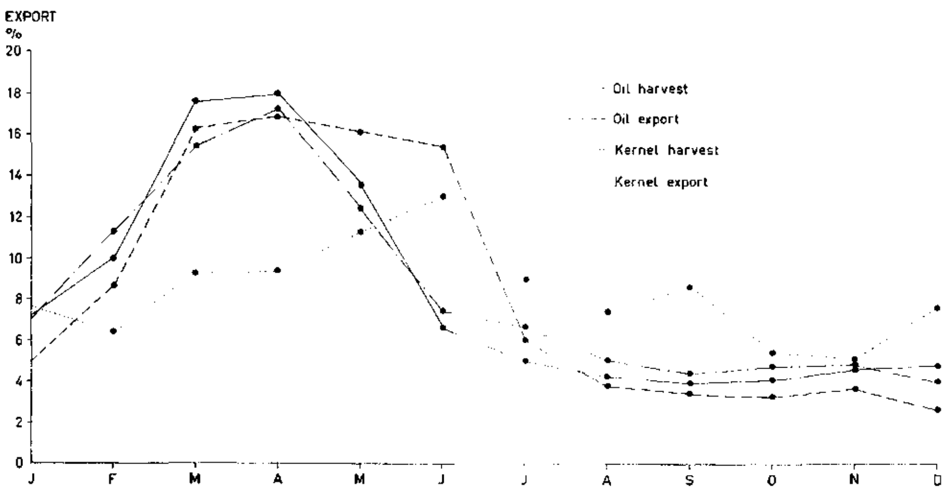

Figure 8. The monthly output of the Ikot Okpong grove and the monthly export figures of oil and kernels of Nigeria

For some district these curves may be different *e.g.* for some areas in Western Nigeria palms owned by cocoa-growing Yoruba are harvested by temporary Urhobo immigrants who only come to harvest the bunches, process the fruits and are sometimes allowed to keep a small farm.

7.2 Rights over palms

7.2.1 Ownership

In this work the term owner of an oil palm is defined as the person or group of persons having the right on the produce of an oil palm, to fell the palm or to allow others to harvest the palms. Therefore the verbs to own and to belong to and their derivatives are used in this meaning and should be seen in the light of a locally operative customary law.

A well-known principle of many systems of land tenure is that rights over land do not necessarily extend to the tree standing in the land (MEEK, 1957, p. 172); in many cases the right on the land and the right on the palm may not be invested in the same persons. So grove palms standing on village land remain to belong to the village after the land has been allocated to farmers. These have only the right to farm the land and not to harvest the palms, although in some cases the farmer may get both rights. This was noticed by the author in the Igala Division of the Nigerian Middle Belt. Grove palms growing on and close to a compound are, generally, owned by its dweller and so, when a new dweller occupies the site, the latter has the right to harvest these palms.

Planted palms belong in general, to the planter, because he is entitled to the product of his labour (KREMER, 1956, p. 279; MEEK, 1957, p. 173; TARDITS, 1963, p. 313). These palms may be sold, pledged or inherited and belong then to the new owner. The land on which these palms stand remains to belong to the village community, unlesss pecial arrangements have been made. After the establishment of demonstration plots in the Asutan Ekpe area (Expt. 560-2) it was difficult to convince the people on whose land these plots were situated, that these palms belonged to them and that they should maintain them. The argument was that since the WAIFOR did the planting, this institute is exclusively entitled to the produce of the palms.

Where palms are owned by a group of persons, in most cases one of these persons *e.g.* the chief or the chief dealing with land affairs, administers the palms as trustee. In this case the trustee receives certain quantities of the palm produce as a gift or a tribute.

The following various types of ownership, quoted in the literature, are mentioned.

With the Adioukrou in Ivory Coast palms of the largest grove are owned by individuals. The various village sections also own groves. During the six months of peak yields every family is allocated a part of the grove within the village section (ANON., 1957a, pp. 112–113).

In the Fanti and Krobo areas of Ghana palms are, except in special cases of agreement, generally exempted from the operation of *abuse* or *abunu* land tenancy. Moreover, the tenant is obliged to improve the growing condition of the oil palms on the land cultivated by him *e.g.* he should clean the palm and clear the bush around them. He is allowed to take palm fruits for private consumption only and so he may not sell them. Nor may the tenant fell any palm without the consent of the owner.

Among some tribes of the Lulua in Congo the non-productive *pisifera* palms are owned by the chief, while all the other palms are owned by the community (JANSSENS, 1917, p. 228).

For Nigeria data for the following tribes have been recorded. Among the Yakö in Eastern Nigeria 'free' palms were found (FORDE, 1937, p. 42). In the Degema Division palms are, according to APPAH (1951, p. 3) owned by the village chief; however the oil palm is not very important to the Degema as they are fishermen and so have other means of sustenance. In the Ibibio districts with the Ikono the palms belong to individuals, but with the neighbouring Ekpe to the members of a village. With the last-mentioned implies membership of the *Ekon* society – a semi-secret organisation – an advantage for harvesting oil palms, since non-members have to pay a small fee to the society. Similar cases were observed by MARTIN (1956, p. 9) and MEEK (1957, p. 174) in those districts. Palms are owned by the village members with the Okun and the Afaha, among whom the *Obong Ison* – the chief dealing with land matters – administers the palms. Young men wishing to earn a dowry are allowed to harvest a certain number of palms, after having paid a fee to the *Obong Ison* (JEFFRIES, 1923a, 1923b; SHUTE, 1925; HAWKESWORTH, 1931). In the Asutan Ekpe area the author was informed that palms on which individuals have the right of harvesting are sometimes temporarily brought under village ownership and that the idea underlying it is that everybody has to pay tax and therefore must have the opportunity to earn money. This is an interesting case in which the rights on the palms shift from individuals to the group and back again. So the rule is that individuals have the right to harvest the palms on their compound during the season of low yield, while during the season of peak yields the palms are invariably harvested by the village. However, the people themselves look upon it as much the same way as they informed the author. CHUBB (1947, paras. 99–111) and ARDENER (1953, p. 900) dealt with the ownership of palms in Iboland. CHUBB reviewed the literature, while ARDENER made a detailed study in the Mba Ise area. It was also he who found that palms in dense groves are group owned, while individuals may own palms by planting or by inheritance. Women may also own palms; they may obtain them as a wedding gift, as a present on the birth of a child or by inheritance where this is matrilineal. It is very likely that this applies to planted palms, because a great deal of planting is going on in Iboland (see section 4.3.3). Small palm owners – both men and women – can increase the number of palms to which they have a right to harvest by pledging. In Nupe country oil palms are usually held by the chiefs and other family heads to whom rights over the palms may have been transferred. Other persons are disentitled to have oil palms and strangers are in no better position with respect to palms on land allocated to them (ELIAS, 1953, p. 176). LLOYD (1962) described various rights over oil palms in some districts of Yorubaland. In Ado Ekiti area the arrangements for harvesting palms vary from one lineage to another. In some the lineage heads have a stand of palms reserved for themselves; in others lineage members may reap the palms either anywhere, or only on land farmed by them, taking some of the oil to the lineage head. In general, the lineage head may grant oil palms to Urhobo; the rent being about 40% of the oil obtained (LLOYD, 1962, p. 209). In

Ijebu area harvesting is done by full members of the village *i.e.* those who fulfilled the village duties. Usually once a month a day is fixed on which in some villages all palms, in other only palms in dense groves, may be harvested. Palms on land cultivated may be harvested by the farmer (LLOYD, 1962, p. 175). One member of a village is allowed against payment of a rent to the village community to lease palms to strangers (Urhobo). These are permitted to harvest as much fruit as is equivalent to a certain number of tins of oil, but with the Ikale the licences are not bound by such a rule. In Ondo area rights over palms on the land of a subordinate town are still ill-defined. It is common practice that the palms are owned by the *oloja* (king) and people farming the land for a long period (LLOYD, 1962, p. 129, 178). Now Urhobo immigrants are doing the harvesting, *e.g.* LLOYD (1962, p. 97) reported that in the Ondo District 2,000 Urhobo oil palm licencees were found.

Plegde has already been mentioned above and it concerns mainly planted palms, but according to MEEK (1957, p. 172) it is common in the western parts of the former Colony of Lagos. There plots with palms are also sold. However, ELIAS (1953, p. 176) reported that in Popo area and West District of the former Colony in the Awori region only persons native to the soil were allowed to harvest palms, although these palms may grow on land used by a non-native to the soil.

Strangers may often harvest palms which stand on uncultivated land (ELIAS used the term 'virgin land'), but they usually cannot do so when the palms stand on cultivated land (ELIAS, 1953, p. 107), but this only holds true where rights over palms are rigid. Then the stranger needs the consent of the owner and has to pay a fee.

A clear case of reversion is described in section 7.2.5. Planted palms may be pledged, sold or bequeathed. HERKOVITS (1938, pp. 92–94) described a case in Dahomey, where large oil palm vineyards are planted by the members of the royal families. These plantations are administered by the head of a family. When he dies the vineyards are divided into two parts which may be equal or unequal. One part goes to the successor as a source of income to maintain his court. The other part goes to the second son, who has to use it as a source of income to pay for royal ceremonies. These sons are not the owners, since they did not do the planting, they hold the plantations as trustees for their family. Here too, rights over palms and over land are separate, *i.e.* the trustee may allot parts to farmers who may not harvest palms standing on this land and they are forbidden to damage the palms by pruning or scorching them. Before setting fire to bush cleared for farming, they must remove the rubbish from under the palms.

7.2.2 Number of palms owned

The number of grove or planted palms owned by a group or individual varies considerably. Not many data are available in the literature and the author was only able to add data on palms of one grove which were owned by individuals.

At time of purchase of the Uruk Obong grove (Expt. 503-1) at the substation of the WAIFOR 1,233 smooth-stemmed, 1,242 rough-stemmed and 625 stemless palms (total 3,100 palms) were counted. These palms were owned by individuals and the number of palms per individual is given in Table 22.

Table 22. Expt. 503-2. Number of palms of the Uruk Obong grove owned by some individuals

Persons and families	Number of palms owned			
	smooth-stemmed	rough-stemmed	stemless	total
1.1	328	363	189	880
1.2	185	212	139	536
1.3	95	97	60	252
Total	608	672	388	1,668
2.1	47	74	26	147
2.2	123	104	57	284
2.3	13	29	6	48
2.4	13	28	12	53
Total	196	235	101	532
3.1	3	3	2	8
3.2	15	8	5	28
3.3	54	31	1	86
3.4	9	17	1	27
3.5	22	20	2	44
Total	103	79	11	193
4.1	24	18	4	46
4.2	19	6	0	25
4.3	15	12	2	29
Total	58	36	6	100
5.1	22	2	1	25
6.1	208	207	111	526
7.1	4	3	2	9
8.1	34	8	5	47
Total	268	220	119	607
Grand total	1,233	1,242	625	3,100
Per individual	65	65	33	163

N.B. These figures include palms growing outside the experimental part of this grove.

The family 1 owned over 50% of all palms. The clan chief belongs to this family. Person 8.1 is an immigrant who is said to have been given the right to harvest the palms from the owner and to have taken ownership for granted after the latter died. It is likely and in one case even certain, that some of the owners also had rights over palms in other groves.

MARTIN (1956, p. 10) gave information on the average number of palms per household, but she admits that in some cases not all palms on which a household had rights were reported to her. She found that the average number of palms per household was 84 ranging from 24 to 225 palms. These 84 palms were divided into 45 old, 23 young and 16 very young palms. These figures are lower than for the Uruk Obong grove.

According to BRASSEUR (1953, p. 96) the number of palms owned per individual varies around Porto Novo in Dahomey. He did not give figures, but said that persons owning 25 or fewer palms would sell the fruit obtained on the market as it was not worthwhile processing.

GROVE (1951, p. 300) reported on the mean number of palms owned by individuals in the Udi Division in Eastern Nigeria. In this area oil palms mainly occur in village groves and have been planted. He said that one man may claim about 20 palms, seven of these palms provided wine and household oil, while the produce of the others was for sale.

7.2.3 Pruning of leaves

In many areas such as those around Abak, Umuahia and Onitsha everybody has a right to cut leaves from palms – even of planted palms. The leaves are cut to give farm crops more light or to use the leaves for thatching or covering compound walls (*e.g.* near Nnewi near Onitsha). In such cases all but the spear leaves are cut.

Whenever green leaves are pruned the growth of the palms (see section 6.1.7) may be retarded and consequently the yield of the palms may be reduced. This custom is, therefore, a nuisance to every owner of grove palms who wishes to improve them and especially to owners of planted palms.

7.2.4 Changes in rights over palms

Due to the opening up of the land and with the advent of various religious mission societies, the establishment of governments and the introduction of tax, some established laws in the oil palm 'culture' have changed or are on the point of changing. For instance, in Benin it was impossible to plant oil palms without the consent of the local authorities. This custom hampered the planting scheme started in 1928. To support this scheme the *Oba* (king) of Benin abolished this custom saying that it was always wrongly 'interpreted' (FAULKNER, 1933, p. 23). With increasing success of the work of religious mission societies, these societies sometimes were accorded the right to harvest a part of a village owned palm grove in the Anang Province and probably other provinces too. Of course such right could only be obtained when a sufficient number of villagers were converted to Christianity. A gradual change from village ownership to private ownership began in the Anang Province in Eastern Nigeria when people started to claim ownership of palms, on the basis that 'these palms were exploited by their fathers' (ANON., 1933).

7.2.5 Rights over palms affecting the actual output of a grove

It has already been mentioned that in many cases the farmer of the land and the harvester of the palms are different persons. The farmer, therefore, has no interest in caring for the palms which hamper his work and shade his crop, and as a result the palms are heavily pruned or scorched by fire. It would be better if the farmer would also be the harvester of the palms and better still if the farmer would own the land *and* the palms on it. This would enable him to make improvements which would increase the yield of his arable crops and that of his palms.

Around Porto Novo in Dahomey, the big owners are not able to harvest all their palms, so some are let to small owners (BRASSEUR, 1953 p. 96). Complete exploitation is assured, but neither the big owner nor the tenant carries out any improvement which would increase the future output of the grove. In the Kigoma district in Tanganyika where the system of reversion is known an old man is likely to be allowed to fell – for wine tapping – the palms allocated to him, in order to make sure, that he himself gets as much out of them as possible before he dies. Due to this custom the oil palm industry in that district was on the decline (CAIRNS, 1937, p. 454). It is often suggested that group ownership hampers any improvement, because such work needs the approval of all the villagers. But an exclusive system of ownership by individuals also hampers such work because then the consent of each owner is required. However, in the latter case an attractive subsidy scheme may have a rapid result.

7.2.6 Rights over palms with respect to the rehabilitation and improvement

Changes in locally operative rights over land and palms, leading to the creation of formal title to land and palms, are necessary if the rehabilitation and improvement of palm groves (see section 10.4) are to be successful. Enterprising men should be able to obtain land and to be allowed to fell any palms and other trees on it. However, they must often realise that their initiatives fail to be successful and any work is destroyed. But occasionally they either get the permission or they take the risk.

During his stay at Abak the author experienced that a person was stopped half way planting a four hectares plantation by another person and that he was threatened either by loss of his palm plot or by going to court. In this case the dispute was privately settled. In another case a planter took a similar risk by planting a three hectares plantation. He happened to be lucky, although even one person could have stopped him. The planter would have a strong position in court if any dispute would arise after a year or so.

A land registry would make rehabilitation easier, as in this case an originator could make arrangements with any co-owner *before* starting the planting. However, the first requirement for land registry will be detailed maps and these are not yet available for many parts in Africa.

7.3 Local consumption

7.3.1 Introduction

The local consumption of palm oil is quite often estimated by taking the difference between the quantity of palm oil believed to be produced in a country and the quantity exported. The total quantity of oil is calculated by assuming that all kernels are exported and that there is a fixed ratio between oil and kernels, but this can only give an estimate within wide margins. For instance in some areas only fallen, half rotten fruits are collected and these yield only kernels; moreover the quantity of oil produced will be affected by the processing methods employed. There is also a drawback to this method of estimation *viz.* it does not differentiate between the use of the oil as food, as cosmetic oil and as fuel for lightning purposes.

7.3.2 Palm oil as food

Palm oil is an important source of fat for the people of Africa and is of particular importance in tse-tse fly infested areas, where animal husbandry is almost impossible. Palm oil is rich in pro-vitamin A and therefore the oil palm has been introduced into some areas where the diet was deficient in this vitamin.

The principal factor influencing the amount of palm oil which is consumed, is its price, but consumption also varies with the season because palm oil cannot be taken on its own, but is eaten with yam, cassava or rice. Thus in periods of food shortage, the consumption of palm oil is also much reduced. Superstition sometimes influenced the amount consumed, as in the case of the Lulua in Congo whose daily consumption was the quantity of oil that sticks to two chicken feathers. They believed that a larger quantity had an adverse effect on their health (JANSSENS, 1917).

In Nigeria the quantity of palm oil available diminishes according to the distance from the main Palm Belt in the South increases, and consequently the contribution to dietary energy also diminishes. The contribution to the diet from palm oil in the Warri area (5° 30N), is 348 kcal, while at Bida (9°30N), where palms are only found in *kurumis* the average contribution is 190 kcal and at Kontagoro (10° 20 N) situated right outside the oil palm range no palm oil is consumed. Generally in the Palm Belt the daily dietary contribution from palm oil ranges from 300 to 400 kcal which is about 15% of the total calorie intake (ALLISON, 1946; ANON., 1957b; GRÜNER, 1904; UNWIN, 1920). Although it is difficult to say what the required fat consumption of a man is, DEN HARTOG (1963) suggested that 25% of the total calorie intake might be derived from fats. Assuming that the total daily intake of an adult farmer is about 2,700 kcal (DUPIN and DUPIN, 1959), it follows that about 675 kcal a day must be obtained from fat. Adding fat from other sources it seems probable that this requirement is fulfilled by people living in the main Palm Belt.

When palm oil is regularly taken no vitamin A deficiency occurs and as it is difficult to consume big quantities of palm oil no cases of hypervitaminosis are observed (DEN HARTOG, 1963).

7.3.3 Palm oil as cosmetic and lamp oil

The use of palm oil for embrocation and lightning has considerably decreased since the introduction of soap, medicine and kerosine, although in many areas it is still used for these purposes. The quantities used in these ways will vary from person to person, from place to place and from season to season, which is borne out by the figures given in the literature ranging from 4 to 100 g a day for cosmetic and from 5 to 50 g a day for lamp oil (HUBERT, 1911; BROUN, 1914; JANSSENS, 1917; UNWIN, 1920).

8 Diseases and pests

8.1 Introduction

The oil palm is remarkably free from pests, but various diseases can cause losses. In some plantations in Africa vascular wilt and recently dry basal rot may be troublesome. Trunk rot is in West Africa the principal cause of death of grove palms, where it should be regarded as a disease of senescence which kills palms when they (and the grove) are passed the optimum stage. In South-East Asia many old and young planted palms are killed by this disease.

Where soils are deficient in one or more major or minor elements, nutritional disease may be of importance, but grove palms often grow on poor soils without the mineral composition of the leaves falling to the level at which deficiency symptoms become apparent. Nutritional diseases were discussed in section 6.1.6.

Other diseases are of minor or no importance in palm groves and will therefore only be mentioned.

In many cases research workers quoted below do not mention in their reports the author(s) when reference is made to species of fungi. In such cases the present author also omits the author's name in order to avoid giving the impression that the fungus worked with and the species originally described are really identical.

8.2 Trunk rot

8.2.1 Introduction and taxonomy

In the palm groves of West Africa most grove palms die from trunk rot which nevertheless is often regarded as being of little economic importance. However, HARTLEY (1954) considered this disease as the main cause of groves having suboptimal stands, with consequent reduced output of fruit. In South-East Asia trunk rot is often of great importance, causing the death of many adult and since 1956 also young plantation oil palms (LARTER, 1956; HEATH, 1958). In affected areas replanting becomes difficult because the stemless palms may become infected. Some investigations, mainly in Asia, have been carried out to prevent palms from becoming infected or to control further spread of the disease in palms which have been attacked.

The first record of a stem rot of the oil palm is given by BROUN (1914) for the Équateur Province of the Congo. He found sporophores of a fungus belonging to the

Polyporaceae on the base of an oil palm. A photograph shows sporophores which resemble those of a *Ganoderma* species. Since then the disease has been reported from all oil palm areas in Africa. Trunk rot was first reported in Asia at the end of the 'twenties' (WIJBRANS, 1955). In 1920 WAKEFIELD mentioned *Ganoderma lucidum* (LEYSS, ex FR.) KARST. as the causal fungus, while in the same year MAUBLANC and NAVEL (1920) mentioned *G. applanatum* (PERS. ex WALLR.) PAT.

The taxonomy of the genus *Ganoderma* (KARST.) EM. PAT., and of related genera is not completely understood. In general, authors referring to the causal fungus of trunk rot mentioned *G. lucidum* without reporting whether the fungus found had been identified as such. VAN OVEREEM (1925) believed that the names of the species *Ganoderma mangiferae* LÉV., *G. sessile* MURR., *Polyporus fulvellus* BRES., *P. resinosus* SCHRAEDER and *P. curtisii* (BERK.) MURR. are synonyms of *G. lucidum*. BOEDIJN (1955) stated that this last-mentioned species only occurs in temperate regions, while WIJBRANS (1955) thought that what was described as *G. lucidum* consists of several species: *G. laccatum*, *G. tropicum* and *G. cochlear*. ROGER (1951) described *G. applanatum* (PERS.) PAT. as a group of species divided into *G. lobatum* (SCHW.) AFK. and *G. applanatum s. str.* He divided the latter into four varieties among them var. *tornatum* (PERS.) BRES., found in tropical Africa, which is said to be the causal fungus of trunk rot in that area.

Other species belonging to the genus *Ganoderma* and a number of species belonging to the genera *Fomes*, *Lentinus*, *Phellinus*, *Polyporus*, *Polystictus* and *Poria* are reported to cause stem rot. All belong to the *Polyporaceae*. Therefore more research should be carried out on the taxonomy of fungus species causing stem rot in oil palms and it should be borne in mind that not all cases of stem rot are caused by '*G. lucidum*'.

The present author understands by trunk rot the wide-spread stem rot of the oil palms of the palm groves in southern Nigeria and often described as '*Ganoderma trunk rot*'. It seems even preferable here to omit '*Ganoderma*' as none of the sporophores from diseased palms were sent to an authoritive mycologist for identification.

Besides the oil palm several other plant species, including palms are attacked by the fungus described as *G. lucidum*. VENKATARAYAN (1936) reported that 44 species belonging to 18 families and 34 genera are attacked. About 39% (17 species belonging to 11 genera) of these are legumes. Coconut palms (*Cocos nucifera* L.) are also attacked by *Ganoderma* spp. This was also noted by the author for some coconut palms standing in the Ikot Okpong and Uruk Obong palm groves (Expts. 501-1 and 503-2). Other plant species often found cultivated or naturalized near grove palms such as bamboo (*Oxytenanthera* sp.), *Coffea* spp., 'King' orange (*Citrus* sp.) and mango (*Mangifera indica* L.) are reported to be susceptible too (ROGER, 1951; PIENING, 1961), and it is likely that they and the oil palm serve as foci of infection.

One of the Ibibio vernacular names for this disease suggests a relationship with *Cola rostrata* K. SCHUM. (see section 8.4).

In Ibibio district in Eastern Nigeria it is believed that the shrub *Millettia aboensis* BAKER (Papilionaceae) induces and promotes the spread of trunk rot especially on the black *mbri* soils (see section 6.1.10). It is said that 'That plant kills the oil palm' because one or two years before the outbreak of trunk rot among the palms, saplings of this shrub may be found growing up under the palms. No sporophores have been found by the author on this shrub, but the possibility that it is an external symptomless carrier of this disease cannot yet be excluded.

8.2.2 Symptoms

There are various external symptoms of trunk rot. When the disease progresses rapidly the leaves collapse basally to form a cloak around the top of the trunk. The 'spear' may often remain erect until it is blown over. This symptom resembles the wilting seen in palms struck by lightning, or lacking water. When the progress of the disease is slow, newly opened leaves are short and yellowish. Sporophores may be formed on the stem, generally on the lower part, but sometimes near the crown. The disease weakens the roots and the stem; the palm is easily blown down, and sometimes the stem cracks at several places when it hits the ground. In such cases sporophores may be present or absent. If the fungus attacks a young palm the symptoms are similar to those found in palms affected by basal decay (BULL, 1954). In the case of smooth-stemmed palms in the Uruk Obong grove at Abak, the average length of time recorded between the observation of the first symptoms of trunk rot and the death of the palm was 19 months, but the time between the actual infection and the appearance of the first symptoms is not known. NAVARATNAM (1961) has made some preliminary investigations on this aspect of the disease (see section 8.2.4).

8.2.3 Incidence

In 1953, R. A. BULL (TOOVEY, 1954) carried out a survey of the incidence of trunk rot among smooth-stemmed palms in the Ikot Okpong grove and in a grove near Obio Akpa, and recorded incidences of 7.7% and 9.7% respectively. The writer carried out a similar survey in October, 1960 and found, in the Uruk Obong grove, the incidence for all palms to be 10.4% and for smooth-stemmed palms 16.4%. No stemless palms with visible symptoms of this disease were found at the time of survey, although they were observed during other visits (see section 8.2.4). It will be shown later that the incidence of externally diseased palms or palms dying depends on the stage of the development of the grove and also on the season. In a dense, mature grove the palms which are attacked are scattered throughout the grove and are mainly the old tall palms only. At a later stage the palms attacked occur in groups. As the process of the decline of the grove proceeds, palms of *all* heights are attacked and killed, gaps are formed in the grove which are then farmed. At the fringe of such spaces many more palms are attacked, thus widening the space, which gradually coalesces with others. Eventually the grove subtype 'Farmland with some palms left' or 'Farmland without palms' is formed.

Plate 12. A 'pocket' of palms suffering from trunk rot. The resulting open area is used for farming.

8.2.4 Dispersal and infection

From literature no clear idea can be formed about the biology and the life of *Ganoderma lucidum* and other *Ganoderma* species. Few experiments have been carried out and most data are restricted to observations. In general woody crops are invaded either through roots or through stem wounds or both. THOMPSON (1937) believed that for the oil palm both stem and roots are invaded. BULL (1954) reported that the oil palm is mainly infected through the roots. But there is no certainty about the natural way – or the common way in case more ways are existant – of invasion of the oil palm by *Ganoderma* spp.

NAVARATNAM (1961) performed inoculation experiments. He succeeded in getting diseased oil palms by inoculating with a pure culture of *G. lucidum* on agar both through a hole in the stem and through roots.

TURNER (1965) did not eliminate infection by air-borne spores via old leaf bases on the bases of the stem of plantation palms in Malaysia. But he thought that root infection is the main form of entrance as he found that a stem of a palm although healthy-looking was infected via the roots. He admitted that the roots might have been infected by spores, but on the other hand he also found dead roots of a diseased oil palm in the area between this palm and a stump of a coconut palm. He concluded that stumps of coconut and oil palms could form foci to newly planted oil palms and that root contact between diseased and healthy oil palms was likely to be the main cause of spread of the disease. Any diseased palm should, therefore, immediately be removed.

In this respect it is interesting to note that in previous years the way and mode of entry of root rotting fungi in tropical crops was discussed. Inoculation experiments with mycelium grown on agar or with spores did not succeed until DE JONG (GARRETT, 1956) proved that a high inoculum potential (GARRETT, 1960) is needed for infection. He obtained invasion of unwounded roots only when pieces of wood overgrown by the pathogen were used as inoculum. Later other investigations confirmed this conclusion. However, RISBETH (GARRETT, 1956), proved that *Fomes annosus*, a species from temperate regions, which infects species of conifers and deciduous trees, by means of spores can invade new cutting areas of stumps. From these it may infect neighbouring trees by root contact. This seems to be a normal way of attack of healthy *Pinus* stands after thinning.

How far wounds on stem or branches of healthy and well growing trees may serve as a way of entry is not clear. Some authors claim that this may be the case.

As stated above in the oil palm no decisive experiments have been performed to prove which is the normal way of infection.

In agreement with the root rots of tropical crops infected roots by root contact or root and stem remnants of formerly infected trees left in the soil likely seem to serve as sources of infection of healthy trees. As regards infection through the stem the situation in oil palm is different from that in other crops. Wounds caused by cutting leaves and bunches, wounds cut in apical tissues for wine tapping purposes and lower in the stem to facilitate climbing are quite common and therefore may serve as a way of entry for spores. Up to now there is no definite proof of the significance of these wounds in the infection process by spores.

In Table 23 the number of palms killed by trunk rot in two plots (total area 0.4 ha) of the Uruk Obong grove from 1949 onwards is given.

It should be borne in mind that several palms were very likely killed before the first plan was prepared. Figure 9 shows the spread of the trunk rot through these plots. It

Table 23. Expt. 503-1/2, plots 19 and 22. Number of palms killed by trunk rot in a part (0.4 ha) of the Uruk Obong grove over the years 1949 – June 1965

Stem type	Number of palms killed			
	1949–1953	1954–1959	1960–June, 1965	per year
Smooth-stemmed	6	6	12	1.4
Rough-stemmed	8	6	12	1.6
Stemless	3	1	2	0.4
Mean per year	3.8	2.2	4.7	3.4

is evident that the disease is ravaging in the middle of the area and is slowly spreading in southern direction. Some smooth- and rough-stemmed palms were still standing in the open area in June, 1965, but most of these palms or all of them will eventually be killed. The mean death rate is three stemmed palms per year, this is 7.5 stemmed palms per hectare per year. The gap will be used for farming and once large enough it could be used for a new residential area.

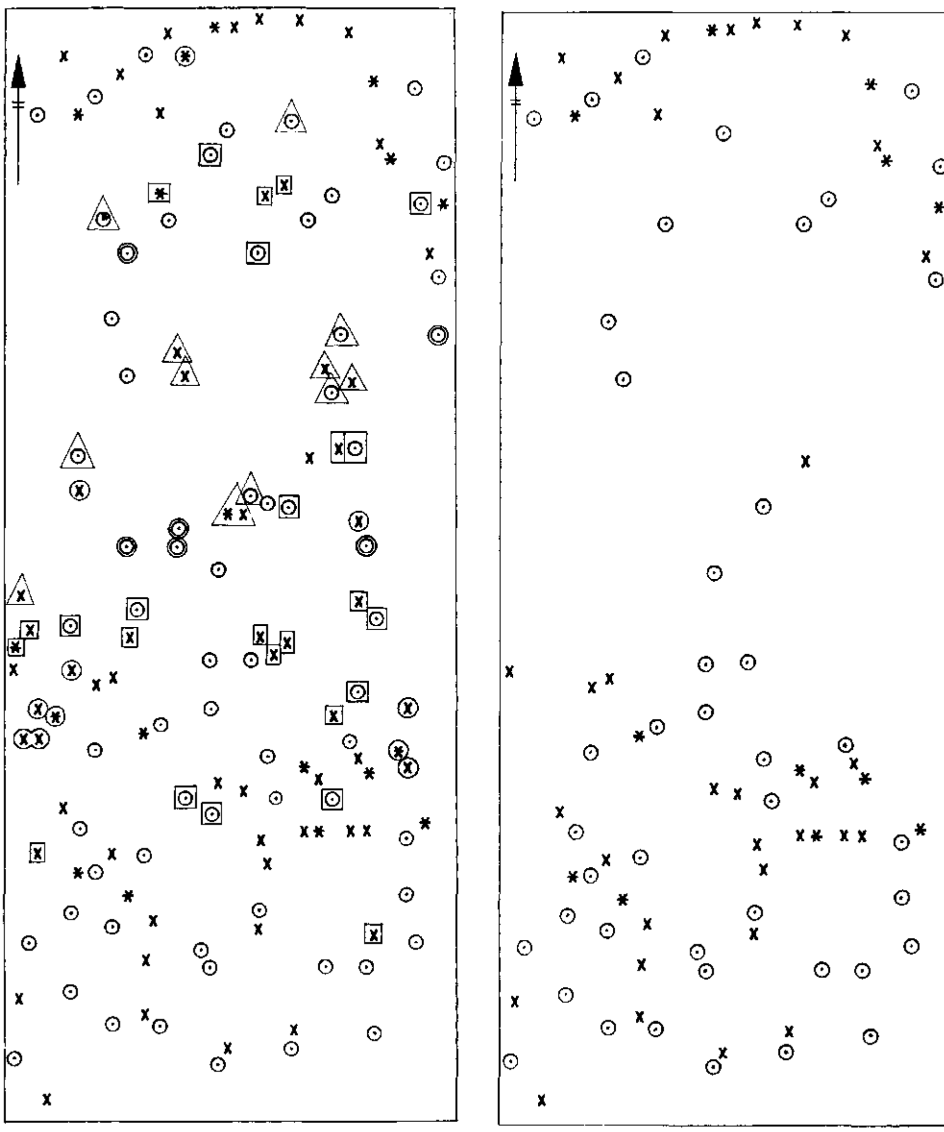

Figure 9. Expt. 503-2. Spot plans of plots 19 and 22 (⊙ = smooth-stemmed palms, × = rough-stemmed palms, ∗ = stemless palms) made in 1949 (left) and 1965 (right). Palms marked with ◯ died in 1949-1953, with △ in 1954–1959 and with □ in 1960–June 1965

8.2.5 Factors influencing host-pathogen relationship

Introduction. The factors influencing host-pathogen relationship are those which influence either the inoculum potential or the host defence mechanism. The factors discussed here are: age, competition, soil and season.

Age. Many young oil palms in South-East Asia become infected when planted on soils which carried oil palms which were diseased by trunk rot. In 1963, the author observed an in 1962 near Abak (Expt. 508-1) planted young palm to have been killed by this disease. This is probably the first record of such a young planted palm being killed from that area. This palm was planted on the root mass of a felled grove palm. Stemless palms in groves are occasionally attacked and killed by trunk rot. Then they often carry sporophores on the stool. The progress of the disease must be rapid as no such diseased stemless palms are generally observed which gives the visitor the impression that only stemmed palms are attacked.

As age is roughly related with height of the palms incidence related with height might give an idea about incidence related with age. Thus R. A. BULL (TOOVEY, 1954) measured the height of smooth-stemmed palms in a part of the Ikot Okpong palm grove and in a grove near Obio Akpa. He found that smooth-stemmed palms below eight metres in height were not attacked nor were rough-stemmed palms or stemless palms. In 1962 the author measured the smooth-stemmed palms of the Uruk Obong grove and noted the disease incidence per height group:

Height group (m)	Number of smooth-stemmed palms	Incidence (%)
>24	2	100.0
18–24	109	27.4
12–18	580	13.8
6–12	321	9.0
<6	104	1.9

Although it is not possible to analyse the data statistically, it is apparent that the incidence of trunk rot increases with the height of the palms and consequently generally with increasing age. In this survey only 0.5% of the rough-stemmed palms and 1.0% of the stemless palms were affected. Stemless palms which were attacked were growing at the base of a diseased smooth-stemmed palm.

REES (1963b) suggested that with increasing age palms become senescent due to the increasing respiratory load, particularly of the stem which contains a high percentage of living material. Eventually photosynthesis is insufficient to maintain respiration, the palm declines in vigour and becomes susceptible to fungal and other attacks. An unfavourable balance between photosynthesis and respiration may be reached earlier if the palm is shaded or if the assimilation tissue is reduced. Root competition may also weaken the palm.

Competition. DELL (1955) stated that in Sumatra, oil palm plantations which were neglected for some years showed a higher incidence of trunk rot, than well-maintained plantations. He believed that the higher incidence might be attributed to the reduced vigour of the palms, which had to compete with regenerating forest flora. A natural example of palms competing with forest flora is provided by palms growing in secondary rain-forests. The majority of the older palms in these areas are killed by trunk rot, but no information is available about the influence of competition between oil palms and forest vegetation at the onset of the infestation and the degree of attack of the disease.

WATERSTON (1953) related the incidence of trunk rot to the density of the palm groves in Ibibio Asutan Ekpe area; this was an error, for in this area the farmers deliberately fell diseased and also healthy palms, and the practice is reflected in the low incidence of trunk rot in that area which reaches a maximum of only 2.5%.

Detailed examination of the data for the Uruk Obong grove failed to show any correlation between the number of palms suffering from trunk rot and density of stand (see table 24), or R/S quotient. The same holds true for the correlation between increasing age of the grove (decreasing R/S quotient) and incidence of trunk rot, although there is a tendency that the incidence increases with the age of this grove.

Table 24. Expt. 503-2. Percentage of incidence of stemmed palms suffering from trunk rot as regards density/ha and R/S quotient, in the Uruk Obong grove

	Density per ha							
	18	27	56	73	91	109	132	148
Incidence (%)	0	16.7	3.6	7.7	14.0	10.5	6.8	5.4
R/S quotient	0	0.13	0.47	0.49	0.36	0.29	0.52	0.44

Soil. The resistance of the palm against a fungus may be influenced by several soil factors. Drought and prolonged waterlogging may particularly destroy the root system of the palm, thus weakening it and allowing a predisposition for infection.

Several authors (*e.g.* ALLEN (1954) and PRENDERGAST (1957)) discuss the nutrient status of the soil and its influence on the susceptibility of plants to fungal diseases. They showed evidence that an adequate supply of potassium slows the rate of infection, while high nitrogen levels have the opposite effect, but how these effects are brought about is not fully understood.

PRENDERGAST describes an oil palm plantation fertilizer experiment in which applications of a potassium fertilizer dressing slowed the spread of vascular wilt caused by *Fusarium oxysporum* (SCHL.) emend. SNYDER ET HANSEN. In the Palm Grove Manurial Trial (Expt. 503-2, described in section 10.3), the number of dead smooth-stemmed palms was recorded for the pre-treatment years 1954–1956 and for the experimental years 1957–1959. The transformed data (angular transformation) were analysed by covariance analysis. The adjusted death rates per treatment expressed in percentages loss were:

Potassium		Potassium × Bunch refuse			
level	% loss	level	% loss	level	% loss
0	7.6	00	16.1	01	10.1
1	2.5	10	2.9	11	5.8
2	3.2	20	7.7	21	6.6

Application of potassium very significantly reduced the rate of death, presumably by increasing the resistance of the palms. It is probable that the effect of bunch refuse is also attributable to the potassium which it supplies. TINKER and SMILDE (1963) found that the dried stalks of fresh bunches contain 2.3% potassium. The precise quantity of potassium applied in the bunch refuse is difficult to assess accurately, but the quantity applied every second year was estimated at more than 1.6 kg of potassium sulphate per palm. There was also a marked response in bunch yield to the application of potassium and this may be partly ascribed to the reduction in the death rate in the plots receiving potassium fertilizer. However, other factors such as density of stand, potential yield capacity and height of the palms must also be taken into account.

ROGER (1951) pointed out that *G. lucidum* was mainly found in dry soils, while *G. pseudoferreum* and other fungi causing stem rots were often found in moist soils. A high incidence of trunk rot on the black *mbri* soils is said to occur in the Ibibio district of Eastern Nigeria (see section 6.1.10), but this local opinion may well have been motivated by the fact that there is a tendency for palms on this soil to die out simultaneously rather than over a period of years, as is the case in the ordinary acid sands. It is also asserted that replanting on such soils would be difficult, but this is not supported by field experience.

Season. Monthly observations were made by the author in the palm groves on the WAIFOR substation on the number of palms showing the first symptoms of trunk rot and on the number of palms dying. It seemed probable that the occurrence of the first symptoms and of the death of the palms might be correlated with climatic conditions; it was found that there is a negative correlation between the number of palms showing first symptoms ($r = -0.37^*$) or dying ($r = -0.51^*$) and rainfall in the same month. However, it cannot be asserted that low rainfall in itself is the causative factor; some other factors may be involved which are also correlated with rainfall. *E.g.* temperature is lower during the rainy season than during the dry season, except for the *harmattan* period. According to CARTWRIGHT and FINDLAY (1934) the temperature is the main factor determining the rate of the development of the fungus in laboratory experiments. Good growth of *G. applanatum* on malt agar was obtained at temperatures ranging from 24 to 34 °C being optimal. These temperatures are usual in palm growing areas of Africa and in Nigeria the temperature of 30 to 32 °C is the average monthly temperature at 14.00 hours during the period from November to May. Furthermore many palms are recorded as dead after heavy rain. The causal factor is not the rain, but tornadoes which blow down the palms which are already weak.

The above observations showed that many palms exhibit the first symptoms of trunk rot in the months of December, January and February (Dry Season) and also in September, but only a few show them in July. The death rate was high in March and in June, and low in December and January (see Figure 10).

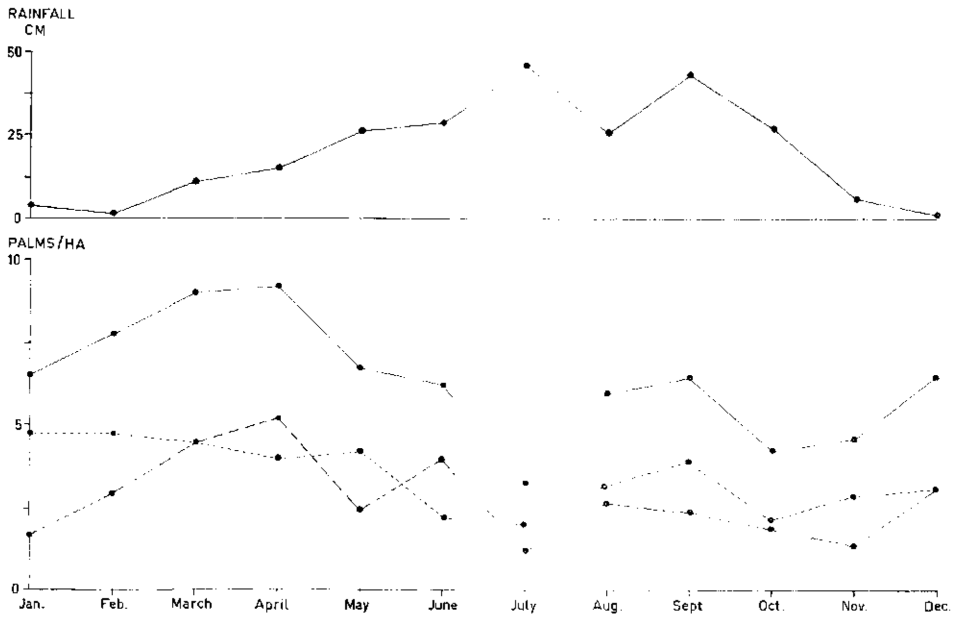

Figure 10. The relationship between the mean monthly rainfall and the mean monthly number of newly observed diseased (·······), killed (- - - - -) and total affected (– ——) stemmed palms per hectare over February, 1960 to January, 1963

8.2.6 Control

No attempts at breeding or selecting for resistance to trunk rot have so far been reported, but this could provide an answer to the problem in South-East Asia. Control by attempting to prevent or eliminate spread of the disease in a palm grove is very expensive, and therefore economically not justified; the best solution is to put in hand a replanting programme.

8.3 Other diseases, injuries and pests

WATERSTON (1953) found patch yellows, bud rot and orange frond disease in addition to trunk rot during his disease survey of the palm groves in Asutan Ekpe area. Lightning damage, injuries caused by insects and palms with cavities of unknown origin in the stem, were also recorded. The latter palms may survive for many years, but are dangerous to climb and therefore are not harvested; they remain as a permanent obstacle to the development and production of neighbouring palms. When the hole occurs in the lower part of the stem, adventitious roots are often found above the hole.

Where standing oil palms are tapped for wine the incidence of stem injuries is high. Plants of species belonging to the genus *Platycerium* DESV. often grow in the holes in the stems. A disease survey carried out in October, 1960 in the Uruk Obong grove, showed that 0.7% of the smooth-stemmed palms, 0.2% of the rough-stemmed palms and 0.2% of the stemless palms were attacked by patch yellows, the causative agent of which is a species of *Fusarium* (BULL, 1954). Symptoms of vascular wilt, were observed in only a few grove palms, but this confirms WARDLAW's (1950) observation that grove palms do suffer from this disease.

In dense secondary forest near Benin 30 stemless oil palms were surveyed for disease in February, 1962. Two of them were affected by a spear rot and would die in due course and one was affected by anthracnose, while the remaining were healthy.

FOX (1964) was astonished at the fact that the pathogen *Armillaria mellea* (VAHL. ex FR.) QUÉL. has not been recorded on oil palms in Eastern Nigeria (and this also applies to all Nigeria) although the oil palm is susceptible and the fungus widespread (WATERSTON, 1953). FOX suggested that the fungus may be present in old palms without being active.

Injuries due to lightning damage are often seen in grove palms, but field observations have shown that the amount of damage depends on the proximity of the palm to the point of strike.

In the groves it is common to find palms which appear to be moribund, but do not show apparent disease symptoms. These palms suffer or have suffered from competition from which they will not recover when environmental conditions are improved. Some of these palms have large cavities in the stem.

No special animal pests are known, although birds and mammals may damage palms. *In fact the principal 'pest' is man, who cuts and scorches the leaves, bores holes in the apical tissues, cuts male inflorescences, makes incisions in the stem and even fells palms for wine tapping or to create farmland.*

8.4 Recognition of diseases by peasant farmers

In areas where the oil palm is common and of economic importance, some peasant farmers are able to recognise plant diseases with remarkable accuracy but the majority can only do so to a limited extent and frequently their diagnosis is incorrect.

The Ibibio farmers commonly recognise trunk rot as a troublesome disease and therefore it has several names in the vernacular. Some of the names are descriptive, while others suggest a resemblance with another plant, or refer to a place where the disease is often found. When the cause of the rot is not understood the farmer may ascribe it to a supernatural influence. The farmers do not always understand that there is a connection between the sporophores on the stem and the wilting of the crown.

In the descriptive class are the names *udip owot eyop* (mushroom killing oil palm) in the Calabar area; *udip ekpat eyop* (mushroom on stem of oil palm) and *eka udip* (big mushroom) in the Uyo area. A name which indicates a resemblance is *uma ison* (ground lightning), indicating the resemblance with the symptoms of a palm struck by lightning. Names referring to places where trunk rot is commonly found are *ubi ison* (black soil) and *udip ndiya* (mushroom on *Cola rostrata* K. SCHUM.). To the 'supernatural' class belong the names *ukan ekpo* (charcoal-black ghost) and *udip ekpo* (mushroom ghost).

Other vernacular names for diseases are *ekpo otop* (ghost harvest) used to describe a bunch rot, *ukom* for a bunch excreting gum, which is sometimes seen in the Rainy Season and *asat* (dry) which describes spear rot. For palms struck by lightning, only descriptive names are used.

Despite the many Ibo dialects the Ibo farmer's names for diseases of the oil palm are less variable than the Ibibio names. In the Umuahia area, trunk rot is called *onwu-nkwu* (death oil palm), while the sporophores are called *ero-nkwu* (mushroom oil palm). The farmers know that when the sporophores appear on the stem, the roots are rotten, although the leaves may still be green. The name for bunch rot is *asaere* in Orlu area and *achaere* in Umuahia area; literally it means 'ripe-rot' and it is believed that small black worms cause the stalk to rot. In Umuahia area, any palm with yellowish leaves, including those suffering from orange frond disease, is called *nkwu akanmara* (oil palm..?..). In Nbawsi area the name for trunk rot is *ero nanegbu nkwu* (mushroom killing oil palm) (WATERSTON, 1953).

In Benin Province the sporophores of *Ganoderma* sp. are named *osi* and are used for sacred purposes (WATERSTON, 1953).

9 Deterioration and retrogression of palm groves

9.1 Deterioration

The deterioration of palm groves shown by the development of a grove subtype into the next, still poorer stage, is discussed in Part 5 and shown in Figure 3. It was explained that in a rain-forest tall palms are eventually overtopped by forest giants and stop fruiting, while small palms can not grow up and die in due course. In Dense groves the main cause of the death of the oil palm is trunk rot, which is described in Part 8. An account of the extent of change of stand in some Dense groves is given below.

9.1.1 Change of stand

The object of the Oil Palm Survey in Asutan Ekpe area (Expt. 560-1) was to study the changes occurring in a grove and thus that of the transformation of one subtype into another. The groves which were classified in 1948 were re-classified in 1963, but it was found that felling of palms had upset the natural cycle and, had thus interfered with that part of the study. It was observed occasionally that a grove of the B-subtype had been thinned, a house erected on the plot and compound crops planted, thereby creating a grove of the E_1-subtype. All three plots of the E_2-subtype were unchanged although the compound of one plot had recently been abandoned, and this plot will now become a young B_1-subtype grove. Of the B-subtype plots 92% were unchanged as were 58% of the C(a)-subtype plots. Some plots defined in 1948 as belonging to the latter subtype were defined as B-subtype in 1963, which was probably due to a difference in classification between two observers. All the plots of the D-subtype were unchanged as were 90% of the E_1-subtype plots, one E_1-subtype plot (10%) being recorded as being of the D-subtype, as the homestead had been abandoned. It appeared that the compound had not been occupied long enough for the plot to become of the E_2-subtype and that, as the owner had not processed fruit there, it was unlikely to become of the B_1-subtype. A plot classified in 1948 as the F-subtype with palms planted about 1930, could not be recognized as such in 1963. An adjacent area still carried old planted palms which suggests that either the plot was wrongly classified or the owner had felled the palms. Parts of some plots had been planted up with stemless palms and these plots were classified by the undisturbed portion.

Changes in density of stand in the groves were recorded and the observations made in Experiments 18-1 and 560-1 have already been mentioned in sections 5.4.1 and

Table 25. Expt. 502-1. Change of stand between 1949 and 1960 in the Uruk Enung grove

Expt. 502-1	Smooth-stemmed palms/ha	Rough-stemmed palms/ha	Stemless palms/ha	R/S
Stand in 1949	96.3	65.4	27.4	0.7
Dead	22.0	11.9	4.0	
Change from: R to S	16.3	16.3	–	
Se to S	–	–	–	
Se to R	–	4.0	4.0	
New	–	4.7	37.8	
Stand in 1960	90.6	45.9	57.2	0.5
Change	–5.7	–19.5	+29.8	

Key: S = Smooth-stemmed palm, R = Rough-stemmed palm, Se = Stemless palm

5.4.4. The observations in the Uruk Enung and Ikot Okpong palm groves are set out in Tables 25 and 26. 23% of the smooth-stemmed palms, 18% of the rough-stemmed palms and about 15% stemless palms died over the period of eleven year. One quarter of the rough-stemmed palms shed their leaf bases to become smooth-stemmed, and these additions almost replaced the number of smooth-stemmed palms which died. There was an increase in number of stemless palms, but this was probably attributable to a difference in the method of classifying small stemless palms since the smaller ones were not counted in 1949 and 1960. The decrease of the R/S quotient indicates an ageing grove.

The picture in the Ikot Okpong palm grove was different (see Table 26). Several areas were occupied by villages until 1930–1940 and these areas now carry a young grove, while some other parts are now denuded of palms. The numerous young palms

Table 26. Expt. 501-1. Change of stand between 1949 and 1960 in the whole and in a part of the Ikot Okpong grove

Expt. 501-1	Esa Ekpo village				Whole area			
	smooth-stemmed palms/ha	rough-stemmed palms/ha	stemless palms/ha	R/S	smooth-stemmed palms/ha	rough stemmed palms/ha	stemless palms/ha	R/S
Stand in 1949	84.0	27.7	10.1	0.3	89.9	45.9	23.5	0.5
Dead	13.1	2.0	0.7		11.6	4.9	4.0	
Change of stem: R to S	5.9	5.9	–		6.7	6.7	–	
Se to S	–	–	–		0.5	–	0.5	
Se to R	–	7.6	7.6		–	7.9	7.9	
New	0.5	41.5	34.3		0.2	8.4	10.9	
Stand in 1960	77.3	68.9	36.1	0.9	85.7	50.6	22.0	0.6
Change	–6.7	+41.2	+26.0		–4.2	+4.7	–1.5	

Key: S = Smooth-stemmed palm, R = Rough-stemmed palm, Se = Stemless palm on the young grove areas have replaced the old palms which died and maintain the balance between stem types so that the overall change in the number of smooth-stemmed palms is small. The largest B_1-subtype grove is four hectares in area and is on the site of the former Esa Ekpo village.

As the Esa Ekpo area only covers about one-tenth of the total 42.5 hectares of the grove the change of stand figures for the remaining parts of the grove differ only slightly from the total figures and are, therefore, not given here.

The increase in the number of rough-stemmed palms and stemless palms in the Esa Ekpo area is very marked, as is the change in R/S quotient, although this did increase slightly over the grove as a whole showing that a small amount of regeneration went on between 1949 and 1960, but this is mainly in the village areas which were abandoned between 1930 and 1940. The death rate of smooth-stemmed palms in the young B_1-subtype grove areas is higher than the average, but the reverse is true for the rough-stemmed palms, of which there are many more than in the grove as a whole, with numerous stemless palms still to develop into the rough-stemmed stage. Of the stemless palms counted in the 1949 survey, 75% had, by 1960, become rough-stemmed palms, and 7% had died. Thus only 5% of the stemless palms counted in 1960 were so classified in 1949 whereas the corresponding figure for the whole area was 50%.

The main cause of the death of the palms is trunk rot (see section 8.2), but stemless palms may also die as a result of unfavourable growing conditions.

9.2 Retrogression

Retrogression of palm groves is shown by the decline in total number of oil palms, and consequently of the oil palm culture, in a district. Several factors may cause an accelerated deterioration while the rise of new palm groves remains the same, is slowed down or entirely stopped, so leading to a decrease in area under palms. Felling palms for palm wine tapping, or clearing of palm groves with the intention of enlarging the area of farmland or for the purpose of planting other cash crops has already been mentioned. As appears from chapter 5 dense palm groves originate on deserted compounds, so when compounds are not abandoned no groves will arise and the oil palm industry in such areas will disappear if no oil palms are planted.

10 Methods of increasing oil and kernel production

10.1 Introduction

The output of oil and kernels can be raised by intensifying the exploitation, by increasing the bunch yield per area, the oil and kernel to bunch ratios and the extraction coefficient. The first, second and fourth components concern the grove and improved (planted) palms and the third matters in dealing with improved palms. The increase of oil and kernels can be induced by improvement or rehabilitation of the palm groves, or by improving the growing conditions by applying manure or fertilizers. The rehabilitation of the groves *i.e.* replacement of grove palms by improved ones in general includes the raising of the oil to bunch ratio, but only in some rare cases palms are planted which are bred for their high kernel yield.

10.2 Intensification of exploitation

In the densely populated palm belt of Eastern Nigeria the groves are sufficiently open to give free access to all the palms because the fallow period is short, and since there are sufficient harvesters to climb the palms, the exploitation of these groves is more or less complete. This may also be true for other densely populated districts, but in other areas where the palms can only be reached after opening a path or where the farmers cannot or do not want to climb all palms, much fruit is lost. In these areas harvesting can be intensified by opening up the groves and climbers may have to be engaged. Opening up of a grove is costly: paths for the climbers and bunch collectors and motorable roads for the transport of bunches by lorries to processing plants have to be made, but by using bicycles the transport of bunches within the grove can be speeded up.

On a wider scale the construction of railways leading to or through oil palm growing districts has improved the transport of palm produce to ports and has made the improvement of the exploitation of the groves in these districts worthwhile.

In some districts where the 'exploitable' number of harvesters is inadequate, outside labour does the harvesting work for the owners. These labourers set up temporary or permanent harvesting camps near the groves. Examples of this system occur in Western Nigeria where the Urhobo from the coastal districts do the harvesting for the cocoa growing Yoruba, while in Eastern Nigeria Ibo people from certain overpopulated districts may do the harvesting for the coastal fishermen or for the palm owners who work in the towns. In other areas contract-harvesters are employed to do the harvesting for the owners of palm grove concessions, for example, in the Kwango district in Congo (DESNEUX and ROTS, 1959) or the villagers themselves construct harvesting camps in remote groves as was done by the Adioukrou in Ivory Coast (DUPIRE and BOUTILLIER, 1958) or in Dahomey (BRET, 1911). In districts where there is a shortage of labour much fruit is lost and POIRET (1937) estimated that only 10 to 20% of the total production in Guinea was collected.

The setting up of produce buying stations near main producing areas for oil and kernels shortens the distance over which the grower has to transport his produce and reduces the number of traders which implies that a larger share of the income goes to the producer rather than to a great number of middlemen.

The only method of harvesting employed is climbing with the aid of a rope. The Malayan harvesting hooks cannot be used, as they are too short to reach the crown of a tall grove palm and also too unwieldy for use in a dense grove. Although MILLIGAN (1914) was sure that his suggestion that the bunches should be lowered to the ground with a rope to avoid bruising of the fruits would evoke immediate response, it has never been adopted.

Group ownership of the palms impedes their exploitation and the improvement and rehabilitation of the groves. Before 1914 in some countries attempts were made to overcome these difficulties by compulsory allocation of palms to individuals and compulsory planting of young palms. For instance, in Cameroon 25 palms were allotted to every house and fifty palms had to be planted for every new house which was built. However, as is the case in the prohibition of wine tapping, such rules are only effective when adequately supervised and enforced. Local rules governing rights over palms might change as a result of incentives given by the government or of the owners' own volition (see section 7.2.4). The trend is that while old group-owned groves will continue to die out gradually, the number of palms owned by individuals will increase, particularly as the former occupants of abandoned compounds or their heirs seek to retain ownership of the palms which grew up on the site.

One man at Abak moved his compound every five years in the knowledge that in future palms would grow on these compounds and that he would be able to claim the ownership or at least the produce of these palms. It was easier for him to obtain consent to build a house on village land than to plant palms in that land.

The replacement of the comparatively low yielding grove palms by improved palms derived from *dura* × *pisifera* crosses, provided these are properly planted and maintained, can result in an enormous increase in yield, as is shown by the figures below. The extraction efficiency has been assumed to be 85% and the price of oil and kernels to be £ 40 and £ 24 per 1000 kg respectively.

	Bunch weight *(kg/ha)*	Actual oil weight *(kg/ha)*	Kernel weight *(kg/ha)*	Gross revenue *(ha)*	Remarks
Dense grove (Expt. 501-1)	2,800	370	270	£ 10	Average 1949–1962
Improved grove (Expt. 505-2, treatment C)	6,100	1,300	370	£ 49	Average 1958–1962
Plantation at Abak (Expt. 506-5)	12,000	2,500	700	£ 117	In third year of harvest (1964)

The main source of improved oil palm seed in Nigeria is the WAIFOR and some is also available from plantation companies. In 1963 the WAIFOR issued 1,720,980 seeds to Western Nigeria, 1,941,003 to Eastern Nigeria and 113,288 to Northern Nigeria, a total of 3,775,271 seeds. Unfortunately despite the improved germination, nursery, transplanting and general cultural techniques which have been developed over the past decade, the percentage of seed which will eventually result in producing oil palms in the field is still distressingly small. The very adoption of recommended agronomic practice would enormously increase the potential area which can be planted annually from existing sources of improved seed.

The rehabilitation of the palm groves will be discussed in the last section of this part.

10.3 Use of manures and fertilizers

Where grove palms are group-owned they do not receive manures or fertilizers, although the farmers may well be acquainted with the beneficial effect of applying compost, but it is only where palms are owned by individuals and where palm produce is much in demand that grove palms may receive some compost or household refuse put around the palm stem.

There are only a few instances of fertilizers being applied to grove palms and only then on an experimental basis or as a demonstration to farmers, because some responses have been obtained particularly to potassic fertilizers.

PREVOT (1955) believed that in Dahomey the leaf nitrogen content of grove palms was generally below the optimal level. In a trial at Dabou in Ivory Coast no response was obtained from an application of a nitrogenous fertilizer (IRHO, 1957).

Throughout the West African palm belt the soils are generally low in potassium, and potassium manuring is essential to ensure maximum growth and production from planted palms.

Responses to application of potassium have also been obtained from grove palms irrespective of whether they exhibited symptoms of potassium shortage. In 1949 the IRHO applied ammonium sulphate, bicalcium phosphate and potassium chloride in various combinations to palms in an improved palm grove at Grand-Drewin in Ivory Coast. The age of these palms was assumed to be 19 years and the density after thinning was 140 palms per hectare, which is less than in a normal plantation. Only potassium gave a response, the yield of the unmanured plot being 7,000 kg per hectare while that of the manured plot was 8,700 kg, which meant an increase in yield of 24%. From this trial it was concluded that application of 1 kg of potassium chloride gave an extra 1.3 kg of oil per palm and the production of kernels was probably also increased. The leaf potassium level of grove palms at Avrankou, Ouidah and Porto Novo in Dahomey and at Agbatope in Ivory Coast was found to be below the critical level and an application of 1 kg of potassium chloride per adult palm gave an economically justified return (RANCOULE and OLLAGNIER, 1952; PREVOT, 1955). For some palms the leaf potassium level was so low that even after an application of five kg of potassium chloride per palm it was still below the critical level, despite the symptoms of potassium deficiency having disappeared (PREVOT and OLLANGIER, 1958).

At Pobé in Dahomey an economic response of 20% in the first year and 40 to 60% in the following years was obtained to a single application of 1 kg of potassium chloride to palms showing deficiency symptoms before manuring (ANON., 1952). These results led to potassium manuring of grove palms in Dahomey and Togo where 15,000 adult palms near the road between Akpro and Avrankou each received 1 kg of potassium chloride (ANON., 1957a; BRASSEUR, 1953). PREVOT (1955) estimated that the yield of these palms would be doubled if this application would be repeated annually or biennially.

In 1956 a 3 × 3 × 2 factorial manurial experiment (Expt. 503-2) was started by the WAIFOR in the Uruk Obong Palm Grove at Abak (Expt. 503-1). Only the smooth-stemmed palms, at estimated ages varying between 50 and 90 years, were manured, the treatments being, per palm:

potassium sulphate at 0, 3.4 or 6.8 kg in 1957 and
0, 1.4 or 2.8 kg in 1961;
magnesium sulphate at 0, 3.4 or 6.8 kg in 1957 and
0, 1.4 or 2.8 kg in 1961;
bunch refuse at 0 or 15 kg every other year, starting in 1956.

The amount of bunch refuse applied was believed to be equivalent to the amount produced by the grove itself. From 1949 to 1956 the average yield per hectare was 2,955 kg of bunches. The above components made up 74.7% of the whole bunch (see section 6.1.9 for the Ikot Okpong grove, Abak), hence 2,207 kg of fresh bunch material should be returned to one hectare of palm grove. The average density of smooth-stemmed palms was in 1954 141 per hectare, *i.e.* each palm should receive 31.4 kg of fresh material every second year. But if only the stalks and spikelets were returned this would amount to 12.7 kg of fresh material per palm every other year. Although the amount of 15 kg was given in the shape of decomposed material the estimation appeared to be not too bad.

Analysis by covariance on pre-treatment yields showed that there was a significant (P = 0.05) response to potassium, the effect being on the weight of the bunches, but not on the number of bunches. Magnesium and bunch refuse had no effect (Table 27). Although the response obtained appeared to be economic it is considered to be wiser to devote the available resources to the rehabilitation of palm groves in the first instance since rehabilitated groves are capable of a much greater potential yield when properly manured.

Table 27. Expt. 503-2. The mean annual yield of the Uruk Obong grove over 1957–1962 over the various potassium treatments

Treatment	Mean annual yield		
	number of bunches	weight of bunches (kg/ha)	mean bunch weight (kg)
K_0	231	2,975	12.9
K_1	310	3,561	11.5
K_2	323	3,581	11.1
Least significant difference at P = 0.05		427	

The effect of potassium on the frequency of oil palms attacked by trunk rot, has already been mentioned in section 8.2.5.

In Dahomey analyses of leaves from grove palms showed that the leaf magnesium levels were adequate (PREVOT, 1955) and this is also the case for the smooth-stemmed palms of the Ikot Okpong grove at Abak. It is probable that where a group of grove palms all show the 'Orange Frond' condition, a response would be obtained to an application of magnesium sulphate, but no factual corroboration is available.

In the NPK-manurial trials carried out by the IRHO on grove palms no response was obtained to the phosphate dressing (IRHO, 1957).

No information is available concerning the effect of applying any other major or minor elements to grove palms.

When compost is applied it has physical as well as nutritional effects on the soil; it acts as a source of slowly-released nutrients and as mulch. Furthermore, it increases the base exchange capacity and waterholding ability of a soil.

Around Porto Novo in Dahomey grove palms have been intercropped with food crops on the same land for the past 50 years with only very short fallow periods during which time only a small amount of 'bush' grows up. When this is burnt, only a small amount of fire damage is caused to the palms. In spite of the heavy food cropping, which is of primary importance, the oil palms look healthy (PICHEL, 1957). This system of cultivation is only made possible by continuous manuring with compost collected from Porto Novo and other places – which enables an equilibrium to be maintained, admittedly at a low level, between palm and food crop cultivation. Higher yields of both crops would result from an additional application of fertilizers, particularly potassium. Palms on compounds and on old village sites benefit from the household refuse thrown away near the dwellings. Despite these effects observed on the yield no response was obtained to the compost (bunch refuse) treatment in the trial in the Uruk Obong grove, but this is probably because the amount applied has been too small to be effective.

It is impossible to give a 'prescription' for the application of fertilizers to cover all oil palm growing areas in Africa, but on the 'Acid Sands' and especially its Calabar Fasc in Eastern Nigeria a 1:1:2 mixture of ammonium sulphate, potassium sulphate and magnesium sulphate (Epsom Salts, 46–48% $MgSO_4$) applied at a rate of 0.675, 1.35 and 2.7 kg per palm during the first three years respectively is used to give the young palms an excellent start. The use of patentkali or kieserite should be considered because these fertilizers are cheaper in use. The fertilizers should be applied in the rainy seasons, while the application of ammonium sulphate in the first year should be divided into two portions, the first together with potassium and magnesium sulphate six weeks after planting and the second in October of the same year.

At present nitrogenous fertilizers are applied after the third year, but forthcoming results of fertilizer trials on these soils may cause an amendment of this advice. In the fourth year 1.35 to 1.8 kg potassium sulphate and the same amount of Epsom Salts should be given, repeated every third year at a rate of 2.25 and 2.70 kg respectively (ANON., 1961).

10.4 Rehabilitation and improvement

10.4.1 Non-WAIFOR trials

As early as 1907 THOMPSON, in Nigeria, advised that by cleaning epiphytes from the stems and crowns of the palms together with the removal of trees and shrubs growing in association with the palms, and thinning of the dense patches in the groves the yield of fruit obtained could be increased by 25 to 50%. Later REDER (1912) in the Cameroons gave similar advice, and suggested that the optimal spacing was 7 m × 7 m, which means about 240 palms per hectare. HUBERT (1911) advised that groves should be thinned to a density of 75 palms per hectare, but present knowledge shows that this would result in sub-optimal stands.

But at the same time this advice was partially counteracted by government rules restricting the felling of palms, which, in some areas, were felled on a large scale for wine tapping. Such rules were enacted in Guinea in 1906 and in 1909 in Dahomey (HUBERT, 1911). It was generally impossible to enforce these rules which also procured a chance of corruption and for these reasons they were abandoned between 1920 and 1930.

For the purpose of this account *palm grove improvement* includes cleaning of the palms, clearing of forest trees and bush undergrowth with or without thinning the palm stand, or planting up of open gaps, the aim being to obtain a higher yield from the existing stand of bearing palms. *Palm grove rehabilitation*, on the other hand, is the planned gradual replacement of the grove palms by planting selected palms. In the process the old stand is first thinned and stemless palms are planted under the remaining old palms. The latter are felled as the young palms come into bearing. The aim in rehabilitation is to increase the yield from a given area by planting selected palms while at the same time retaining sufficient old palms to give the farmer some income while the young palms establish themselves. An extension of palm grove rehabilitation is *palm grove replacement* which involves clear felling of the old stand and planting of selected palms. Planting may also be carried out in areas of forest, savanna or farmland where no palms are growing at the time of planting.

The first recorded palm grove improvement trial was started in Ghana in 1915 at Peki Blengo where a grove of two hectares was cleared and thinned from 197 to 138 palms per hectare (ANON., 1920; SLATER, 1925). Unfortunately no 'control' area was retained and the annual yield of the improved plot could only be compared with the yield obtained from an unspecified number of scattered grove palms in the area. However, the yield of the improved area was eventually 453% greater than in the first year of recording, the increase being attributable to more and heavier bunches being harvested per palm. The yield of the scattered 'control' palms also increased by 181% which rather decreases the value of the result of the experiment. Nevertheless SLATER used the results to demonstrate the favourable effect of improvement.

In 1910 LEVERHULME acquired concessionary rights over large areas of palm groves in the former Belgian Congo, and in 1917 DYKE (1924) started an improvement trial in a grove near Leverville. The area of the grove was approximately one hectare; it had been cleared and the palms cleaned in 1913. The operation was repeated in 1917, the palms were then numbered and individually harvested. In 1920 and 1921 this grove was thinned to a density of 200 palms (including stemless palms) per hectare, but here, again, no control area was retained.

The improvement carried out resulted in there being fewer palms to maintain (–10%), more palms bearing (+7%), more bunches per bearing palm (+15%), a higher average bunch weight (+23%), a higher yield per bearing palm (+32%), and a higher yield per hectare (+42%).

In such work, economic considerations require that the initial cost of clearing, cleaning and thinning together with the cost of harvesting the extra fruit should be covered by the value of the additional fruit produced. In this case the main increase in yield came from the palms exceeding 4.5 m in height so it is not clear whether the cost of harvesting was in fact reduced in the initial stage of improvement. But gradually younger, and thus shorter, palms came into bearing and as they contributed to an increasing extent to the production from the grove, so harvesting costs per ton of fruit declined.

In 1920 a palm grove at Likakula and another at Rive near Barumbu (near Basoko, former Belgian Congo) were rehabilitated, but no information is given on the method used. Their average annual yield of bunches were over 1939 to 1946 3,382 and 6,527 kg per hectare respectively (INÉAC, 1940–1947). Both groves gave a higher yield than an unimproved grove and especially the yield of the rehabilitated grove at Rive is high and comparable with that of the rehabilitated plots of the later described Expt. 505-2 (vide section 10.4.2).

DYKE (1927) reported on another improvement trial in which the results were very unsatisfactory. He attributed the low yield of the improved plot to the death of the palms which were retained, especially those in a clean-weeded area. He believed (vide LEPLAE, 1939) that the 'natural balance' had been disturbed in some way and concluded that it was better to plant selected material than to improve the existing stand.

LEPLAE (1922) advised that grove palms should be thinned to 6–7 m spacing (about 250 palms per hectare) and that old tall palms should be felled rather than the smaller ones. JANSSENS (1927) said that the distance left between palms should be 8 to 12 m, (which gives a stand of about 125 palms per hectare) and that open spaces in the grove should be filled by planting two year old palms grown from seeds obtained from *tenera* palms.

An improvement trial started in 1918 in a grove at Ibadan (ANN. BULL. AGRIC. DEPT. NIGERIA, 1923, 1924, 1925). The yield from an uncultivated part of the grove was compared with that from an improved plot. This plot was clean-weeded in 1918 and again in 1921 after which a bush cover was allowed to grow up, but this treatment had no effect on yield. The difference in density in the two sections was not very great and any beneficial effect on the yield of the palms of clearing and cleaning may have been obscured by the weeding method. The layout of the trial was not very satisfactory and the absence of pre-treatment yields further limited the information which could be obtained from it (HARTLEY, 1954). However, it was observed that young palms in the cleared plot did come into production earlier, but their influence on the total yield was negligible. The general conclusion drawn from the trial was that it would be better to develop palm plantations than to improve palm groves.

VAN PELT (1920) reported that in an improved grove near Bingerville in Ivory Coast, the yield was doubled in the first year after improvement and quadrupled after three or four years. This trial also had no control.

In 1928 following the recommendations of an Advisory Committee, a start was made on a scheme to rehabilitate and replant palm groves in Nigeria (see section 11.1) with the object of enabling Nigeria to meet the competition from South East Asia in the oil palm produce market. This scheme was preceeded by some rehabilitation trial, in which the yield from a replanted plot with or without some old palms left, was compared with the yield obtained from untreated plots. These trials are fully described by HARTLEY (1954), but it was not observed that the yield of the control plots at first increased as a result of the reduced competition on the fringes of the plots consequent on the felling of palms in adjacent improved plots (this was also strikingly shown by the palms in the control plots of Experiment 505-2). This effect is apparent from figures 1 and 2 given by HARTLEY, which show that after about seven or eight years the yields in the control plots fell back to the level of the first year and continued to decline. The yield from the planted palms was also disappointing, which was probably partly due to low genetic potential, but mainly to bad maintenance and low soil fertility, since no fertilizers were applied. HARTLEY concluded that replanting with clearing and maintenance only was not the final answer to the problem of palm grove rehabilitation.

A third rehabilitation trial was started at Barumbu in 1930 (INÉAC, 1938). In part A the whole area was cleared, while in part B the forest trees were only felled and the grove palms remained standing. The whole area was planted with young palms. In 1934 and 1935 all the palms of the *dura-macrocarya* fruit type in part A were removed, leaving 120 planted palms per hectare and in 1937 every second row of planted palms of the whole area was felled to give the remaining palms more space, but no data are given about the density.

The whole area was maintained as a plantation, a cover crop of *Calopogonium mucunoides* DESV. and later *Pueraria phaseoloides* BENTH. was grown. The yields in 1937 were:

	Number of bunches (*ha*)	Weight of bunches (*kg/ha*)	Average bunch weight (*kg*)
A. young palms	1,228	6,905	5.6
B.1. old palms	131	2,127	16.2
B.2. young palms	573	2,918	5.2
B. total	704	5,045	–

It was concluded that lack of light reduced the number of bunches produced by the planted palms under grove palms, but the average bunch weight is not much affected by the influence of the grove palms. The unshaded planted palms were more vigorous than the shaded ones (INÉAC, 1938). This trial showed that complete felling and complete planting was better than partial felling and complete planting. However, any possible difference in fruit quality has not been taken into account.

SCOTLAND and MARTIN (1930) working in Sierra Leone advised that palm stands should be thinned to about 173 palms per hectare; that gaps should be planted up to give a palm density of 100 palms per hectare; that young and old palms should be protected from fire and that replanted plots should be maintained. SLATER (1925) suggested that fire damage resulted in a 90% loss of yield, but he did not specify for how long. The influence of fire is discussed in section 6.1.7. LEPLAE (1939) working in Congo mentioned that improvement of groves would result in an annual increase in yield from 1,000 to 2,000 kg bunches per hectare.

Two further improvement trials were started at Odumasi and Anaji in Ghana (WILLIAMS, 1930). A 'wild' grove was compared with an improved grove, in which gaps were planted up and dense patches thinned to about 160 palms per hectare, but in this case also the statistical lay-out was unsatisfactory and pre-treatment yields would have aided the interpretation of the results. In the Odumasi trial the yields were the same for both treatments, and rather high, *viz.* 11,000 kg of bunches per hectare. At Anaji the yield from the improved plot was 1,500 kg of bunches per hectare and from the untreated plot only 525 kg. At both sites thinning resulted in a higher average bunch weight.

A replacement trial was started, again at Barumbu (former Belgian Congo) in 1934 (INÉAC, 1953). The whole area was cleared, after which the following treatments were applied: 1) replanting immediately after felling, 2) replanting after two years fallow with *Mimosa invisa* MART. and 3) replanting after one to two years bush fallow. FERWERDA (1955a) concluded that as this experiment only consisted of long single plots for each of the three treatments, it would be difficult to draw any conclusion and that the yields – varying between 322 and 1,289 kg of oil/ha – did not bear any sensible relation to the treatments.

An improvement trial was started at Grand-Drewin (Ivory Coast) in 1947, the comparisons being (1) a 'wild' grove, (2) a grove thinned to 160 palms per hactare and (3) a grove thinned to 140 palms per hactare (IRHO, 1950; FERRAND and OLLAGNIER, 1950; ANON., 1957a; DESMAREST, 1962). The average annual yield over the first 12 years of harvesting was:

Treatment	'Wild'	160	140
Yield in kg bunches per ha	4,300	6,400	6,200

Although there is a proper control treatment this experiment suffers from the absence of an adequate guard strip around the plots. The increase in yield of the control plot (1,655 kg in 1947, 3,570 kg in 1948, 7,570 kg in 1949 and 6,120 kg in 1950) may well be due to an increase in the yield of the 'fringe' palms. The difference in yield between the two thinning treatments is not large, but suggests that thinning to 140 palms per hectare is too rigorous and results in a suboptimal stand of palms.

Later the untreated plot was divided into two parts, (1a) untreated and (1b) cleared and cleaned, but not thinned.

The conclusions drawn from this experiment are:

1. Cleaning and clearing result in an increase in yield of 3,000 kg fruit bunches per hectare per year (+60%) and thinning out gives an additional increase of 2,000 kg (+40%) while the two operations carried out together result in an increase of 5,000 kg. Thus it is possible to obtain an annual yield of 10,000 kg of bunches per hectare from this improved grove.
2. Despite the higher yield in the improved grove, harvesting costs per unit weight are lower, because fewer palms have to be climbed to harvest more and also heavier bunches.
3. The cost of labour and the local prices of palm oil and kernels determine whether these improvements are economically justified.

Resuming the results of the Anglo-French Oil Palm Conference in 1956, PICHEL (1957) concluded that the optimal stand in an improved grove is 115 palms per hectare, *viz.* 42 adult and 73 young palms, while the yield expected from such a grove would be 3,000 to 5,000 kg per hectare, which is appreciably lower than the yields in the Grand-Drewin trial.

In 1948 a replanting trial (Brabanta 1) was started in an improved grove situated on the southern bank of the Kasai River at Kanangai in Brabanta, former Belgian Congo (FERWERDA, 1955a; 1955b). The improvement of the grove was realized in about 1925 and included cleaning of the palms, clearing of trees and shrubs, selective thinning to about 200 palms per hectare and filling up gaps with material derived from *tenera* grove palms, after which the grove was managed as a plantation.

The design of the experiment was a 4 × 4 Latin Square with guard rows around the plots and the four treatments applied in 1948 were: 1) young palms planted under the canopy of the old palms; no fertilizers applied, 2) old palms felled before planting of the young palms; no fertilizers applied, 3) young palms planted under the canopy of the old palms; fertilizers applied to the young palms, and 4) old palms felled before planting of the young palms; fertilizers applied to the young palms. The planting material used was obtained from open pollinated good *tenera* palms and was planted at a spacing of 8 m between the lines and 4 m within a line, giving a density of 312 planted palms per hectare, *i.e.* in the plots with old palms left the total number of palms was about 500 per hectare. The remaining grove palms were felled in 1952, 42 months after planting of the improved palms. At the end of 1953 the density of the planted palms of treatments 2 and 4 was reduced to 156 palms per hectare by removing every other palm in a line. Two years later the density of the planted palms of treatments 1 and 3 was also reduced to 156 per hectare (FERWERDA, 1965).

The development of the planted palms was followed by recording the number of new leaves, length of the youngest fully opened leaf at certain times, percentage of dead palms, disease incidence, number of male and female inflorescences and the chemical composition of the first and ninth leaves at certain times. The conclusion was that in October 1951 (the young palms were 36 months in the field then) shaded planted palms were about 12 months retarded in their development in comparison with unshaded palms, and that palms not receiving fertilizers were six months behind palms receiving fertilizers (FERWERDA, 1955b).

No precise data of yield of the old stand were kept, but it must be very low as it was suggested that the difference between the yield of the planted palms of the felled plots and that of the unfelled plots harvested over the first five years was 8,846 kg per hectare and that this difference would make up for the loss of yield of the felled old palms. Thus the yield of the old palms was about 8,846 kg per hectare divided by 42 months resulting in about 2,500 kg of fruit bunches per hectare per annum. This is rather low.

In 1961 the experiment was terminated as too many palms were either killed or diseased by vascular wilt disease.

The cumulative yields of the young palms over 1954 to 1961 were:

Treatment	Bunches (*ton/ha*)	Percentage of increase
(1) no felling, no fertilizers	20.5	–
(2) felling, no fertilizers	32.2	+57
(3) no felling, fertilizers	33.7	+64
(4) felling, fertilizers	44.7	+118

The final conclusion is that treatment (4): felling of old stand and applying fertilizers to young palms was the best treatment, but that it would be worth while to investigate the effect of a gradual removal of grove palms on the development and yield of the underplanted palms (FERWERDA, 1965).

If account is taken of the yield of the grove palms of treatments (3) and (4), which was estimated to be 8.8 tons per hectare over 42 months they could be added to those of the planted palms giving the final cumulative yields per hectare over 1948 to 1961 (1) 29.3 ton, (2) 32.2 ton, (3) 42.5 ton and (4) 44.7 ton. Treatment (4) is still leading, but it is doubtful whether the difference from (3) would be significant. The same holds true for the difference between the yields of (1) and (2). Furthermore as yet no data are available with respect to the bunch and fruit composition of the two palm populations.

10.4.2 Three WAIFOR trials: Expts. 505-2, 560-2 and 509-1

In 1953 a rehabilitation trial (Expt. 505-2) was started in the Obio Akpa Palm Grove (Expt. 505-1) situated on the Ministry of Agriculture Farm at Obio Akpa near Abak. The experiment takes the form of a 5 × 5 Latin Square with plots of 0.2 hectare. All planted palms were grown from improved seed and the treatments were:

A. Control: Undisturbed palm grove;
B. Control: Complete clearing and complete replanting;
C. Improvement treatment (a): Thinning in a practical manner to leave 101 grove palms per hectare; open spaces were filled with about 44 improved young palms per hectare;
D. Improvement treatment (b): Thinning on a yield basis (previous yields 1949–1951) to leave 69 palms per hectare; open spaces were filled with about 79 improved young palms per hectare;
E. Rehabilitation treatment: Complete replanting under 74 tall grove palms per hectare, which were felled in 1958.

The land in one row of the Latin Square was farmed annually on a five years rotation. The non-farmed plots of treatment B, C, D and E were maintained normally and the regrowth in the non-farmed A-plots was allowed to grow unchecked. The planted palms were manured in accordance with standard WAIFOR practice. This trial had the same practical defect as rehabilitation trials carried out elsewhere, namely that the peripheral palms in the A-plots benefited from the felling of palms in adjacent plots, while planted palms in these adjacent plots were to some extent shaded by the tall palms of the A-, C- and D-plots. For this reason only the yields of the palms growing in the inner part (0.08 ha) of the plots are used here.

The initial densities of the palm stand in the plots of treatments C, D and E were given by HARTLEY (1954, 1957). These treatments were included because any method which entails the immediate removal of large number of bearing palms is likely to be unpopular for two reasons: the farmer needs an income during the period before the planted palms can begin to bear and, secondly, every palm is considered as a potential source of income and therefore not to be felled without good cause.

Thinning on the basis of bunch yield resulted in the remaining old palms tending to be grouped, with open spaces between the groups. Fruit type was not used as a criterion for retention of any palm, but as it appears that the *dura* palms gave a higher bunch yield than the *tenera* palms relatively more *tenera* palms than *dura* palms were felled. Thinning by eye gave an even distribution of the old palms because both appearence and site were considered. The cumulative yields from 1953 to 1962 are given in Table 28.

Table 28. Expt. 505-2. Cumulative yield of fruit bunches, oil and kernels per treatment from planted and grove palms from 1953 to 1964

Treatment	Yield in kg per ha								
	fruit bunches			oil			kernel		
	planted 1957-1964	grove 1953-1964	total	planted 1957-1964	grove 1953-1964	total	planted 1957-1964	grove 1953-1964	total
A	–	44,656	44,656	–	7,145	7,145	–	4,466	4,466
B	51,258	–	51,258	11,277	–	11,277	3,075	–	3,075
C	6,366	69,841	76,207	1,400	11,175	12,575	382	6,984	7,366
D	18,114	47,365	65,479	3,985	7,578	11,563	1,087	4,736	5,823
E	48,487	14,808	63,295	10,667	2,369	13,036	2,909	1,481	4,390
L.S.D. at P = 0.05			15,814						

See p. 133 for a description of the treatments

After eleven years the yield from treatment C is significantly better than that from both the control treatments A and B. The longer the trial runs the smaller becomes the difference in total yield between treatments B and C and the greater the difference between treatments A and B. However, it must be emphasized that the yield from treatment E is so far about 13,000 kg of fruit bunches per hectare more than that from treatment B. The extra production was obtained in the early years of the experiment and this would be important to the farmer. In 1962 the difference in yield between the B- and E-treatments was negligible. It seems likely that the initial difference in bunch yield will persist, and thus it might be concluded from this experiment that complete replanting with some grove palms left during the first four years (treatment E) is the best method of rehabilitating a palm grove.

There are, however, certain difficulties connected with recommending this method. If the farmer is not fully aware of the importance of felling the old grove palms in the fourth year, he will allow them to remain, especially since the yield from them will have increased (see section 10.5). He must understand that notwithstanding the increased yield being obtained from the grove palms the planted palms will produce more fruit of greater value and be much easier to harvest in future.

The bare data for bunch yield do not take any account of the differences in fruit quality between the grove and the planted palms, nor of differences in agronomic practice and harvesting and processing techniques. If the oil and kernel production is taken to be (MENENDEZ, 1964):

	Oil to bunch	Kernel to bunch
for grove palms:	16%	10%
for D × T palms:	22%	6%

the potential output of oil and kernels from the palms in the Obio Akpa experiment is then as shown in Table 28. These figures demonstrate that all the improvement and rehabilitation treatments result in an increase in the production of oil and that the total oil yield of these treatments is about the same, but higher kernel yields are obtained in those treatments in which all or the majority of the grove palms remain. This may be attributable directly to the large kernels characteristic of the grove palms in this area. The presence of tall grove palms for the first four years after replanting makes the costs of production per unit quantity of palm produce higher in treatment E than in treatment B, because harvesting, transporting and milling of fruit of grove palms all cost more. But against this extra cost has to be placed the advantage of a continuing income for the farmer during these four years. When the nuts are cracked by hand the cost of cracking those derived from planted palms is higher because the nuts are much smaller and more of them have to be cracked to render a sack of kernels and, moreover, they are more tedious to crack.

The conclusion to be drawn from this trial is that partial felling and complete replanting is to be recommended, but the remaining tall grove palms should number not more than 37 per hectare and they should be felled in June of the fourth year after planting. Diquat (GUNN and TATHAM, 1960; SHELDRICK, 1963) or another suitable arboricide may be used to kill the old palms, thus avoiding damage to the underplanted young palms which is possible in case of felling these old palms.

Data on the growth, flowering and yield of the planted palms are presented in Table 29. The height of the stems was measured in June, 1963, leaf flowering observa-

Table 29. Expt. 505-2. Data on growth, flowering and production of the planted palms

Treatment	Stem height per palm (cm)	Annual leaf production per palm	Number of female and hermaphrodite inflorescences per palm per year	Number of male inflorescences per palm per year	Percentage of female and hermaphrodite inflorescences	% floral abortion	Number of ripe bunches per palm per year	% bunch failure	Mean bunch weight (kg)	Yield per palm per year (kg)
B	250	23.2	7.2	13.8	34.3	8.7	5.3	26.4	8.9	47.2
C	189	21.8	5.0	11.4	29.6	25.8	4.1	18.0	5.6	23.0
D	165	23.2	6.4	13.6	31.2	14.8	5.1	20.3	6.6	33.7
E	134	23.6	8.0	13.2	38.4	14.8	6.8	15.0	7.8	53.0
L.S.D. at P = 0.05	45	4.4	1.9	3.7	11.9	7.6				

See p. 133 for a description of the treatments

tions covered the years 1960 to 1962 and as the period between leaf opening and ripening of the bunch is about 15 months for these palms (BROEKMANS, 1957) the mean number and weight of bunches per palm a year and the average weight of these bunches concern the yield period 1961 to 1964.

It is difficult to draw any conclusion from these data. The treatments have differentiated the speed of development and hence the average physiological age of the palms per treatment is different at present. Height is also an inadequate criterion as it indicates either an advanced or an etiolated growth. However, the palms which grew or still grow under grove palms have a significantly smaller height than the palms growing in the complete cleared plots. The C- and D-palms are physiologically younger than the B-palms, and should, therefore, have on the average a higher leaf production than the B-palms (SPARNAAIJ, 1960). However, the differences between the numbers of leaves are not significant and this might have led the reader to suggest that the grove palms produce no adverse effect.

The same leaf production means that the mean number of inflorescences initiated per palm must be the same for the four treatments and so the differences of the annual yield per palm between these four treatments are a result of a direct effect (shading, root competition) and an indirect effect (different physiological age of the palms) of the presence of the grove palms on the yield components.

In the Ibibio-Asutan Ekpe clan area seven plots of the Oil Palm Survey (Expt. 560-1) were rehabilitated in 1959, six more were rehabilitated by the author in 1961. The purpose was to show the members of the Asutan Ekpe and other clans, and the members of the Ministry of Agriculture and their trainees and visitors, that it was worthwhile to rehabilitate palm groves, but only when the planted palms are well maintained. By way of demonstration all the grove subtypes except E_2 were included. The latter was excluded as in the Asutan Ekpe area oil palms, except some single palms planted for traditional purposes are not planted on compounds. All plots were intercropped in the first two years. Intercropping is farming between the young palm stands. In Abak the main crops were maize and cassava, while in Benin they were yam, maize and cassava. It is experienced that intercropping improves the development of the young palms, which come earlier into bearing (reviewed by SPARNAAIJ, 1957; OCHS, 1963). It was difficult to stop the owners from intercropping in the third and following years as the plot owners and their wives were attracted by the high yields of the farm crops, which was probably caused by the fertilizers applied to the young palms. The owners of the plots with strips for farming were taught to bring the cut and dried regrowth to the centre part of the strip, before setting it to fire, but as farming is the woman's task this instruction was often forgotten.

Yield recording of the 1959 plots started in 1962 and although the bunches were small, some plots gave high yields for three and four year old palms as is shown in Table 30.

There is a strong correlation between the density of the old stand and 1963 yield per planted palm ($r = -0.9544^{***}$) and between the density of the old stand and 1962 + 1963 yield per hectare of the planted palms ($r = -0.9836^{***}$) (see Table 30) indicating

Table 30. Expt. 560-2. Yield per palm, percentage of bearing palms and number of grove palms of seven rehabilitated plots at Asutan Ekpe

Plot	Treatment	Grove palms remaining till 1962 (ha)	Yield (kg) per palm		% bearing palms in 1962
			1962	1963	
4-B	Replanted at normal density	45	6.2	20.3	55
17-B	ditto	49	6.0	21.1	57
45-E_1	ditto	12	19.4	29.0	85
47-B	ditto	45	5.3	16.2	50
50-E_1	ditto	–	15.9	36.8	85
71-E_1	Replanted at half density	5	18.7	34.4	100
76-E_1	Replanted at two third density	10	16.6	38.4	91

B = Dense grove; E_1 = Grove of compound palms near homesteads recently set up in farmland

the harmful effect of the old stand on the development and yield of the young palms. The plots 71 and 76 were excluded from these calculations as they have a reduced stand of planted palms to allow farming in the wider interlines. The yields per palm of these plots are about the same as that of plot 59, but more palms produce, thus giving a higher yield per area under palms.

In Table 31 the yields of the grove and planted palms have been given. As the oil and kernel to bunch ratios are different for grove and planted palms the total yield per plot from 1959 to 1963 is also given in oil and kernels. The cumulative oil and kernel yields per plot are shown in Figure 11. The ratios given for Expt. 505-2 were kept on.

The effect of the grove palms on the yield of the planted palm is clearly shown. However, the plots with a high number of old palms remaining have produced, as was expected, more than the other plots. The low yield of plots 71 and 76 is caused by the overall low density of these plots. The yield based on area under palms only was 7,848 and 9,179 kg/ha over the years 1962 to 1963. No conclusions can yet be drawn as to the final yields, but similarly with respect to Expt. 505-2 can be stated that the yields obtained from the grove palms is of utmost importance to the farmer and so the initial draw-back of the young palms caused by the presence of the grove palms must be accepted as unavoidable.

It was disappointing to experience that at least up to the end of 1964 none of the plot owners themselves had rehabilitated a grove, but encouraging was to notice that grove owners living at some distance away started to follow the demonstration. A big success was that officers of the Ministries of Agriculture became convinced that a palm grove rehabilitation scheme would be successful provided the farmers followed the advices on planting and maintenance of the palms.

In 1963 another rehabilitation trial (Expt. 509-1) was established near Abak by the author, with the object of examining various methods of rehabilitating a grove, particularly with regard to the number of old palms that should be retained and for

Table 31. Expt. 560-2. The yield of bunches, oil and kernels of seven rehabilitated plots in the Asutan Ekpe area

Plot	Yield of old palms (kg/ha)								Yield of young palms (kg/ha)					Total (kg/ha)	
	bunches						oil	kernels	bunches			oil	kernels	oil	kernels
	1959	1960	1961	1962	1963	total			1962	1963	total				
4-B	2,145	2,306	3,474	1,036	–	8,961	1,435	896	913	2,960	3,873	775	233	2,210	1,129
17-B	3,059	3,090	1,669	1,948	–	9,766	1,562	977	884	3,082	3,966	793	238	2,355	1,215
45-E_1	950	718	986	222	–	2,876	461	288	2,875	4,300	7,175	1,435	430	1,896	718
47-B	2,967	3,632	3,343	3,038	1,887[1]	14,867	2,379	1,487	784	2,404	3,188	638	191	3,017	1,678
59-E_1	–	–	–	–	–	–	–	–	2,359	5,444	7,803	1,561	469	1,561	469
71-E_1	452	497	438	188	188[1]	1,763	282	177	1,382	2,542	3,924	784	235	1,066	412
76-E_1	271	625	1,089	504	116[1]	2,605	417	260	1,854	4,265	6,119	1,224	367	1,641	627

[1] Palms felled during this year
B = Dense grove; E_1 = grove of compound palms near homesteads recently set up in farmland

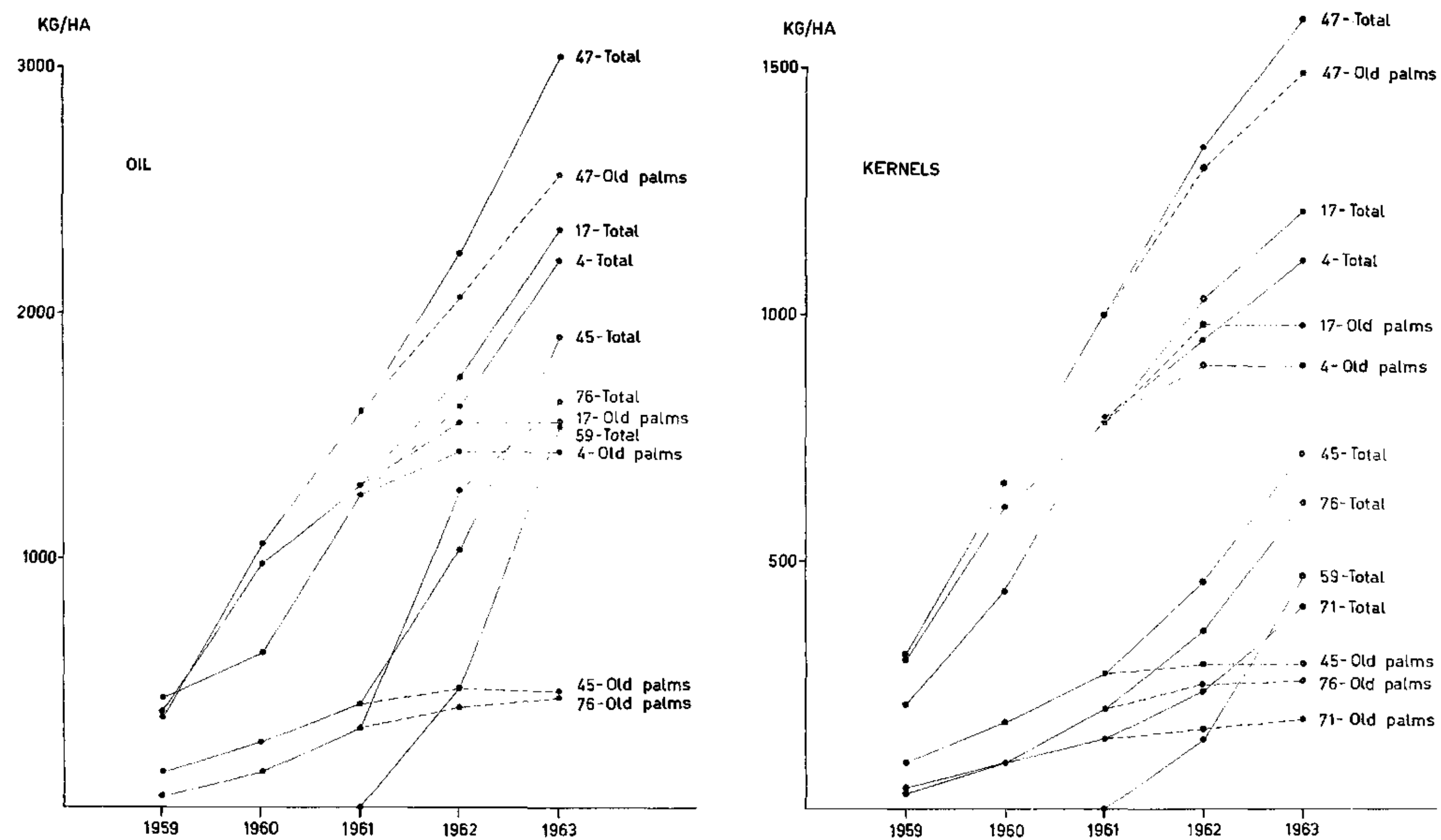

Figure 11. Expt. 560-2. The cumulative yields of oil and kernels of seven rehabilitated and improved plots in the Asutan Ekpe area

Plate 13. A rehabilitated palm grove near Abak, Eastern Nigeria. Note the small planted palms between the felled stems. In the background a B_2/C-grove subtype is seen. Photograph NIFOR.

how long. From Expt. 505-2 at Obio Akpa it was concluded that rehabilitation (treatment E) was better than improvement, particularly when the higher yield potential of the planting material now being issued by the WAIFOR for extension work is taken into account. So no improvement treatments other than the control were included. In laying down the trial steps were taken to ensure that the border effects which affected the results of the Obio Akpa trial were avoided. The treatments in this trial are:

A. Control: Grove thinned to 111 bearing and 62 'follower' palms per hectare;
B. Control: Clear felling and complete replanting;
C. Complete replanting and grove thinned to 52 bearing palms per hectare of which 13 will be felled in each following year;
D. Complete replanting and grove thinned to 30 bearing palms per hectare, which will be felled in June, 1965;
E. As D, but old palms felled in June, 1967;
F. As C, but with an additional dressing of potassium during the establishment of the young palms.

The first five treatments are self-explanatory, but treatment F requires some explanation. In the palm grove manurial trial (Expt. 503-2) a higher percentage of the small palms were bearing in plots receiving a high potassium application than in other plots, despite the higher density of tall palms in the high potassium plots. It is thought that in this new experiment young palms growing in the shade of tall palms may show better development when they receive additional potassium. As the stand of tall palms is gradually thinned the amount of extra potassium applied will also be reduced.

10.4.3 Cost of rehabilitation and improvement

The cost of rehabilitation depends on the amount of 'bush' within the grove, the density of the palms and on the distance between the nursery or motorable road and field (which determines the cost of transporting and carrying the palms to be planted). Examples, based on the work of the institute in the groves near Abak and in Asutan Ekpe, are given below.

The assumption is made that all the grove palms are felled and the cost is expressed in man-days (of seven hours) per hectare.

Item		Dense grove	Thin grove
1.	opening of area	×	×
2.	cutlassing, underbrushing and pegging	17	20
3.	felling	22	12
4.	further preparation	20	20
5.	carrying	×	×
6.	planting	20	20

× not specified

10.5 Palm grove improvement only

The production of the grove palms which remain in an improved grove increases considerably. This is shown by the yield from the thinned grove plot (treatment C) in rehabilitation trial I (Expt. 505-2), in which the density of stemmed palms was reduced in 1953 from 272 to 101 palms per hectare. The palms which remain are very vigorous; the mean annual yield per hectare is given in Table 32.

Table 32. Expt. 505-2. Mean annual yield per hectare and per bearing palm in an improved grove at Obio Akpa; year of improvement is 1953

Year	Palms	Yield per hectare			Yield per bearing palm	
		number of bunches	weight of bunches (kg)	mean bunch weight (kg)	number of bunches	weight of bunches (kg)
1949–1952	All	336	3,464	10.6	1.2	13.1
1949–1952	Selected	222	2,643	11.9	2.2	26.1
1954–1957	Selected	306	3,986	13.0	3.0	39.4
1958–1962	Selected	425	6,092	14.3	4.2	60.2

Before the improvement the 101 palms which now remain produced 74 % of the yield. The increased yield per hectare and per palm results from a larger number of individually heavier bunches. There was also a small additional yield from the few planted palms in the plots. It is worth noting that the density of 101 palms per hectare is suboptimal, other plots in the same experiment in which the density is about 150 palms per hectare having produced 8,000 to 8,500 kg of bunches.

In addition to giving an increased yield of palm fruit improvement of a grove creates more ground space, and allows more light to penetrate, two factors which facilitate farming within the grove. Conversely, thinning of a grove primarily to create farmland, also has the effect of improving the yield of fruit bunches from the remaining palms.

The advantage of palm grove improvement is that it is cheap and simple work giving a quick return. In cases where for some reason rehabilitation of the groves has to be delayed, palm grove improvement may be introduced as a precursor of rehabilitation.

10.6 Improvement of milling and cracking equipment

In section 11.3 the methods to raise the extraction coefficient and the methods to improve the cracking of kernels are discussed.

11 Efforts to improve the oil palm economy of Nigeria

11.1 Introduction

In 1926 the first scheme to improve the Nigerian oil palm industry was launched. The aim of this scheme was twofold *viz.* to increase the quantity of palm fruit and to improve the methods of extracting the oil. After 1920 competition from the growing oil palm industry in South East Asia and the then Belgian Congo was feared by the West African countries, whose economy largely depended on the products of the oil palm industry. In 1923, a Committee was appointed by the Secretary of State for the Colonies of the British Government to investigate means of improving the oil palm industry in what was then British West Africa. This Committee presented its report in 1924 (REPORT, 1924). In 1926, the first governmental measures directed to this purpose were approved on the understanding that there was to be no interference with local systems of land tenure and no coercion.

More palm fruit can be obtained by increasing the yield per unit area, by increasing the area under palms and by intensifying the exploitation of the existing palms. The Committee suggested that the crowns of the palms should be cleaned and the bush cleared, that planted plots should be created and that felling of palms for wine tapping purposes should be restricted. In 1923, some improvement and rehabilitation trials were started to investigate methods of improving the existing palm populations. These trials have been discussed in section 10.4.

11.2 First Rehabilitation and Improvement Scheme

In 1928, the first Palm Grove Replacement and Palm Planting Schemes were started. Seeds were obtained from Ndian Estate and some from the plantation belonging to the Alake of Abeokuta, but stemless palms collected from groves were also used. For example, in the Uyo Province 14 hectares were planted in 1936, but only nine of these were planted with young palms sold by the Agricultural Department. The aim of the scheme was to plant at least 4,000 hectares per year, but unfortunately it failed completely. Only 3,793 hectares were planted during the eleven years the scheme lasted. 3,512 hectares were registered under the Palm Planting Scheme and only 21 hectares under the Rehabilitation Scheme while 260 hectares were rejected. Only in the Benin Province the Planting Scheme had success; there 2,189 hectares were planted. The remaining 1,604 hectares were scattered over the rest of Nigeria (MACKIE, 1939). In

1935, the Government tried to make the scheme more attractive by offering financial incentives to planters. At the same time it was realised that more research into the cultivation of oil palms was needed and this led to the setting up of the WAIFOR's predecessor the Oil Palm Research Station near Benin in 1936.

11.3 Improvement of extraction methods

Although an exhaustive account of the improvement of extraction methods is beyond the purpose of this part, it would not have been well to leave this subject undiscussed, because it accompanied the palm planting schemes. The improvement was based on the introduction of hand screw presses and of nut crackers, the establishment of palm oil mills and the introduction of regulations to control the quality of palm produce for export.

Introduction of hand screw presses. The first hand screw presses were imported in 1931 for sale to farmers on easy terms. Initially there was little demand for these presses, but then there was a gradual increase. Finally they were in great demand, especially in the Nnewi-Ozubulu area near Onitsha, Akpabuyo area near Calabar and around Okigwi until in some areas there were soon too many presses in use. In the period 1931 to 1934 only 100 presses were sold, but in the last four years of the scheme 719 were purchased (MACKIE, 1939). BUCHANAN and PUGH (1958) estimated that in 1948–1949 there were 1,600 presses working in Nigeria 1,300 of which were in Eastern Nigeria. Clearly the introduction of these hand presses was a great success.

Introduction of nut crackers. However, the introduction of nut crackers was not successful. They were liable to break down and although the Government and private companies did everything they could, the repair of these nut crackers continued to be a problem. In 1950, 37 of the 78 nut crackers in Eastern Nigeria were out of order. A second disadvantage of the nut crackers was the large amount of labour needed to sort the kernels from the broken shells and uncracked nuts after cracking.

11.4 Palm Oil Mill Subsidy Scheme

The aim of the Palm Oil Mill Subsidy Scheme was the establishment of mills by private companies in the palm grove areas. To encourage these companies the Government undertook to underwrite any loss. The first and only mill under this scheme was erected by the United Africa Company (Ltd.) at Ibagwa near Abak. As the purchase price for fruit was only equal to that paid by the 'middlemen' for the hand presses, an insufficient quantity of fruit was offered to the mill which could not afford to pay more without incurring financial loss. This scheme was most unsuccessful and the mill was closed down and removed.

11.5 Palm Produce Inspection Service

The introduction of hand presses improved the quality of the oil, but quality was still low and often worsened by adulteration. For instance, stones, shell refuse and dirt were often found in bags of kernels, and wooden blocks were fixed inside drums containing oil to increase their weight. To tackle the problems the Palm Produce Inspection Service was established, first in Western Nigeria in 1926, then in Eastern Nigeria in 1928 and after some time it was extended to cover the whole of Nigeria. Inspection led to an immediate improvement in quality; in obvious cases of adulteration fines were imposed. The object was to encourage the planting of oil palm and the Act allowed owners of palm plots of five or more hectares to reclaim part of all of the export duty on the oil. When the oil had an f.f.a. content of 4% or less the whole export duty was remitted, when the f.f.a. was 5–8% nine tenths of the duty was remitted. Oil derived from grove palms or from unregistered plots did not qualify for any rebate.

The price paid for oil from grove palms was irrespective of whether its f.f.a. content was 1 or 11% and this led to mixing of bad and good oils to make an oil with an f.f.a. content of about 11%. From 1938 onwards, the United Africa Company (Ltd.) paid a higher price for oil with an f.f.a. content below 5%. This measure, which found general acceptance, was soon adopted by other firms. Inspection and the premium for better oil lead to a considerable improvement in the quality of the palm produce presented for export.

11.2/5.1 Causes of failure and success

It is of interest to examine the causes of failure and success of these schemes because these must be taken into account when considering new schemes. The causes of failure of the introduction of nut crackers and of the establishment of mills, and the reason for the success of the introduction of hand presses and of the inspection of the quality of the palm produce have already been mentioned. The causes of the failure of the Palm Grove Replacement and Palm Planting Schemes will be more fully examined. Earlier and concise accounts have been given by FAULKNER (1929, 1931–1936), MACKIE (1937–1939), BRIDGES (1939), FORDE and SCOTT (1946) and HARTLEY (1954).

Human factors. The various rights over land and palms were the main obstacle to the success of these schemes, especially in densely populated Eastern Nigeria. There the planting of palms in farmland could not be advocated, because the area available for farming was already limited, and agreement to replanting of land already carrying palms was difficult to obtain because the palms are often group owned and, of course, replanting of groves was more laborious because the existing palms had to be felled. Quite apart from the amount of work involved, the farmers were and are reluctant to fell palms because every palm is a source of income and in any case the necessity of attending young palms was completely alien to them. What they wanted was improved planting material, which would grow in competition with the bush regrowth, as happens under conditions of subspontaneous and natural regrowth.

Inadequate propaganda led to misunderstandings about the purpose of the Government schemes for planting palms. It was believed that a planter or a press owner would have to pay more tax, or that the Govenement would take possession of the plots as soon as the palms came into bearing. The Government was considered the planter of the plot and therefore also as the owner.

Agricultural factors. When these schemes were started information on the best practices to be adopted was inadequate. Little was known about nursery and planting techniques. The young palms planted in the field were too small; many still had non-pinnate leaves. The retention of 125 old palms per hectare was ill-advised, and no advice was given about the application of fertilizers. Present knowledge makes it clear that the young palms suffered from an inadequate supply of nutrients, especially when planted in farmland.

Administrative factors. It seems that there was insufficient propaganda about the schemes and inadequate following up after the palms were planted with the result that the farmers lost interest and many replanted plots were abandoned. It took too long before the farmer reaped the reward for his work; payment of a subsidy during the years of establishment of the palms would have helped to maintain his interest. Another unfavourable factor was that the farmer had to sell his oil to export firms in order to obtain the rebate of the export duty.

Economic factors. During the course of the scheme the prices for palm produce dropped in some years, and this, quite naturally, had an immediate adverse effect on the farmers' enthusiasm to plant palms. Interest was also lacking in areas having another main cash crop *e.g.* kola, cocoa or rubber.

Legal factors. The success of any scheme as affected by (customary) legal factors has been discussed in section 7.2. ALLAN (1965, p. 357) reported that in Nigeria the idea of planting of small plots was resisted by the chiefs on the grounds that such a development would lead to individual rights on land and this, in turn, to the collapse of the group authority. It should be added that in many cases it is the group which does not like the idea of some individuals being proportionally more privileged than others, *e.g.* by obtaining land for planting palms. Many plots planted under this scheme were owned by village and clan chiefs, who have already a privileged position. However, the author did not investigate the history of these plots.

11.2/5.2 Suggestions

In 1938, an Administrate Officer, A. F. B. BRIDGES, was instructed to prepare a full report (BRIDGES, 1939) on the oil palm industry in Eastern Nigeria and to make suggestions which could lead to its improvement. He suggested that instead of a rebate for the oil produced a subsidy should be given at the time of planting. He therefore divided Eastern Nigeria into four zones, and for each zone he set up a subsidy scheme. Zone A was the part of the palm belt having a population density of 200 to 300 persons per sq.km. He advised that a subsidy of £ 1.5.0 d. per hectare of improved or rehabilitated palm grove should be paid to the farmer, but that no subsidy should be given for palm planting in farmland. Zone B was the part of the palm belt having a population density of more than 300 persons per sq.km. The individual plots in this zone are sometimes very small and BRIDGES recommended that a subsidy scheme here should be on the basis of single palms, rather than on area, and that it should amount to one shilling per palm replaced. It was also in this case that no subsidy was to be given for palms planted in farmland. Amalgamation op plots was to be encouraged. Zone C was the open grassland area, in which the soils are liable to erode, and where planting of palms would assist in soil conservation. The subsidy suggested was an initial payment of £ 2.16.0 d. per hectare plus a further 15/- annually for the next five years as a contribution to the costs of maintenance, including the prevention of fire. No subsidy would be given for replacement of palms in the village groves. Zone D was the remaining area where there is no shortage of land. The subsidies were to be the same as for zone C. It is evident that BRIDGES based his subsidies on the fact that where there was a shortage of farmland, planting of this land with oil palms should be discouraged, whereas in zone C the subsidy would be paid to assist in control of erosion, and in zone D to promote development of new land.

BRIDGES made the further suggestion that instead of a rebate of duty being paid on oil produced from registered plots, a premium should be paid on the quality of the oil irrespective of its origin, and that any scheme should be backed by adequate publicity.

His suggestions could not immediately be brought into practice due to the war, which caused a shortage of staff, the officers remaining being fully occupied in fostering the production of food crops. Nevertheless every year a few hundred hectares were planted with palms grown in the nurseries of the Agricultural Department and after the war attempts to improve the oil palm industry were renewed.

11.6 Second Rehabilitation and Improvement Scheme

The Second Rehabilitation and Improvement Scheme started in December 1953 (for Eastern Nigeria only) when BRIDGES' advice on payment of a subsidy was put into practice, and started with a Pilot Scheme in the Uyo Province. Two methods of rehabilitation were used *viz.* (1) partial felling (leaving 74 grove palms per hectare) and complete replanting at a triangular spacing of 8.7 m and (2) partial felling and replanting in twin rows of palms at a distance of 4.5 m between the lines of a pair and 10.5 m between pairs of twin rows. Both systems gave the same plant density, but the twin row system left space for farming. The subsidy was £ 12.7.0 d. per hectare and was paid as follows:

£ 3.14.0 d. on completion of felling and clearing;
£ 3.14.0 d. on completion of planting with improved palms;
£ 1. 4.9 d. a year during the next four years provided the maintenance was satisfactory.

Later the schedule of payment was changed slightly, the aim being to maintain the rehabilitated plot at a high standard, but the total subsidy remained the same. The payment of £ 7.8.0 d. originally made in the first year, was now spread over the first two years and supplying of vacant stands was made attractive.

The new schedule was:

£ 3.14.0 d. on completion of felling and clearing;
£ 1.17.0 d. on completion of planting;
£ 1.17.0 d. for satisfactory establishment of the plot;
£ 1. 4.0 d. for satisfactory maintenance and supplying of vacancies;
£ 1. 5.0 d. a year during the next three years provided maintenance was satisfactory.

The progress of this scheme is not well recorded in the Annual Reports (1954–1960) of the Eastern Nigerian Ministry of Agriculture. In the first half of 1954 39 hectares were planted under a Pilot Scheme in the Uyo Province, but unfortunately 20% of the young palms died within a year. Their death was caused by technical difficulties. In 1955 21 hectares were rehabilitated in Calabar Province and 3.6 hectares in Owerri Province. In 1956 59 hectares were rehabilitated and in 1957 none, as a result of the late payment of the subsidy in 1956. However, in 1958 66 hectares were rehabilitated, all in Calabar Province. Thus over the first five years about 189 hectares were treated, but precise information is not available for the period after 1958. Fortunately only a few hectares were planted on the twin-row system which has been shown to give a much reduced yield due to high within row competition (Sly and Chapas, 1963).

This scheme failed for much the same reasons as the first scheme, and it was quite obvious that the success of any such scheme completely depended on the financial incentives it offers.

At the same time as this scheme was in operation, planting material was issued to farmers for planting in plots too small to come under the scheme. During the years 1956–1960 about 124,000 young palms were issued annually in Eastern Nigeria. This is equivalent to about 840 hectares of plantation. At that time the WAIFOR's Extension Work seed consisted of *dura* × *dura* and *dura* × *tenera* material.

11.7 Second Palm Oil Mill Scheme

Like the previous plan the activities concerning the realization of a net-work of palm oil mills had to be postponed till after the war. Then the work was undertaken by the three regional development corporations by building Pioneer oil mills. It was intended to sell the mills to local cooperations as soon as they were in good working order. In 7.1.4 quite a number of mills were reported to have been closed down during parts of the year, because of lack of input. Some of these mills were shifted to other areas which looked promising. Some other mills have been sold to cooperations.

11.8 Third Rehabilitation Scheme

When it was realised that the incentives of the second rehabilitation scheme were insufficiently attractive to farmers a new scheme was formulated as part of the Nigerian Six Year Development Plan, and started in Eastern Nigeria in 1962. Details of it are given here not only to complete the picture, but also because the author was associated with the planning stage and trained the first fifty rehabilitation officers.

This scheme has the dual object of improving the farmer's income and raising the revenue derived by the Government from the various taxes and levies on palm produce, which in 1960 are shown in Tabel 33.

Table 33. Revenue accruing to the Nigerian Government from Palm Produce in £ per English ton

	Palm oil	Kernels
Purchase tax	£ 4	£ 2
Export duty	£ 6.17.7 d	£ 5.19.4 d
Marketing board levy	£ 6. 9.2 d	£ 6. 9.2 d
Total	£ 17. 6.9 d	€ 14. 8.6 d

Since 1960 the amount paid to the growers by the Marketing Boards has been reduced without a corresponding fall in the world price of palm produce, and this had reduced the profit margins of both farmers and traders and raised the amount accruing to the Revenue.

An adult plantation produces about 2,800 kg more oil and 400 kg more kernels per hectare than a palm grove and when the increased quantity of produce is exported the Government stands to gain additional revenue. In fact MENEKAYA (1961) calculated that the Government should recoup the subsidy paid to assert replanting within one year and five months of a plantation coming into production.

11.8.1 Details of scheme

This scheme will last for six years, the target being to rehabilitate 24,300 hectares of palm grove. A subsidy of £ 44.9.2 d. will be paid in cash and in kind per hectare of rehabilitated palm grove. The subsidy in kind takes the form of planting material and fertilizers; the cash is intended to cover part of the cost of the labour used for felling and preparing the land and later for maintenance, and the loss of income during the first four years after replanting. In order to qualify for subsidy the minimum area of grove to be rehabilitated is two hectares. Only few farmers own such a large area, but the subsidy is thought to be attractive enough to induce the farmers to cooperate. The main advantages of these blocks are that the work of the Ministry of Agriculture can be better concentrated and that when the palms are in production, processing of fruit can be carried out on a cooperative basis.

The planting distances recommended by the WAIFOR for this scheme are either full plantation density or, when farmland is also wanted, double rows of palms with a strip for farming between these pairs of double rows obtained by omitting one or more palm rows. The Ministry of Agriculture also recommends a single row arrangement *i.e.* one row planted, one row omitted, but this may lead to farming under the palms, with consequent pruning and scorching of the leaves. Fifty grove palms per hectare are allowed to remain standing during the first four years to provide the farmer with some income from palm produce during that period.

11.8.2 Early results

The target in the first year (1962) was 1,215 hectares, but only 702 hectares were rehabilitated and the target in 1963 was 2,835 hactares, with only 1,536 hectares rehabilitated. Thus during the first two years only 55% of the target figure was achieved, and this means that 22,000 hectares have to be done during the remaining four years.

Unfortunately many of the young palms issued to farmers were too small, and were planted too late in the year. EICHER and MILLER (1963) also noted that fertilizers were applied too late, and that the replanted areas were not well maintained. Payment of the subsidy was often late and the distribution of palm grove rehabilitation officers was somewhat peculiar *viz.* one in Uyo Province (dense palm grove area) and 21 in Abakaliki Province which is not a dense palm grove area (EICHER and MILLER, 1963).

11.8.3 Conclusion

Comparison of the preliminary results of this scheme with those of the earlier schemes shows that the same mistakes are being made, and greater effort will be required if this scheme is to be successful. It must not be forgotten, however, that the policy of the Marketing Boards to pay low local prices for palm produce has a directly contrary effect upon to that intended to be engendered by there planting scheme.

11.9 Introduction of hydraulic hand presses

Since 1964 attempts have been made to introduce hydraulic hand presses to the peasant farmers of Eastern Nigeria. It is suggested that several farmers should cooperate and together establish a milling plant as designed by NWANZE (1963, 1965).

It is too early to discuss the results of this scheme.

12 Future of oil palm industry, a general conclusion

Ecological and human factors at work in palm grove formation, deterioration and exploitation have been analysed. The high population density in some areas and its present rapid increase are putting a heavy strain on the available land, resulting in a progressive reduction in the length of the fallow in the food crop rotation. This lowers yields and exhausts the farmland and oil palms may be felled to provide more land for growing food crops. As people settle permanently, the cause of the origin of palm groves disappears and the oil palm industry declines. Permanent settlement arises from the desire for 'modern' ways of life. As a result the population increases, school-leavers often turn their backs on agriculture and particularly on climbing palms, although they can live in a modernized town or village enjoying such amenities as electricity, mains water and medical care and can reach the farm quite easily by bicycle.

With population still increasing the standard of living is bound to deteriorate, unless improved methods of growing subsistence and cash crops are adopted, and this can only be brought about through changes in the traditional pattern of agriculture. One method of raising output is the replacement of the palm groves by community plantations and small holdings, thereby releasing land for arable farming. This will be an expensive undertaking, not only in terms of money, but also in human effort, and success will depend on the simultaneous adoption of up-to-date agricultural techniques.

Summary

Introduction. An outline of the industry of the oil palm (*Elaeis guineensis* JACQ.) in Africa is given. The economy of some regions as Eastern Nigeria, south Dahomey, the Kwango district in the former Belgian Congo depends for a great part (if not entirely) on the oil palm.

The oil palm is indigenous to Africa and from there it was taken to America and Asia. This conclusion is based on data extracted from old documents, and on its vernacular names in Africa and America. In 1608 CLUSIUS in DODONAEUS' *Cruydt-boeck* even called the oil palm *Palma Guineensis* and in 1763 JACQUIN did not hesitate to use this specific epithet. Furthermore, fossil pollen grains closely resembling the present ones continuously occur in sediments of the Niger delta since the Miocene era.

The trade in palm oil started early, but since the abolishment of the slave trade and the start of the industrial revolution palm oil has become an important export commodity.

Researches on the palm groves were mainly carried out on the substation of the West African (since October 1964 Nigerian) Institute for Oil Palm Research, near Abak in Eastern Nigeria. The situation of this Station and the relevant climatological data collected are given.

Design and execution. This part contains basic information on the design of the book, the execution of the work and explanations of some technical terms. It should be pointed out that although the term seedling for a nursery palm is widely used, this name is unsatisfactory because such a palm no longer depends on its seed or this name may apply to all oil palms as they all grow from seed. It is, therefore, preferable to call palms that are still in their rosette stage stemless palms.

The field work started at the end of 1959 while collecting data practically ended at the end of 1963.

Centres of variation, natural habitats and present geographical distribution. It is impossible to establish exactly the centres of variation of the oil palm, but these centres seem to be located in the eastern part of West Africa and in Central Africa.

The oil palm naturally grows in areas which are too wet for dicotyledonous trees. Such habitats include springs, banks of rivers and lakes, wet valleys and swamps. Most of the palms which now grow in these sites probably derive from seeds taken by men and animals. The present large palm groves occur apart from river banks, mainly in areas distributed by man, but which would carry rain-forest as climax vegetation.

In Africa the oil palm occurs mainly in three areas. The largest area covers the coastal zone of tropical West Africa and the adjacent Central Africa; it is still extending to the east. A second area is found along the coast of Kenya and north-east Tanganyika and on the islands of Zanzibar and Pemba. The third area is western Madagascar. It is possible that the palm has been introduced into the last two regions when the Arabs were taking negro slaves from Central Africa to the coastal area and later to Madagascar. These slaves would have taken oil palm seed. This chapter is concluded with a description of some recent introductions.

Domestication and selection. The domestication of the oil palm is complete only in a few areas. In general, complete domestication is unnecessary because the oil palm grows easily under varying conditions. Despite its utility as a source of fat some tribes in Central Africa did not know this palm.

The competition between the oil palm and other plant species in a rain-forest, and between certain oil palm types within an oil palm population is discussed. The oil palm or some of its types may be replaced in the vegetative succession. Factors involved may be the height of the competing plant species, or differences in reproductive capacity of certain oil palm types.

Production may be improved by the following methods:

1. Sowing of seeds obtained from grove palms.
2. Transplanting of young grove palms to a more suitable site.
3. Sowing of selected seeds and transplanting of the resulting young palms. This selection may be made on various characteristics such as *tenera* shell, high wine production or big kernels. This would result in palm populations with high frequencies of certain types.
4. Selective thinning of oil palm groves during the creation of more arable land.

Unintentional selection occurs where the fruits of the *dura* type are sold and relatively great numbers of the *tenera* type are left for germination in the village, or where 'mantled' fruits are left in the grove to rot. Such a relation may work in various directions.

Origin and classification of oil palm groves. Oil palm groves arise on abandoned compounds when the former dwellers have left a great number of viable fruits. Some palms may grow up during the occupation of the compound, but many young palms are destroyed during the preparation of gardens. Palms are planted only where insufficient numbers are available to provide enough oil and wine. Some palms grow up on farmland, but many of them will be damaged by pruning and fire.

Several authors have tried to classify the various grove types. Generally such classifications are based on the density of the grove, but in some cases on habitat. The present author has made the following classification: 1. Secondary rain-forest with oil palms, 2. Palm bush, 3. Dense palm grove/Farmland with oil palms, 4. Thinned grove, 5. Sparse grove, 6. Village grove, and 7. Peasant plantation. These palm grove types, except type 7, originate under the influence of different population pressures.

A Secondary rain-forest with oil palms develops in sparsely populated areas. At higher population densities Palm bush grows up, and at still higher densities the Dense grove/Farmland with oil palms arises. With a further increase of the population it becomes necessary to fell palms to create farmland: Thinned grove. In Sparse groves dead and felled palms are replaced by regrowth of palms, but if the area is too frequently burned, no new palms grow up and the grove disappears. In such cases it is necessary to plant palms which is done on the compounds. Grove type 7 arises only with modern agricultural methods.

Dense palm groves are almost pure. They were superficially studied since the beginning of the present century in Nigeria, but in 1945, a more thorough investigation was begun. This grove type is subdivided into: E_2 grove of compound palms near homesteads set up about 12 years earlier in farmland, B_1 grove of young palms on abandoned compounds, B_2 grove of adult palms in dense stand, C thinning grove with patches of farmland, D grove of open farmland palms, and E_1 grove of compound palms near homesteads recently set up in farmland.

The Asutan Ekpe Oil Palm Survey groves belong to the Thinned grove type. However, at the beginning of this investigation in 1948 the continuous felling of the palms was not recognized. This grove type may be subdivided into: E_2 grove of compound palms near homesteads set up about 12 years earlier in farmland, B_1 grove of young palms on abandoned compounds, B_2(a) grove of adult palms in dense stands, in a later stage gradually affected by thinning and farming, C(a) thinned grove, some young palms growing up, D grove of old and some young open farmland palms, and E_1 grove of compound palms near homesteads recently set up in farmland. Felling is mainly carried out during the preparation of the farmland.

Palms planted on compounds and in peasant plantations are selected. In these grove types the domestication of the oil palm is complete. Village grove palms look healthy because they grow on fertile soil, but the peasant plantations are often established on exhausted farmland where no fertilizers are applied. Such palms do not produce much, but when they receive potassium fertilizers, yield may increase more than 100%.

Yield. The number of bunches and their average weight are influenced by the environment and other factors. Some of these factors are discussed. The density of a palm grove influences the yield of that grove: with increasing density the palms compete more and more with each other and yield per palm decreases, but the yield per hectare may still increase until an optimum density has been reached. The height of the palm is partly influenced by the density of the grove and the age of the palm. Palms 15 to 20 m high yield most; they produce about 77% of the total yield. To characterize the age of a grove the author used the R/S quotient: the ratio between rough- and smooth-stemmed palms.

To get some information on the production of leaves and inflorescenses of grove palms, these characteristics were determined on 180 smooth-stemmed Dense grove palms over three years. The annual production of leaves of unshaded and almost unshaded smooth- and rough-stemmed palms varied from 15 to 19 per palm. The stemless palms did not give a clear picture; the average age of their leaves was calculated. The results, combined with other data, indicate a retarded development of the palm with age. This causes the seasonal peak of yield in old palms to be later than in young palms. After giving the number of leaves per palm height, floral abortion and bunch failure are discussed.

An impression of the nutrient status of the leaf was obtained by analyzing samples of leaflets.

During the preparation of farmland, leaves of young palms are often cut and fire may scorch all leaves, even of tall palms. In some regions leaves are used for domestic purposes. This reduces the leaf area, but unfolding of undamaged 'spears' and production of new leaves increases it again. However, low leaf area has a direct effect on the bunch weight and an indirect effect on the sex ratio of the inflorescences, and thus on the immediate and later yield of the palm.

In section 6.1.8 the frequencies of the fruit types and the *idolatrica* leaf type are mentioned. The next section discusses the composition of bunches and fruits.

Soil samples were taken in the same grove as leaflets for a chemical analysis. Especially in the grove areas of West Africa a potassium deficiency was noticed. Yields increased with potassium fertilizers. Some data concerning soil analyses of other groves are given.

In some areas the oil palms are tapped for wine. For this purpose the palms are either left to stand or felled. The last method can only be justified when enough palms are available or when oil extraction is difficult because of lack of water. The effect of tapping a standing palm on bunch production needs further investigation.

Competition between palms, its effect on yield per palm and per hectare have already been mentioned. The results of our investigation show that an increase of palm numbers in a 'rain-forest with oil palms' does not result in a proportional increase in production, but to a lower production per palm (except when low numbers of palms are considered).

The mean yield in bunches of an average Dense grove/Farmland with palms is about 2,800 kg per ha. On average about 65% of the stemmed palms are in production.

As has been mentioned, the peak of the yield shifts with the age of the grove. Hence this peak may coincide with the peak in the preparation of fields for farming. The ratio of the highest monthly yield to the lowest monthly yield influences the economy of the oil mill. At Abak this ratio was less unfavourable than in some groves of Sierra Leone.

The actual production of a grove is less than the potential, because several factors mentioned in this and the next part reduce the final yield of a grove.

Exploitation, extraction of oil, cracking of nuts, rights over palms and consumption. The exploitation of a palm grove depends on various factors such as harvesting systems and methods. Harvesting systems of some villages are described. These systems may change with time. There are two types of climbing ropes. One, the sling, is much quicker in use; the other, a set of two ropes, is much safer. In some areas palms are not climbed, but the fallen fruits and nuts are collected. Types of traditional oil processing and of cracking nuts are described. Improvements of these methods are the screw hand press, the hydraulic hand press, the oil mill and the nut cracker. They do not always fit in the local economy which has resulted in failures and financial losses.

Rights over palms have an important influence on the output of a grove. They are described and it is indicated that they may be adapted to changed circumstances. Not many data are available about the number of palms owned by farmers; they could only be obtained for one grove.

Palm oil is a food; the quantity used depends on the price and on the season. It is also used as a cosmetic and for lamps.

Diseases and pests. The main cause of death of the grove palms is trunk rot. Usually *Ganoderma lucidum* is mentioned as the pathogen, but the taxonomy of the genus *Ganoderma* and related genera has not yet been fully studied and hence the literature on this subject has been reviewed. In this book the common name for this disease *viz.* '*Ganoderma* trunk rot' is not used to avoid confusion.

Other plants attacked by stem rot are mentioned; the external symptoms of a diseased palm are given. The course of infection is not yet clear. Some factors which influence the occurrence of this disease are discussed. One of the results of our investigations was that the application of potassium fertilizer reduces the number of killed palms over a certain period.

Pests are uncommon with the oil palm. In fact man is the main 'pest' since he cuts and scorches leaves, bores or cuts holes in the stem, cuts holes in the stems of female inflorescences, cuts off male inflorescences and even fells the palms. But it should also be remembered that man has created large areas suitable for the oil palm.

The farmer's knowledge of trunk rot is discussed.

Deterioration and retrogression of palm groves. With increasing average age of a palm grove the yield will decrease with a decrease in the number of yielding palms. In a rain-forest, gaps left by dead palms, will be filled with rain-forest trees. In a Dense grove gaps will be used for farmland and partly as residential areas.

One of the subjects to be studied by the Asutan Ekpe Oil Palm Survey was the developmental cycle of a Dense grove, but at the time of establishment of this trial the Thinned grove type was not recognized. By cutting palms the 'ordinary' course of things is seriously disturbed. Density and stem type in two Dense palm groves, and in a Rain-forest with oil palms were determined twice to give an impression of the development of these groves. The oil palm economy decreases with the diminishing numbers of oil palms in a certain area. Felling for wine tapping and to increase the farmland area have already been mentioned. But with the introduction of a modern way of life the people settle permanently, so new palm groves no longer develop and the number of palms decreases. This trend can be counteracted by planting.

Methods of increasing oil and kernel production. The oil and kernel production of a grove can be increased by a more intensive exploitation, by increasing the bunch yield per hectare, by increasing the oil and kernel to bunch ratios, and by increasing the extraction coefficient.

In the densely populated regions of Eastern Nigeria the palm groves are sufficiently accessable to ensure a relatively easy way of harvesting every palm. In thinly populated regions the accessibility is less, and fewer people are available to harvest the fruits. Here permanent or temporary migrant workers may solve the problem. A well designed marketing system may relieve the farmer of time-consuming transport of oil and kernels. The development of a transport system may open up new areas which will enable the farmers to sell their products more easily than before.

Fertilizers are not frequently used. Only a few cases are known in which compost or fertilizers are applied and they often concern trials or demonstrations. A review of these trials and demonstrations is given. A trial of the WAIFOR is discussed. Application of potassium fertilizers may significantly increase yield.

The grove may be bettered by rehabilitation and improvement. Early in this century recommendations were already made on improvement. These recommendations were based on common sense and experience gained with other crops. In addition some demonstration and experimental fields of improved groves were established. In most cases, the layout of the trials was statistically inadequate.

Two improvement and rehabilitation trials were established by the WAIFOR in Dense grove/Farmland with oil palms and one in a Thinned grove. The conclusion was that there was no objection to leave some old palms during the first four years, provided the farmer was aware of the fact that these palms should be felled in the fourth year. These old grove palms will considerably increase their yield, but planted palms of high quality will yield more on the long run. As the farmer is not yet fully acquainted with the production of these selected palms he is inclined to leave the old palms.

A discussion of the cost of rehabilitation and the ease of obtaining higher yields from improved groves concludes this chapter.

Efforts to improve the Nigerian oil palm economy. After 1920, the oil palm economy of West Africa was seriously threatened by the fast growing oil palm plantations in South East Asia. To counteract this threat, in former British West Africa a committee proposed a four-point program. The causes of success and failure of parts of this plan are discussed. In 1938 a new plan was proposed for Eastern Nigeria. Due to the Second World War this plan could not be started before 1953 and then only in a modified form with the establishment of the Second Rehabilitation and Improvement Scheme. This scheme was not successful either. A separate plan to establish oil mills in southern Nigeria was carried out at the same time; only a few of these mills could be run without financial losses.

A third rehabilitation and improvement scheme was started in Eastern Nigeria in 1962. The results obtained in the first years are not encouraging.

Samenvatting

Inleiding. Een kort overzicht wordt gegeven van de cultuur van de oliepalm (*Elaeis guineensis* JACQ.) in Afrika en wat daarmee annex is op het gebied van oogst, handel en verwerking. De economie van enkele streken zoals Oost-Nigerië, zuidelijk Dahomey, het Kwango district in de vroegere Belgische Congo is, zo niet geheel, dan toch grotendeels van de oliepalm afhankelijk.

De plant is inheems in Afrika en is daar vandaan naar Amerika en Azië gebracht. Deze conclusie berust zowel op gegevens verkregen uit oude documenten als op de naamgeving van de oliepalm in Afrika en Zuid- en Midden-Amerika. Al in 1608 noemde CLUSIUS in DODONAEUS' Cruydtboeck de oliepalm *Palma Guineensis* en JACQUIN aarzelde niet deze specifieke naam te gebruiken in zijn *Selectarum stirpium americanarum historia*... van 1763. Verder werden fossiele stuifmeelkorrels in miocene en jongere gesteenten uit de delta van de Niger gevonden, die zeer veel gelijkenis vertonen met die van de huidige oliepalm.

De handel in palmolie begon al vroeg, maar ze nam pas aan het einde van de 18e eeuw een grote vlucht, toen door de opkomst van de industrie de vraag naar smeeroliën toenam.

Het onderhavige onderzoek in de oliepalmbossen werd voornamelijk verricht op het substation van het West African (sinds oktober 1964 Nigerian) Institute for Oil Palm Research te Abak, Oost-Nigerië. De klimatologische gegevens, die op dit station betrekking hebben zijn vermeld in tabel 1.

Ontwerp en uitvoering. Dit deel bevat naast gegevens betreffende de indeling van de stof en de uitvoering van het werk een verklaring van enige vaktermen. Hier was gelegenheid te wijzen op het onjuiste gebruik van de term 'seedling' voor kwekerijplanten, daar deze benaming alleen geldt voor die jonge planten, die nog afhankelijk zijn van het zaad of voor alle uit zaad ontstane planten zonder hun leeftijd in aanmerking te nemen. Daarom is het beter palmen, die nog in hun rozetstadium verkeren stamloze palmen te noemen.

Het onderzoek werd voornamelijk in de periode tussen eind 1959 en eind 1963 uitgevoerd.

Verspreidingscentra, natuurlijke groeiplaatsen en huidig verspreidingsgebied. Het blijkt niet mogelijk te zijn om de juiste verspreidingscentra van de oliepalm aan te geven, maar vermoedelijk liggen deze in het oostelijk deel van West-Afrika en Centraal-Afrika.

De natuurlijke groeiplaats van de oliepalm vindt men op terreinen die te nat zijn voor dicotyle boomsoorten. Deze plaatsen zijn bronnen en oevers van rivieren en beken, vochtige dalen, oevers van meren, moerassen, alluviale vlakten e.d. Dit betekent niet dat alle palmen, die tegenwoordig op zulke groeiplaatsen voorkomen wild zijn: de meeste zaden zullen daar door de mens gebracht zijn. De huidige uitgestrekte palmbossen komen, naast rivieroevers, voornamelijk op terreinen voor die tropisch laagland-regenbos als climax droegen.

In Afrika kunnen drie hoofdgebieden worden onderscheiden waar de oliepalm voorkomt. Het grootste gebied omvat de kustzone van Tropisch West Afrika en West en Centraal Equatoriaal Afrika; aan de oostelijke zijde breidt zich dit gebied nog uit. Een tweede gebied ligt aan de kust van Kenya en Noordoost-Tanganyika en de eilanden Zanzibar en Pemba. Het derde gebied ligt op westelijk Madagascar. Het is mogelijk, dat de twee laatstgenoemde arealen ontstaan zijn, toen Arabieren negers als slaven uit Centraal Afrika eerst naar de kust en later naar Madagascar brachten. Deze slaven zouden oliepalmzaden meegenomen kunnen hebben.

Dit deel wordt besloten met een beschrijving van enige recente introducties in andere gebieden.

Domesticatie en selectie. In de meeste gevallen is volledige domesticatie van de oliepalm niet nodig, omdat hij gemakkelijk opgroeit in anthropogene milieus. Desalniettemin kenden enkele stammen in Centraal-Afrika deze palm niet als een olieleverend gewas.

De concurrentie tussen de oliepalm en andere plantensoorten in een regenbos en ook tussen bepaalde typen oliepalm binnen een oliepalmpopulatie in een 'Dicht palmbos' wordt besproken. Door deze concurrentie kan de oliepalm geheel uit de vegetatie verdwijnen of kunnen bepaalde typen zijn uitgeschakeld. Factoren zoals hoogte van de concurrerende plantensoorten en verschillen in reproduktievermogen van bepaalde oliepalmtypen spelen hierbij een rol.

Verder is het feit gereleveerd, dat de mens bewust en onbewust de oliepalmcultuur verbetert. De bewuste verbetering kan in vier delen onderverdeeld worden:

1. Het zaaien van zaden, geoogst van halfwilde palmen.
2. Het overplanten van jonge, halfwilde palmen naar geschiktere plekken.
3. Het zaaien van op bepaalde eigenschappen geselecteerde zaden en eventueel overplanten van verkregen jonge palmen. De zaden worden geoogst van palmen met een of meer gewenste eigenschappen, bijv. een dunne schaal (het zgn. *tenera*-type), een hoge wijnproduktie of grote palmpitten. Een dergelijke selectie kan leiden tot oliepalmpopulaties met hoge frequenties van bepaalde typen.
4. Het dunnen van de oliepalmbossen om meer bouwland te krijgen, waarbij tijdens het vellen voornamelijk slechte en niet-producerende palmen worden gekapt.

Onbewuste selectie vindt ook plaats: halfrotte trossen worden in het bos achtergelaten, trossen van een bepaald type worden naar een andere plaats gebracht waardoor later op die plek een palmbos met een hogere frequentie van een bepaald type kan optreden. Andere factoren, zoals rechten over de palmen, kunnen het ontstaan van geografische rassen bevorderen. Door transport van planten, vruchten en stuifmeel kunnen ontstane verschillen echter weer vervagen.

Ontstaan en indeling van de oliepalmbossen. Oliepalmbossen ontstaan op verlaten erven als de vroegere bewoners een groot aantal levenskrachtige palmvruchten om hun huis hebben achtergelaten. Voor gebieden met dichte palmbossen wordt het aantal weggegooide vruchten op 4000 per erf per jaar geschat, maar in gebieden met secundaire regenbossen zal het aantal veel kleiner zijn.

Op het erf laat men, tijdens de bewoning, dikwijls enkele oliepalmen opgroeien, maar in het algemeen zullen jonge palmen tijdens de verbouw van erfgewassen verloren gaan, tenzij het aantal palmen buiten het erf te gering is om voldoende olie en/of wijn voor de bewoners te produceren. Dan kan de oliepalm ook een erfgewas worden.

Op bouwland komen verspreidstaande palmen voor. Deze worden vaak door snoeien en tijdens het branden zwaar beschadigd.

Verscheidene schrijvers hebben gepoogd om de verschillende oliepalmbossen te classificeren. In het algemeen zijn dergelijke indelingen gebaseerd op de dichtheid van het palmbestand, maar in sommige gevallen op de groeiplaats. Schrijver dezes heeft de volgende indeling gemaakt: 1. secundair regenbos met oliepalmen, 2. palmbosje, 3. dicht palmbos/bouwland met palmen, 4. gedund palmbos, 5. open palmbos, 6. dorpspalmbos, 7. palmgaard.

Deze typen palmbos ontstaan onder invloed van verschillen in bevolkingsdichtheid. Bij een steeds toenemende bevolkingsdruk ontwikkelt het type 'Secundair regenbos met oliepalmen' zich eerst tot een 'Palmbosje' en tenslotte tot een 'Dicht palmbos/Bouwland met oliepalmen'. Bij een nog verdere toename van de bevolking is het nodig palmbossen te dunnen om bouwland vrij te maken: 'Gedund palmbos'. Via 'Open palmbos', waarbij de regeneratie van het bos gelijke tred houdt met sterfte en kap, wordt het gehele gebied als bouwland gebruikt. Opslag van oliepalmen wordt dan door het regelmatig branden verhinderd. Om toch over oliepalmen te kunnen beschikken, worden deze op de erven aangeplant. Palmbostype 7 ontstond onder invloed van moderne landbouwmethoden.

Dichte palmbossen worden door een bijna zuivere populatie van oliepalmen gekenmerkt. Zij werden in Nigerië sinds het begin van deze eeuw oppervlakkig bestudeerd, maar pas na 1945 is een begin gemaakt met een meer diepgaande studie.

Een onderverdeling van dit palmbostype werd als volgt gemaakt: E_2 palmen op woonerven die ongeveer twaalf jaar eerder in bouwland werden gevestigd, B_1 jonge palmen op verlaten woonerven, B_2 volwassen palmen in dichte bestanden, C palmen in zich lichtstellend bos met plekken bouwland, D palmen op bouwland, E_1 palmen op recente woonerven. Een ruwe schatting van het aantal jaren, dat verlopen is sinds de bewoning begon en van de duur van de bewoning, alsmede een ruwe tijdschaal voor de leeftijd van de oliepalmen van deze subtypes wordt gevolgd door een beschrijving van vijf dichte palmbossen.

De palmbospercelen van de Asutan Ekpe Oil Palm Survey behoren tot de gedunde palmbostypen; in de beginjaren van deze survey heeft men het voortdurend vellen van palmen niet onderkend. Een onderverdeling van dit palmbostype loopt parallel met de boven gegevene, behoudens de onderscheiding van B_2(a) volwassen palmen in dichte bestanden, maar geleidelijke invoering van dunning door kappen en van landbouw en van C(a) palmen in gedunde bestanden, enige regeneratie. Het kappen vindt vooral gedurende het klaarmaken van de akkers plaats.

De palmen in de Dorpspalmbossen en Palmgaarden zijn geselecteerd en de plant is hier volledig gedomesticeerd. Dorpspalmbossen zien er gezond uit, omdat ze op vruchtbare grond groeien; die van de Palmgaarden zijn dikwijls op uitgeboerde grond geplant. De palmgaarden produceren weinig, maar indien zij vooral kalimeststoffen ontvangen, kan de opbrengst meer dan het tweevoudige worden.

Factoren die de opbrengst beïnvloeden. Het aantal trossen per palm en het gemiddeld trosgewicht worden door het milieu en andere factoren beïnvloed. Enkele van deze factoren worden besproken.

Bij een wijde stand geven de palmen gemiddeld een hoge produktie. Bij toenemende dichtheid zullen de palmen meer en meer met elkaar gaan concurreren, waardoor de opbrengst per palm daalt. De opbrengst per oppervlakte-eenheid kan echter nog stijgen totdat de dichtheid optimaal wordt.

De hoogte van de palm wordt beïnvloed door de dichtheid van het bos; palmen van 15 tot 20 m vormen de belangrijkste producenten (77% van de totale opbrengst). Verder speelt de leeftijd natuurlijk een belangrijke rol.

De gemiddelde leeftijd van de palmen is een maatstaf voor de ouderdom van het palmbos. Om de leeftijd te karakteriseren, werd het R/S quotient ingevoerd: de verhouding tussen het aantal ruwstam- en gladstampalmen. Ruwstampalmen hebben stammen die nog bezet zijn met dode bladvoeten; bij gladstampalmen zijn deze bladvoeten afgevallen. Een jong palmbos heeft een hoog R/S quotient; na verloop van tijd kan dit quotient tot 0 dalen.

Als een vervolg op een onderzoek naar de produktie van bladeren en bloeiwijzen van halfwilde palmen uitgevoerd in de twintiger jaren, en op latere soortgelijke studies van geplante palmen, werd gedurende drie jaar van ongeveer 180 halfwilde palmen in enige percelen Dicht palmbos de produktie aan bladeren en bloeiwijzen nogmaals opgetekend. Het jaarlijkse aantal gevormde bladeren voor niet of weinig beschaduwde glad- en ruwstampalmen varieerde van 15 tot 19. De stamloze palmen gaven een onduidelijk resultaat.

De gemiddelde levensduur van een blad van een ruwstam- resp. gladstampalm werd geschat. Deze en andere gegevens duiden erop, dat de ontwikkeling van oudere palmen trager is dan die van jonge palmen. Hierdoor verschuift de piek in de opbrengst met toenemende leeftijd van de palmen naar een later tijdstip in het jaar of naar het volgend jaar.

De afstoting van bloeiwijzen vóór de bloei en mislukking van de trosvorming is hoog en neemt toe al naar gelang de palm meer beschaduwd is.

Door analyse van de bladslippen van het negende blad van gladstampalmen is een indruk verkregen van de gehalten aan macro-elementen in het blad. (zie tabel 17).

Gedurende het klaarmaken van de akkers worden vaak bladeren van vooral jonge palmen afgekapt, terwijl door het branden vaak alle bladeren, ook van hoge palmen, worden verschroeid. In enkele streken worden bladeren gebruikt als dekmateriaal. Beide oorzaken hebben tot gevolg, dat het assimilerende oppervlak van de palm afneemt. Door ontplooiing en vorming van nieuwe bladeren neemt het weer toe. Dit heeft een direct effect op het gewicht van de trossen, die gevormd worden en leidt later tot vermindering van het aantal trossen.

De frequenties van de verschillende vruchttypen en van palmen met ongedeelde bladeren (het *idolatrica*-type) zijn in tabel 16 vermeld. Bepaling van de tros- en vruchtsamenstelling gaf een vrucht/trosverhouding van 69,3%, een olie/trosverhouding van 15,7% en een palmpit/trosverhouding van 9,7%.

Het onderzoek van grondmonsters, gestoken in het bos waarin ook de bladmonsters waren verzameld, leidde niet tot bepaalde conclusies. Het is echter bekend dat kaliumgebrek algemeen voorkomt in de Afrikaanse oliepalmstreken. Hogere opbrengsten zijn dan ook vooral door kalibemesting te verkrijgen.

In sommige streken wordt plantensap gewonnen voor de bereiding van wijn, hetzij door de staande palm te tappen, hetzij door hem te vellen. De tweede methode is alleen gerechtvaardigd, wanneer voldoende palmen aanwezig zijn of wanneer de winning van olie wordt belemmerd door gebrek aan water. Het effect van het tappen van de staande palm op de opbrengst is nog onbekend.

De concurrentie tussen palmen en de uitwerking daarvan op de opbrengst per palm en per hectare wordt besproken. Slechts in één Dicht palmbos/Bouwland met palmen is de dichtheid hoger dan de optimale dichtheid, terwijl in drie gevallen de stand ijler is. Het resultaat van het onderzoek van het Regenbos met oliepalmen is niet duidelijk.

De gemiddelde opbrengst van een gemiddeld Dicht palmbos/Bouwland met oliepalmen is ongeveer 2800 kg trossen per ha. Het aantal palmen met een stam, dat in één jaar produceerde, was lager dan 65% van het totale aantal. Dit percentage is hoger, wanneer het berekend wordt over verscheidene jaren, omdat niet alle palmen jaarlijks produceren.

Zoals vermeld, verschuift met toenemende leeftijd de maand met de hoogste opbrengst. Daardoor kan de piek in oogstarbeid samenvallen met die in de veldarbeid. In dichte palmbossen is dit het geval. Verder is het quotient van de hoogste maandelijkse opbrengst en de laagste maandelijkse opbrengst van belang voor de economie van een oliefabriek; in Abak is deze verhouding minder ongunstig nl. 5 tot 6 dan die in Sierra Leone, waar hij 20 tot 30 is.

Exploitatie, extractie van olie, het kraken van de noten, rechten op de palmen en consumptie. De exploitatie van een palmbos hangt af van verscheidene factoren, zoals oogstsystemen en methoden.

De vermelde oogstsystemen van verschillende dorpen worden gegeven, deze kunnen met de tijd veranderen.

De voornaamste methode van oogsten is het gebruik van klimtouwen. Meestal gebruikt men een enkel touw (wat vlug is in het gebruik), soms gebruikt men twee touwen (wat veiliger is). In sommige gebieden worden de oliepalmen niet geoogst, daar worden de op de grond gevallen vruchten en noten opgeraapt.

De traditionele typen van oliebereiding en het kraken van noten worden beschreven. Verbeteringen van deze methoden zijn de schroefhandpers, de hydraulische handpers, de oliefabriek en de notekraker. Zij passen echter niet altijd in de plaatselijke economie en dit heeft tot mislukkingen en financiële verliezen geleid.

Rechten op de palmen kunnen een belangrijke invloed uitoefenen op de opbrengst van een palmbos. Zij worden wanneer nodig, gewijzigd. Er zijn weinig gegevens over de aantallen palmen, die in het bezit zijn van de boeren; slechts van één palmbos konden cijfers worden verzameld.

De werkelijke produktie van een palmbos is uit de aard der zaak lager dan de potentiële produktie, door de hierboven besproken factoren.

Palmolie, en in veel mindere mate palmpitten, vormen een belangrijke voedselbron; de genuttigde hoeveelheid hangt van de prijs en van het seizoen af. Palmolie wordt ook als een cosmeticum en voor lampolie gebruikt.

Ziekten en plagen. De meest voorkomende ziekte van de halfwilde oliepalm is stamrot. Meestal wordt *Ganoderma lucidum* als pathogeen genoemd. De systematiek van het geslacht *Ganoderma* en verwante geslachten is echter onduidelijk. Daarom wordt dan ook de gangbare naam '*Ganoderma* trunk rot' niet gebruikt om de indruk te vermijden, dat de oorzaak van een stamrotzieke palm zonder meer toegeschreven zou moeten worden aan een schimmel, behorende tot het geslacht *Ganoderma*.

Het meest kenmerkende ziektepatroon is het verwelken van de ontplooide bladeren, die dan naar beneden gaan hangen, terwijl de 'speer' of 'speren' meestal rechtop blijven staan. De wijze van infectie is nog niet duidelijk. Factoren, zoals de leeftijd en bodem kunnen het voorkomen van stamrot beïnvloeden. Een kalibemesting resulteerde in een vermindering van het aantal palmen, dat over een bepaalde periode aan deze ziekte stierf.

Plagen komen weinig bij de oliepalm voor. In feite is de mens, die bladeren afkapt en verschroeit, gaten in de stam boort of kapt, gaten in de stelen van vrouwelijke bloeiwijzen steekt, mannelijke bloeiwijzen afhakt, en zelfs palmen velt, de voornaamste 'plaag'. Maar aan de andere kant vormt de mens de uitgestrekte groeiplaatsen, waar de halfwilde palmbossen voorkomen.

Verslechtering en teruggang van de palmbossen. Bij een toename van de gemiddelde leeftijd van een palmbos zal door de afname van het aantal producerende palmen de opbrengst per oppervlakte-eenheid dalen. In een regenbos zullen open ruimten, ontstaan door het sterven van palmen, opgevuld worden door bomen. In een palmbos zullen open plekken als akkerland en gedeeltelijk als woonterrein gaan dienen.

Eén van de oorspronkelijke studie-onderwerpen van de Asutan Ekpe Oil Palm Survey was de bestudering van de ontwikkelingscyclus van een Dicht palmbos, maar door het kappen van palmen wordt de 'gewone' gang van zaken ernstig verstoord.

Dergelijke cycli werden in twee Dichte palmbossen en in een Regenbos met oliepalmen uitgevoerd en geven een indruk van de ontwikkeling van deze palmbostypen.

Verder is aandacht geschonken aan de teruggang in de economie in een streek door afname van het aantal palmen. Als oorzaken zijn al genoemd het vellen van palmen voor het tappen van het sap en voor het vergroten van het areaal akkerland. Daar komt nog bij dat door moderne ontwikkeling de bevolking permanente woningen gaat bouwen, waardoor de oorzaak van het ontstaan van nieuwe palmbossen verdwijnt, tenzij men overgaat tot aanplant.

Methoden ter vergroting van de olie- en palmpitproduktie. De olie- en palmpitproduktie van een palmbos kan worden vergroot door intensivering van de exploitatie, door vergroting van de olie- en palmpitproduktie per hectare en door verbetering van de extractie.

In de dichtbevolkte streken van Oost-Nigerië zijn de palmbossen voldoende ontsloten om op betrekkelijk gemakkelijke wijze elke palm te bezoeken. In dunner bevolkte gebieden zou de aanleg van wegen de produktie kunnen verhogen. Het kan voorkomen, dat de bevolking door andere werkzaamheden bezet is; hier kan immigratie of het inschakelen van gastarbeiders een oplossing brengen. Een goed ontworpen opkoopsysteem kan het tijdrovende vervoer door de boer verminderen.

Bemesting wordt zelden of nooit toegepast. Er zijn slechts een paar gevallen bekend, waarbij compost of kunstmest werd gebruikt en dit betrof dan vaak proeven of demonstraties. Bemesting met kalimeststoffen resulteerde in een proef van het WAIFOR in een belangrijke opbrengstverhoging.

Door verbetering en rehabilitatie kan de produktie verhoogd worden. Vroegere adviezen tot verbetering berustten meestal op gezond verstand en praktijkervaring opgedaan met andere gewassen. Ook werden reeds vroeg hier en daar demonstratie- en proefvelden aangelegd van verbeterde palmbossen. Het is echter gebleken, dat in vele gevallen de experimenten proeftechnisch niet goed opgezet waren.

Twee proeven met betrekking op verbetering en rehabilitatie werden door het WAIFOR in Dichte palmbossen/Bouwland met oliepalm en een derde in een Gedund palmbos opgezet. De conclusie was, dat de combinatie van het laten staan van enkele oude palmen gedurende de eerste vier jaar in een gerehabiliteerd palmbos geen bezwaar is, mits de boer doordrongen is van de noodzaak deze oude exemplaren in het vierde jaar te vellen. Men heeft de neiging dit achterwege te laten, daar deze oude palmen hoge opbrengsten geven. Daarbij verliest de boer uit het oog, dat hij nog hogere opbrengsten kan krijgen van veredeld materiaal.

Wanneer een rehabilitatie niet uitgevoerd kan worden, is een snelle en gemakkelijke maar tijdelijke methode om hoge opbrengsten van palmbossen te krijgen, deze te verbeteren.

Pogingen om de Nigeriaanse oliepalmeconomie te verbeteren. Na 1920 begon de opkomende oliepalmcultuur in Zuid-Oost Azië die van West-Afrika ernstig te bedreigen. Om aan deze het hoofd te kunnen bieden werd in de toenmalige Britse gebieden, naast het aanleggen van enkele demonstratiepercelen, een commissie ingesteld, die dit probleem moest bestuderen en aanwijzingen moest geven om tot een verbetering te komen. Voor Nigerië werd op advies van deze commissie een vierdelig plan opgesteld. De oorzaken van het slagen en het mislukken van de verschillende onderdelen van dit plan worden besproken. Vooral wordt ingegaan op de factoren, die de rehabilitatie en verbetering van de palmbossen deden mislukken. Als gevolg van deze mislukking werd in 1938 voor Oost-Nigerië een nieuw plan opgesteld. Door de Tweede Wereldoorlog kon dit plan pas in 1953 in gewijzigde vorm worden uitgevoerd met de aanvang van het tweede rehabilitatie- en verbeteringsplan. Ook met dit plan werd geen wezenlijk succes bereikt. Daarnaast werden in geheel Zuid-Nigerië oliefabrieken opgericht; slechts enkele ervan zijn rendabel gebleken.

Een derde rehabilitatie- en verbeteringsplan begon in Oost-Nigerië in 1962 als onderdeel van het Nigeriaanse zesjarenplan. De resultaten, verkregen in de eerste jaren, zijn niet bemoedigend.

Toekomst van de oliepalmindustrie, een algemene conclusie. De uitgevoerde onderzoekingen hebben geleid tot een analyse van de ecologische en menselijke factoren die van invloed zijn op de vorming, verslechtering en exploitatie van de palmbossen. De hoge bevolkingsdichtheid en haar huidige snelle toename veroorzaken een hoge druk op het land. Dit heeft geresulteerd in een steeds korter wordende braakperiode in het toegepaste landbouwstelsel, een verkorting die nog voortgaat. Daardoor dalen de opbrengsten; de grond raakt uitgeput, en het vellen van palmen om meer landbouwgrond te krijgen neemt hand over hand toe. Hierdoor zal op den duur de levensstandaard dalen, tenzij verbeterde teeltmethoden worden aanvaard, en veredelde inheemse en betere exotische gewassen worden verbouwd. Dit kan alleen gebeuren, als de traditionele landbouwmethoden worden gewijzigd of opgegeven.

Eén van de methoden om de opbrengsten aan landbouwprodukten te vergroten, is de vervanging van een gedeelte van de palmbossen door palmgaarden en plantages, zodat de totale produktie aan oliepalmprodukten ten minste op peil gehouden kan worden. Het land, dat door het kappen van de resterende palmbossen vrijkomt, kan dan voor teelt van andere gewassen worden gebruikt. Ook kan men natuurlijk een deel van het land voor de oliepalmcultuur gebruiken om de olie- en palmpitproduktie te vergroten. Deze vervanging zal een kostbare onderneming zijn; niet alleen kostbaar wat geld aangaat, maar ook wat menselijke energie en kennis betreft. Het succes zal afhankelijk zijn van een gelijktijdige toepassing van moderne landbouwmethoden.

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